# Player Responses to a Live Algorithm: Conceptualising computational creativity without recourse to human comparisons?

**Oliver Bown**
Design Lab
University of Sydney
NSW, 2006, Australia
oliver.bown@sydney.edu.au

### Abstract

Live algorithms are computational systems made to perform in an improvised manner with human improvising musicians, typically using only live audio or MIDI streams as the medium of interaction. They are designed to establish meaningful musical interaction with their musical partners, without necessarily being conceived of as "virtual musicians". This paper investigates, with respect to a specific live algorithm designed by the author, how improvising musicians approach and discuss performing with that system.

The study supports a working assumption that such systems constitute a distinct type of object from the traditional categories of instrument, composition and performer, which are capable of satisfying some of the expectations of an engaging improvisatory performance experience, despite being unambiguously distinct from a human musician. I investigate how the study participants' comments and actions support this view. Specifically: 1) participants interacting with the system had a stronger sense of the nature of the interaction than when they were passively observing the interaction; 2) participants couldn't tell what the "rules" of the interactive behaviour were, and didn't feel they could predict the behaviour, but reported this as being a positive, engaging aspect of the experience. Their actions implied that the improvisation had purpose and invited engagement; 3) participants strictly avoided discussing the system in terms of virtual musicianship, or of creating original output, and preferred to categorise the system as an instrument or a composition, despite describing the interaction of the system as musically engaging; 4) participants felt the long-term structure was lacking.

Such results, it is argued, lend weight to the idea that as CC applications in real creation scenarios grow, the creative contribution of computer systems becomes less grounded in comparison with human standards.

## Introduction

Live algorithms (Blackwell, Bown, and Young, 2012) are software systems designed to autonomously perform music with live musicians, typically in an improvised music format. There has been a great deal of activity in this area recently, owing to the increasing ease with which artist programmers can put together powerful realtime systems incorporating machine listening, realtime synthesis and patterning, and forms of adaptive behaviour. Recent concerts, attached to electronic arts and music conferences such as the International Symposium on Electronic Arts (ISEA) 2013, and New Interfaces for Musical Expression (NIME) 2014, have demonstrated the diversity of approaches to live algorithms (see Bown et al. (2013) for a discussion of these concerts).

As in all aspects of computational creativity, the question of evaluation in live algorithms requires detailed consideration, as there are no simple, objective measurables that indicate when computer generation of output has been creatively successful. Two issues are important: how system output is evaluated by humans, and the extent to which we can attribute the creative component of the output to the system, rather than to its maker or to the 'inspiring set' (Ritchie, 2007): the set of all examples given to the system.

In live algorithms, the creative process is somewhat different from many instances of automated creative generation, since the output is always the result of the interaction between a human and a computer system. It is an interactive creative scenario. This muddies the issue of the attribution of the creativity further, but at the same time presents alternative, more tractable questions regarding the success of the system in its collaborative, improvisatory role.

Whilst it should be borne in mind that such questions regarding the interactive experience of live algorithms are separate from the core questions of computational creativity evaluation, there is still much to be learnt from such an analysis. In Bown (2014), I argue that a human-focused, qualitative, and strongly context-aware approach to studying computational creativity systems is important to advancing evaluation. In the case of an artistic robot, for example, one should begin by examining the full set of interactions between the system, its maker, its operator, its audience and so on, before deciding how one should frame questions of creative ability. This is to avoid the danger of inappropriately framing the activity and the agency of participants in that activity. How is the creative attribution divided between these actors? How do people perceive the system, not only in terms of good or bad output, but in terms of the way in which the system's activity is presented in a social context? Others, particularly Colton (e.g., (Colton et al., 2014)) have emphasised the management of the social interactive context in computational creativity, presented as a means to enhance the perception of creativity, rather than as a means to better understand interaction with creative systems to improve their design and efficacy in areas of application.

Such developments point to the possibility that any proposed *measure* of the creativity of a system is significantly less fruitful than a *rich description* of the system as an agent with creative affordances described by its networks of interaction. This neutralises the crisis of working out how to score creativity, and provides simple practical analysis which can support real applications in the way that human computer interaction (HCI) and interaction design does to great success. Thus a qualitative descriptive approach is pursued in the present research, in order to build a rich descriptive understanding of human-machine creative interactions in practice in the context of live algorithms.

