Exploring the Effect of Interface Constraints on Live Collaborative Music Improvisation

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ABSTRACT

This research investigates how applying interaction constraints to digital music instruments (DMIs) affects the way that experienced music performers collaborate and find creative ways to make live improvised music on stage. The constraints are applied in two forms: *i*) Physically implemented on the instruments themselves, and *ii*) hidden rules that are defined on a network between the instruments and triggered depending on the musical actions of the performers. Six experienced musicians were recruited for a user study which involved rehearsal and performance. Performers were given deliberately constrained instruments containing a touch sensor, speaker, battery and an embedded computer. Results of the study show that whilst constraints can lead to more structured improvisation, the resultant music may not fit with performers' true intentions. It was also found that when external musical material is introduced to guide the performers into a collective convergence, it is likely to be ignored because it was perceived by performers as being out of context.

Author Keywords

DMI design, interaction, live music collaboration, constraints, performance studies

ACM Classification

H.5.5 [Information Interfaces and Presentation] Sound and Music Computing, H.5.2 [Information Interfaces and Presentation] User Interfaces—Input devices and strategies.

1. INTRODUCTION

Group music making is often a challenging activity in which the musicians are bounded with a set of limitations and they need to *work* together with others [6]. The limitations originate from the instruments themselves as well as from the environment, musical genre and audience expectation. As musicians are subject to many constraints during live music performance, they usually enjoy being in a creative box that challenges them, so that they collaborate and tackle these challenges together.

In recent years, both qualitative and qualitative methods from HCI have been applied for studying DMIs, but it has been stated that such methods are limited [20]. The experimental approaches which involve case studies help performers develop and explore creative practices [20]. Rather than evaluating an existing DMI, this study is about specifically designing a purpose-built instrument to support research. Like the case studies of Marquez-Borbon et al., a DMI is designed to explore the phenomena underlying digital music interactions [20].

Although constraints and affordances have been a major topic in HCI [23] and constraints have been investigated in recent years [15, 28], the influence of constraints in collaborative music making is yet to be explored. This paper investigates how experienced musicians collaboratively make music together given a specific set of constraints. To explore this subject, six experienced music performers were recruited to take part in a study of how they improvise together with DMIs with different interaction constraints. This study was based upon the findings of the studies of Zappi and McPherson [28] and Gurevich et al. [15] with the following aims in mind:

- To identify the relationship between collaboration and design limitations.

- To explore the appropriate ways of applying design constraints for collaborative creation.

- To study the influence of transparent and hidden constraints.

2. BACKGROUND

Nijs et al. suggests that symbiosis between musician and musical instrument, in time, leads to the integration of the two, in turn leading to the transparency of the musical instrument which becomes akin to a body part and disappears from consciousness [22]. Referring to the core concepts from ecological philosophy, activity theory [2] and flow/presence research [3], which state that this musician-instrument connection determines the interaction between the musician and the live musical environment, arranges the directions in structure of music performance and is strongly related to the musician's subjective experience during performance [26]. However, these components are only available through dealing with the challenges of both *affordances and constraints* [23].

Boden describes **constraints** as '*a territory of structural possibilities which can be explored and perhaps transformed to give another one*' and claims that they are one of the fundamental sources of creativity [5]. In music making, they can be both limiting and liberating [9]. They bring boundaries that cannot be crossed, but also create tensions between conflicting demands, which can lead the creator to new ideas or in new directions and so change the creative outcome to a great extent. Norman proposes a model of constraints [23]: Physical, logical and cultural constraints. Physical constraints determine what is physically possible [23, 19]. From a music perspective, Pearce and Wiggins categorizes constraints as *stylistic constraints* relating to genre

or style, *internal constraints* that define the logical possibilities of the progressions of a piece and *external constraints* imposed by the physicality of the instrument and performability [24, 19].

2.1 DMI Design

An important aspect of DMI design is mapping (correspondence between control parameters and sonic output parameters [17]) and its dimensionality. As Zappi and McPherson state [28], it is a common assumption that increasing the number of dimensions to control an instrument leads to a wider range of expression from the musician's side. They studied the effect of dimensionality on performers' creativity with very simple cube-instruments and found that adding a dimension of control reduced the exploration of hidden affordances of the instrument [28].

In the study of Gurevich et al. [15], nine performers were given a *one-button instrument*, which had a simple two-state design (tone or no tone). Despite its simplicity, performers developed a wide variety of musical interaction styles. Although an expected use for the instrument was creating rhythmic patterns, many performers came up with unconventional techniques. Several participants reported that they have not mastered it despite the simplicity. The authors argue that 'the instrument was so constrained helped to make space for this personal element to emerge' [15].