A central motivation for conducting the following study is to conduct computational creativity research that is more focused on the details of a participant's interaction with a creative system, involving a number of dimensions of experience that are relevant to creativity, and in doing so contribute to an understanding of how such systems work in practice in real creative contexts.

In this paper I study the responses of improvising musicians to Zamyatin, a live algorithm system that I have developed and worked with artistically since 2010. Zamyatin has performed with a wide variety of musicians. It is conceptually speaking a very simple system as far as creative systems go, in terms of the generation of original content *on its own*. Specifically it is less driven by the use of musical intelligence than by an interest in low-level gestural interaction. But in light of the value of diverse approaches to computational creativity, I view the system as a useful experiment in computational creativity in that it is successful in establishing an autonomy of behaviour, both conceptually and as perceived.

The questions the study looks at are focused on the ways in which participants experience and benefit from the creativity of a system: (1) how effective the system is at contributing to an effective performance; (2) the extent to which the participant experiences the system as autonomous, and also human-like, and how this influences other aspects of the perception of the system, and; (3) whether the participant experiences the system as originating novel output, and how this influences (and is possibly influenced by) the general perception of the system.

These are issues that we must clearly gain an understanding of as part of a body of knowledge in applied computational creativity. The computational creativity literature remains lacking in work that formally studies these basic forms of interaction and experience using qualitative methods.

The first question has self-evident value, and in one form or another is naturally asked in the course of creating any musical system. A challenge for a more experience- and interaction-focused computational creativity research program is to balance this goal with that of advanced computational generative sophistication. The perception of autonomy addressed in the second question is an important topic for the study of computational creativity. Autonomy is a critical component in the making of creativity: a system can only be called creative insofar as it possesses some degree of autonomy in the output it creates. Perceived autonomy may not be actual autonomy and vice versa, and actual autonomy anyway lacks a robust applicable definition. The distinction between software autonomy in general and human-like autonomy is one that will need to be unpacked further as we witness computationally creative systems at play in real interactive scenarios, and it is important to understand how individuals experience that autonomy and how that influences their behaviour towards the system and their own activities. Finally, in the context of interactive music creation we are interested in how the system can drive surprise and intrigue in the co-performer, and under what circumstances the performer acknowledges something as either creative, or in terms that connote creativity. Here it is particularly interesting to look at the language used, as this is an area where the anthropomorphism of cognition comes up easily.

I begin by describing the motivations behind the design of Zamyatin in the following section, before moving onto describing the study and results.

## Zamyatin

Zamyatin is a software system in ongoing development since 2010 (Bown, 2011). Before describing the design of Zamyatin, it is necessary to explain some of the design considerations, including a number of aesthetic decisions. An earlier description of Zamyatin's design is given in Bown (2011).

One of Zamyatin's main goals was to emphasise the experience of interacting with something that 'felt' autonomous and engaged in interaction, even if, it does not make sophisticated use of musical knowledge. For this, the free improvised mode provides a context that allows one to explore behaviour in a more abstract way than is afforded by many musical genres. Improvising software agents are a longstanding area of activity. George Lewis' Voyager system(Lewis, 2000) is a widely known example, and uses a hand-coded complex of interacting generative elements to create rich, diverse and musically responsive behaviour. Musicians performing with Lewis' system can be seen deeply engaged in the musical interaction as if performing with another human improviser. The use of a Disklavier (an acoustic piano that can be controlled by MIDI via mechanical actuators) limits the sense of a computer being involved. Artists such as Lewis have reported the responses of musicians performing with their systems, but such reports increasingly show that it is hard to pin down exactly how musicians think about, understand and evaluate such systems, suggesting the need for studies that get into more detail about the conceptual language and approaches used. Banerji (2012), for example, takes an anthropological approach, with a strong focus on working in real contexts, and looking as much at how the system influences the performer's behaviour as at how the performer judges the system. Other projects such as the work of Plans Casal and Morelli (2007), focus strongly on using low-level realtime audio analysis and resynthesis to give the performer a strong sense that the software acts as a responsive agent, through interactive immersion. Pachet's (2004) approach to establishing engagement is to mimic the style of the improviser in a call and response fashion. Similarly with Blackwell and Young (2004) and Brown, Gifford, and Voltz (2013), who draw on a style analysis and resynthesis of the performer's input to establish a strong sense of engagement. Although these projects report on user-responses, further research is needed to determine whether these are indeed effective strategies for creating desirable interactive musical experiences.

A common challenge for the makers of generative systems is how to endow the system with autonomous behaviour that transcends the rules put into it by the programmer. That is, if your system is a collection of procedural instructions defined by the programmer, then even if the specific behaviour of the system is original, being some possibly unexpected product of the interacting rules, the general nature of the system's behaviour remains down to the programmer, since no new knowledge has been gained by the system.

There are three commonly cited ways around this problem (Todd and Werner, 1999). The first is already implied above: if the set of rules I provide are complicated enough, then from the interaction of these elements there will emerge new, higher-level behaviours that were not anticipated. The classic example is flocking behaviour, where the programmer defines the behaviour of individual 'boids' (Reynolds, 1987), but nowhere dictates that the system should start forming oscillating blobs on a macroscopic scale. Classical work from the generative art canon also highlight the value of this approach. Both Harold Cohen's celebrated AARON system (McCorduck, 1990) and George Lewis' Voyager system (Lewis, 2000) consist of complex rule sets that result in outcomes even their makers find surprising. In this case, it is perhaps wrong to describe what emerges from these systems as new knowledge.

The second approach is that the system learns. This is easily understood by analogy with how humans acquire knowledge that they are not born with. A large number of systems use learning to build musical knowledge, and famous examples include David Cope's EMI (Cope, 1996) and François Pachet's Continuator (Pachet, 2004). In these cases, the input knowledge now comes from a body of input musical data as well as the programmer. One problem then is how to avoid the system becoming just a copycat. The system needs not only to learn the style but to learn how to produce new material in that style. Current systems have yet to show how the learning itself can perform this extrapolation.

A third approach uses targeted evolution or another form of optimisation, dictated either by a measurable target behaviour, or user-feedback applied to a population of evolving behaviours. The rationale goes that a target behaviour itself does not contain the knowledge about how to achieve that behaviour, but running an evolutionary system to achieve that target can discover novel solutions which themselves constitute knowledge. Experiments in artificial evolution have shown the discovery of such solutions. For example, the coevolution of predator and prey systems reveal the emergence of specific hunting or hiding techniques (Cliff and Miller, 1995). Here the knowledge is produced through interaction, or learning-by-doing. Thus by specifying a target behaviour in the form of an evolutionary goal, one can drive a system to discover component behaviours that are not specified in that goal.

Unlike the majority of live algorithm approaches to deriving behaviour, Zamyatin is not a corpus or machine-learning based system, and employs this third approach to achieving autonomy. I draw on Blackwell and Young's PfQ framework to describe the system (Blackwell, Bown, and Young, 2012). Passing from the input (P) layer to the inner 'patterning' (f) layer are low-level feature values derived from the input musical data of the system. Passing from the inner layer to the 'instrument' or 'sounding' layer (Q) are control signals. These can be thought of as the equivalent to the human physical control 'signals' applied to a musical instrument, i.e., the movement of the hands, feet, breath, etc., although the object being controlled might involve its own generative elements. In Zamyatin, the inner patterning system is a type of decision tree, coupled with a internal array of states, that together feedback on themselves. This inner patterning system is connected to the outside world though the input layer and output layer. Somewhat like a traditional feedforward multilayer neural network, the connections between these layers flow in the forward direction only.

A decision tree is a binary tree that propagates a decision making iteration from the root of the tree to one of the leaves (leaves represent decisions), at each junction choosing to go one way or the other based on whether a single numerical value is above or below a single threshold. Decision trees are used commonly as efficient classifiers. The internal state array is simply an array of floating point values in the range [0,1]. In addition to the internal state, the system is constantly being fed an input state derived from low-level features of the incoming audio. Decisions at each node in the decision tree are made based on either the current state of the low-level audio features being passed into the system, or the internal state array. A leaf in the decision tree contains a list of actions which include passing on control commands to the musical system (Q) and also updating the state array. In this way, the decision tree and state array form a feedback system that can exhibit complex dynamics in the absence of any input, and can also be driven by changes to the input. Previous work (Bown and Lexer, 2006) has looked at the musical use of neural networks with similar properties.