This paper focuses on physical/external constraints of DMIs and internal constraints perceived by the user to be embedded into the system. In HCI, affordance is the perceived possibility that a system offers a certain action [23]. It is a feature that is to be acted upon. On the other hand, constraints are not immediately visible and perceivable. They have to be engaged with, experienced and understood [19]. As Magnusson argues, the musician is concerned with the affordances of the interface in learning an instrument and engaging with its expressive potential at first [19]. However, they spend most time appropriating the constraints of the instrument as it is these that define the primary characteristics of what is possible.

2.2 Multi-user Interaction and Collaboration

Making music is one of the key forms of human collaboration. Musicians share sonic and visual information by different means, such as sounds from their instruments and themselves [12], their bodies [16] and -if available- recorded audio/video [21].

Group improvisation in music is a great example of collaboration and it requires shared working knowledge [26]. In group improvisation, interaction between co-located performers happens immediately during the performance and each performer contributes something original to the evolving emergent in each act [26]. The process of group creativity is coincident with the moment of reception and interpretation by other participants. In terms of structure, improvisation is always unpredictable for both performers and the audience. This introduces a risk: As the form gets more free, the variability in quality increases.

In the last decades, collaborative music making has shaped and evolved around the technology. In the early years, network music was the focus [13]. For example Gurevich's JamSpace is an interactive music environment to support real-time jamming over a network [14]. As the NIME evolved, much more research was carried out [27, 6, 18]. In particular, Blaine and Fels analyze a number of collaborative music systems in terms of *constraint* over a variety of design elements of the interfaces [4]. More recently The Bucket System [10], The Smartphone Ensemble [1] and Moodifier-Live [11] have been introduced in NIME. Using the *Daisy-*

phone, [6] Hamilton and Bryan-Kinns found that awareness of identity in group music making increases mutual engagement [7]. In this regard, mutual awareness and engagement -when people creatively spark together- [7] are important for understanding music collaboration with and through DMIs.

2.3 Experimental Contexts and Performance

Music performance is an interdependent art form [27]. Real-time acts of the performers are constantly affected by what they hear from the others. This interdependency has unique social consequences such as the formation of leaders and followers or alterations in individual players' dynamics and timing in correlation to group synchronization [25].

Marquez-Borbon et al. [20] states that regarding performance, experimental methodologies have been increasing in NIME. However, very few studies involve systems that are specifically tailored to examine group synchronization behaviours in performance. Instead, they either carry pure artistic purposes or rely on an existing DMI. They discarded usage scenarios in experimental contexts and instead, enable users to develop their own styles according to their identities (i.e. musical backgrounds). This was only possible with a minimalistic design, which is also a design approach that this research adopts [20].

3. STUDY DESIGN

This study aims to explore: *i*) how introducing hidden constraints affects collaborative music making *ii*) what results from the introduction of external musical material (beats) is introduced. To do this a constrained DMI was developed whose interaction could be manipulated by the researcher.

3.1 Instrument Design

A simple, physically constrained, cube-shaped DMI, C-Box (Connected Box), was designed to be used in the study. It is based on the cube-instrument study of Zappi and McPherson [28]. C-Box consists of 15cm laser-cut wooden panels, embedded electronics, a battery, full range speaker facing outside and a touch sensor on the top. The idea behind C-Box is straightforward: touching, tapping or pressing on the touch strip on the box triggers and manipulates sound from a simple synthesizer.

In addition to the physical constraints, hidden constraints were build in to C-Box: i) *solo rule* on the network forces one member to play solo for 10 seconds if they have been playing louder relative to the others. This was implemented to see if the players would develop a certain composition structure, turn-taking behavior among themselves or a competitive attitude towards each other; ii) *beat rule* in which 8 beats are played from the average tempo of the players is used to explore the reaction of the performers to convergence of tempo.

3.2 Hardware: Bela

Inside the plywood box, there is a Bela[1] cape -an ultra-low latency embedded system for real-time audio processing with sensor connectivity-, BeagleBone Black[2] with 8GB micro-SD card attached, a small breadboard, connectors, a 5V rechargeable battery for Bela, and a USB wireless network adapter. Bela was chosen due to its low latency, as the networking were expected to increase response time.

There is a TouchKeys[3] sensor on top of the box and two FSRs underneath the TouchKeys sensor, so that the system

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[1] http://bela.io/

[2] http://beagleboard.org/black

[3] http://touchkeys.co.uk/
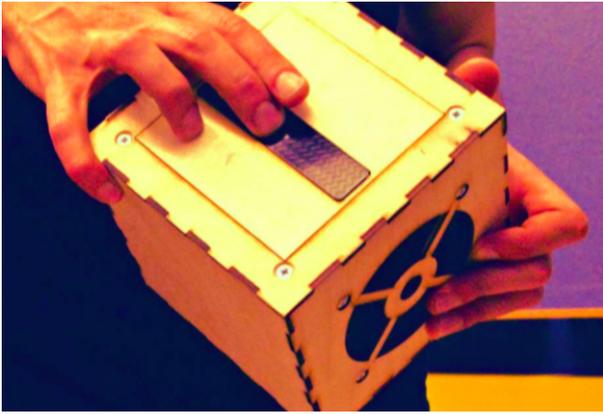
Figure 1: The C-Box instrument used in the study.
can continuously receive the location of a user's touches, size that a finger occupies on the sensor, and the applied force.