An evolutionary approach is applied to the design of the decision tree, including the architecture of the tree (which can grow or shrink over time), the parameters of each decision node (which value to query and what threshold to apply) and the (variable length) list of actions to perform at each leaf. Actions control how the internal state array is updated, applying simple arithmetical operations to the state values.

The inner layer updates at a 'control rate' of around 20hz. It outputs two forms of control data at each update: a single integer, representing its current decision state, and an array of floating point values in the range [0-1], representing its internal state. Both are actually used to control the musical output. In evolving the system behaviour, a fitness function is hand-coded, that takes into account the pattern complexity, and other patterning properties such as degree of variability and repetition, of the system's output under various input conditions. Different variant fitness functions are used to create large populations of decision tree candidates, which are then creatively explored during the preparation of musical work.

Like procedural systems, Zamyatin does not draw on a corpus of musical knowledge, but instead attempts to establish novel behaviour through the interplay between the programmer specifying a behavioural target and the system evolving novel behaviours that achieve that target. The target behaviour does not describe the final musical output, but the output of the nested control system (f) that operates a number of virtual musical instruments. This target behaviour is defined by the programmer and the selection or definition of different target behaviours to suit the performing musician becomes part of the creative process of preparing Zamyatin for each new performance.

## Musical Study

Three improvising musicians (P1, P2, P3) were invited to attend a focus group to investigate musician responses to Zamyatin. The goal was not to set up a musical Turing test: there was no attempt to conceal the computational status of the system. Instead, the study looked at questions of engagement, experience and perception in improvised interaction.

The study was set up as a focus group in order to stimulate interaction between the participants, to look at the way they discussed musical interaction, and to get them to observe each other playing.

Participants were first shown a video recording of the system performing with a musician and asked questions about how they perceived the interaction with the musician. They were then played an audio recording of an earlier manifestation of the system performing with another musician and asked similar questions. They were then asked to perform with the system and develop their responses to it.

The author initially did not explain the design of the system, but later answered questions and provided more context as the study progressed, in response to the participants' questions.

Several other interviews with performers conducted prior to the focus group have influenced the expectations of the author in approaching the focus group. These will be reported in full in a forthcoming journal paper.

## Results

Three main results are considered here:

1. **Participants interacting with the system had a stronger sense of the nature of the interaction than when they were passively observing the interaction.**

   During the initial observation of the pre-recorded concert, all three participants said that they did not see any clear clues as to how the system was responding, what information it had access to from the musician, and what the interaction paradigm was. This was manifest largely in the sense of uncertainty surrounding the interaction. The musicians had no way of identifying clear paths of causality from the musician to the system.

Of the system in general, P2 says the following:

> The system of interaction is not obvious to me. . . . I can't tell. At times [the musician] is loud and I don't think the software's responding, or vice versa, and then sometimes the two things are loud or the two things are soft. The obvious parameters you can sample and listen to are like dynamics and pitch, timbral stuff . . . There doesn't seem to be any clear one-to-one relationships with what the software does, or it changes over time? Sometimes it reacts in a particular way and sometimes it doesn't.

In performing with the system the musicians' responses shifted from this ambiguity to a greater sense of awareness that the system was responding to their playing. A good deal of uncertainty remained about precisely how the system behaviour was influenced by the musician, and as discussed below this is a theme in itself.

After watching P1 performing, P2 says:

> It was way more dynamic than it comes across in the flat stereo recordings, it was actually really good. It surprised me a few times how loud it was prepared to go and transgressive of the duo in a way . . . mainly with dynamics but sometimes placement too . . . it did some bizarre things and you go "oh that's cool". . . . but when it's compressed . . . you don't understand the dynamics that much. . . .
> (Participant was asked to explain 'transgressive') It did naughty things, to do with timbres and placement. If it was someone playing that material you'd go, they're being a bit upfront, kicking the thing along a bit, putting provocations in. I like that.

P3 adds:

> That's the weird thing about it; you can really sense that something's happening but I can't tell what it is.

Interestingly, also, the critical analysis of the system naturally extended to the performing musician as well. The evaluation of the improvisation by the participants naturally applied as much to the performers as to the systems. This may be more their habit, but of some relevance, Banerji (2012) has proposed looking at the impact on musicians' playing as a form of ethnographic approach to studying the qualities of live algorithms.

> P3: One thing I found that the second musician wasn't interacting with the software at all. I felt like maybe they were just playing. I didn't hear too much active listening, they were obviously playing with it, but didn't really feel like they were kind of . . . that level of interactivity wasn't really there from their performance. . . . It was a real contrast of style I thought. I thought the first guy was really overtly interacting with it to quite a large extent, and the second I thought wasn't. But it's hard to say what the agenda is. . . . It's not that I enjoyed the first one better. It's more that if someone told me if the second player was in another room not being able to hear the performance I could believe you.

2. **Participants couldn't tell what the "rules" of the interactive behaviour were, and didn't feel they could predict the behaviour, but reported that they did experience the behaviour as interactive, and presented this uncertainty as being a positive, engaging aspect of the experience. Their actions implied that the improvisation had purpose and invited engagement.**

   In discussing what if any cues revealed the nature of interaction between system and human performer during the video playback section of the study, participants noted that any candidate explanations they developed for the behaviour of the system were frustrated by its seemingly changing interactive behaviour. For example, one participant began thinking that the system was matching the intensity of the performer's behaviour, but then found that the oppose suddenly occurred.

   During interaction with the system, performers remained unsure about exactly what the responsive behaviour consisted of, but reported that they did feel that there was some sort of complex interaction taking place, and finding this particularly engaging, owing to the uncertainty of the system's behaviour.

   > P2 (describing performance with P1): That started off with a noisy atmospheric tone. P1 came in and it maintained its thing, it kept its thing for a while. which kinda surprise me. I thought the introduction of a strong tone would shift it, but it didn't shift it and I thought "that's cool". . . . the fact that it doesn't jump the whole time makes it worth listening to. If it was jumping the whole time with your stimuli, with the distinction from the live instrument to a clear distinction from that it would drive you crazy.

   This uncertainty was also described as potential source of frustration. Equally, the stability of the system over the long-term was described as a potential source of boredom. But on the whole participants agreed that the balance between uncertainty and predictability was well measured to create an effective sense of engagement for the musician.

   > P1: To begin with, and that's the same with the other ones I saw, it takes the musician to initiate the interaction. . . . it was playing a long granulated tone, I came on top of that with a between note, probably to create some symbiosis with what it was doing. Then I found as I went into it that I wanted to find out that it reacted to what I was doing, and this was less clear. Sometimes it did and sometimes it didn't.

   > P3: There was a really loud section with no stimulus behind it, and its like, where did that come from, but I'm getting closer to seeing [the relationship] . . . actually I'd find it quite stressful to perform with.

3. **Participants strictly avoided discussing the system in terms of virtual musicianship, or of creating original output, and preferred to categorise the system as an instrument or a composition, despite describing the interaction of the system as musically engaging.**

   The participants were clear explicitly – in response to direct questions about it – and implicitly – in the way they described the interaction with the system – that they felt no compulsion to see the system as a 'performer', preferring instead to view it as a form of complex instrument, or interactive score. However, the participants equally acknowledged that the behaviour of the system made it stand out from other types of digital interactive systems or instruments, particularly in terms of the autonomy of behaviour. To some extent this afforded the use of terms such as a perceived volition, that are arguably not normally associated with machine behaviour.

   As an example of a clear shortcoming, P2 states:

   > It seemed a bit confused with the very high frequencies . . . I felt that it kind of suddenly went "I can't actually see you" . . . It was quite interesting. If it was another player you'd go, ok, that's working.

   They elaborate on their perception of the system in terms of humanness:

   > I've steered clear from [referring to] anything to do with a performer because it doesn't feel like a human being at all, but it feels interesting, you've set up a compositional tool that's not momentary predictable but in the long term its predictable.

   The participant describes this engagement further as follows:

   > It was good, it was something I wanted to do listening to the other things: give it its own space, do its thing. It's an intriguing notion that you didn't play for a while and then it comes up with something else. It kinda lets the audience know. It's not some sort of stupid device, something of its own volition.

   When asked how it compared to 'mere tape', P2 elaborates:

   > I think audiences are pretty smart, they understand what tape is, what predetermination is and what liveness is, and if the audience were sitting there knowing that it's a live system and it seems to have some initiative without the player, I think that's an interesting moment. . . . But I'd say the choosing the samples becomes this overridingly important compositional decision. . . . I feel that with this, whatever samples you put into the composition . . . the machine has some sort of ability to stop and start things.

4. **Participants felt the long-term structure was lacking.**

   It was widely agreed that the system did not convincingly deal with long term structural management of the performance.

   > P2: Listening to both of those things a lot of the activity is very much less than 3 seconds, so there's a lot of active many-events-per-minute sort of feel to it, and because it goes on for some time in that way it then has a sort of strange flatness as a result, and after a while you settle into the fact that there aren't going to be any super-long events, and so in a sense it kind of flattens the whole thing down and makes it kind of amorphous.

The participant frames this in the context of contemporary improvised music:

> It's a subject right at the heart of what's going on in improvised music. Probably always has been, but seems really central to it these days. It feels to be generational as well. The older generation may feel that they're not interacting and reacting (themselves) but they tend to more than younger generations. . . . I feel like there's players around now who work in much longer structures and they don't want to have a dialogue which is over some 10 second framework.

## Discussion

The results of this study go some way to confirming existing assumptions and findings about evaluation of musical systems.

The first result affirms a general principle that certain knowledge is better acquired through active participation. Interacting with a system tells you more about its interactive capacity than watching an interaction with a third party. This may not be manifest in the form of a expressible understanding of what the system is doing, as was the case in the present study, but nevertheless the participant in the interaction gains a direct sense of the interactive nature of the system, that may be obscure from outside.

This has implications for the audience experience of the work. They may not be fully aware of the experience of the musician during the performance. On the other hand, the expression and observed response of the musician can be important to an observer understanding the interaction, and may indirectly reveal the experience. Pachet has shown how the video footage of participants, or simply composers engaged with the treatment of their own work, can do a fantastic job of revealing basic facets of user-experience (Addessi and Pachet, 2006; Pachet, 2014).

Related to this, a common theme in the evaluation of autonomous music and art system is the question of making use of a Turing-style test (e.g., (Ariza, 2009; Bishop and Boden, 2010; Pease and Colton, 2011)). Results such as those of Moffat and Kelly (2006) show that positive results can be easily achieved in situations where people try to guess whether artefacts were computer or human generated, i.e., the system generated output can pass as human. However, without involving any form of probing or interaction with the system, the test in this form doesn't really tell us anything about the system, its intelligence or creative capacity (Pease and Colton, 2011). Despite what is said about the great communicative power of art and music, these artefacts form a poor window onto their creators.

Nevertheless, it is still reasonable to expect that in general there are *cues* in creative outputs which reveal aspects of the nature of the system producing them, and which may be identified in interactive scenarios, but also possibly without the need for interaction. These cues may not be reliable identifiers of whether or not the system is computer or human, and should be better understood as contributing to a qualitative evaluation of creative or interactive behaviour. More generally, we may talk of the character of the system and how it contributes to or stimulates a productive musical process.

The musicians participating in the study did develop a sense of the cues that indicated Zamyatin's responsive behaviour in certain ways, sometimes, but without certainty. This led them to feel that the system was nontrivial and invited an engagement with the behaviour of the system.

Related to this are the other two results. The character of the system is one in which an actively obscure relationship between performer action and system result is sought. To this end the evolutionary strategy has proven to be a convenient approach to relieving the system designer from the task of dictating the system's response directly, working around the "Lovelace objection" that a computational system might only do what it has been programmed to do.

Finally we come to the issue of whether the system was at all perceived as bearing the qualities of a human performer. The response was resoundingly negative in answer to this question. Whilst, as stated in the introduction, the aim of the system design was never to simulate or mimic human behaviour, a stated goal has been to explore the middle ground between inanimate objects that do not exhibit adaptive or proactive behaviours, and sentient humans, or other creatures. The participants unambiguously placed the system in the category of objects, as opposed to any sort of 'performer', equating it either to an instrument or composition. It does not follow that they perceived this object as dumb or lacking lifelike properties.

### Scoring Zamyatin

From these results we can consider the questions posed at the beginning of the paper:

1. (Q1) *How successful is it as at creating effective performances with improvising musicians?* The participants' responses give enough support to a positive answer to this question, specifically in terms of the interesting dynamics produced by the system's interactive behaviour.
2. (Q2) *To what extent do performers conceptualise of and perceive Zamyatin as autonomous, as well as human-like, and how does this influence other aspects of the perception of the system?* The responses are more ambiguous with respect to this issue, not least because the definition of autonomy is itself hard to pin down in application. Because of this, participants were not asked to discuss autonomy directly, but we may make inferences based on their responses. Significantly, they perceived the system as being both (i) not passive in the form of its responses to input, and (ii) able to drive the performance through spontaneous action that appeared to come from nowhere. These support a technical definition of autonomy as behaviour that is not entirely determined from outside of the system, and the varying nature of the system's predictability supports an information theoretic form of this. However, there are other senses of perceived autonomy that could be achieved. Future studies could work towards understanding in greater detail the space of possible types of autonomy (for example as discussed in Eigenfeldt et al. (2013)) that might be perceived in a system.

3. (Q3) *Does Zamyatin actually originate novel responses as far as the performers are concerned?* The predominant response to this from participants was ‘no’. They quickly perceived that the system worked within strict limits, with the musical style and much of the content (e.g., choice of sounds, pitch sets, etc.) dictated by the system designer. But equally the participants responses indicated that they did attribute actions to the idiosyncratic nature of the system, which was described to them as having resulted from an evolutionary search that went beyond the input of the designer. For example, on numerous occasions the behaviour of the system was described by participants as surprising, and not like anything a human would do, coupled with value judgements ranging from this being highly engaging, to it being frustrating. We could claim that a surprising and valued response is technically speaking creative, according to the most commonly agreed definition of the term. This would be a generous interpretation, since many ‘dumb’ processes might achieve some such level of surprise in interaction. If instead we were to apply Colton’s ‘creativity tripod’ of imagination, skill and appreciation (Colton, 2008), we would have to accept that at best only skill could be claimed (I would claim that the system can appear skilful in the complex manipulation of electronic sound). An open question is what kinds of systems stimulate ‘perceived imagination’ and ‘perceived appreciation’, and whether these are in fact always relevant in contexts such as this: is it important to the perception of musical creativity that such elements are perceived?

## Conclusion

The evaluation of systems from computational creativity, using qualitative analysis grounded in specific contexts of creative interaction, is an important part of the emerging suite of research methods we use to discover and understand how systems can act successfully to support creativity or act as creative agents. This paper has attempted to dig deeper into how improvising musicians, presented with a live algorithm system, approach, interpret and engage with that system in an applied context.

The results suggest ways in which the system, Zamyatin, could be improved to create more compelling improvised musical experiences. Good long-term structure is a challenging area that this system could improve upon. The results appear to affirm the value of exploring forms of software-based musical agency that does not conform to human modes of behaviour but that still produce engagement. This could be developed further by categorising these kinds of behaviour.

The relationship between the behaviour of the system and the engagement of the performers could be developed by improving the user-interface to the underlying evolutionary techniques, possibly using interactive evolutionary techniques, so that there is a real capacity for a musician to feedback on and modify the behaviour of the agents. It was also apparent from the study that certain traits of the system, such as the degree of uncertainty of its behaviour, could be explicitly recognised as adding to the musicality of the system, and could be codified into future fitness functions. An immediate goal for Zamyatin is to create a modular system that can be easily incorporated into live performance sets by non-programmer musicians, and these ideas can be incorporated into that design.

In addition, the view held by this author is that questions of computational creativity are now shifting towards more applied areas where the comparison with human creative activity is less of a concern than a more open-ended understanding of how machines may act creatively. This is weakly supported by the research in this paper, in which a failure to stand up to any sort of Turing-style test does not diminish the discussion of the creative potential of the system. This is a perspective that warrants further study across a range of systems.

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