3.3 Software, Mapping and Hidden Constraints

C-Box runs optimised C code on Bela. All the interaction information received by the sensors is used for controlling the synthesizer. As Hunt et. al suggest, the mapping between musicians' input and the musical output are cross-coupled [17]. Pitch range of 3 octaves is mapped to y-position of the finger on the TouchKeys sensor. If the player applies a lot of force on the sensor, the pitch can be detuned. This relation exists in many traditional instruments such as pulling/pushing the neck of an electric guitar.

The timbre is cross-controlled using filters and distortion depending on the force applied, finger size, and current pitch. The loudness is mapped to both the force applied to the sensor and the finger size. The output levels are calibrated.

Only one finger is registered for sound making. If multiple fingers are placed on the sensor, only the last finger's position is accepted, but the size is still the combined area of all placed fingers up to the sensor's limit. Therefore, using multiple fingers only increases the size parameter which can add the distortion as intended.

3.3.1 Heavy API, Pure Data and Networking

The Heavy Audio Tools from Enzien Audio[4] use Pure Data[5] (PD) as a front-end to generate optimised C code. Using Heavy API was beneficial, as it is computationally more efficient than using libpd[6]. Heavy API analyses the connections between objects in a PD patch and produces high-performance C code that suits well to use on the BeagleBone Black. The downside of this way is that you are limited to using objects supported by Heavy.

The Heavy API was used to code the network communication among C-Boxes. Message objects in PD were used to pack the information needed to be sent or received over the network using a dedicated wi-fi router. First, a communication protocol was defined in PD in the form of messages. Then, one master-all slave (defining the master as a slave as well) relationship is defined, so that the calculations are only performed in one of the C-Boxes, commands are sent to the router, and distributed over the network. All messages are stored and only executed, when a change made by the master. All boxes have individual ID numbers which define their role, so that there was no need to write different patches for each box. The messages that are sent by the slaves are ignored, unless the receiver is the master. This

[4]http://enzienaudio.com/
[5]http://puredata.info/
[6]http://puredata.info/downloads/libpd

master/slave relationship and networking avoided having to compile patches one by one which saved a lot of time. The communication frequency is set to 50ms.

3.3.2 Network Rules

The hidden constraints are defined for multi-user interaction on the network. The two rules are: i) *beat rule* and ii) *solo rule*. Beat rule is implemented for understanding the tendencies of the group, when some external musical material is introduced. A series of beats in a certain tempo is played to see if the group would use these beats to converge to a collaborative behaviour. Solo rule is implemented to understand the consequences, when a player is allowed to play solo (forced by the system). These rules are also integrated in the PD patches and they are only triggered when multiple people are using C-Boxes.

1. Beat rule: This rule is for playing 8 beats from one of the boxes with the average tempo of the three boxes. The tempo value is calculated as beats per minute, however there is no complex beat detection algorithm because as the Heavy API does not support external libraries. Therefore, a much simpler way of tempo detection was chosen - the beats are generated by simple filtering of a sine wave. Here is how this network rule works step by step:

- Whilst playing, the number of total touches are calculated over 40 seconds a for each instrument and simply converted to beats per minute.
- These values are sent over the network at the end of this 40 seconds, then immediately the master box calculates the average and commands the box that has the closest BPM value to this average BPM value to play 8-beats with that average tempo.
- After playing 8-beats, another 40s window opens and this continues until the end of the performance.

2. Solo rule: The solo rule is implemented for allowing a user to play solo by muting all others for 10 seconds based on the average loudness value produced by a user for a duration, compared to the average loudness produced by all of the users for that duration. Here is how it works:

- The algorithm calculates the average loudness value in dB(RMS) of an instrument's audio output over a 10-second window.
- If that value is at least 10 percent higher than the average 10-second value of all the C-Boxes, then that instrument will allow it's user to play solo for 10 seconds: basically the other instruments are muted.
- The calculation window is toggled on and off for each 10 seconds, so that it does not clash with the Beat Rule.
- Also, there is a threshold to trigger this rule: If the 10-second average value is below 60 dB(RMS), then the rule is not triggered, even if that box is at least 10 percent louder than the average. Therefore, the solo rules does not kick in, if the performers choose to stay silent.

4. USER STUDY

Six instruments were built. The software inside the Bela capes were coded to write all interaction data and the audio outputs to binary files.

4.1 Participants

Six experienced music performers took part in this study. The participants are chosen to be active performers who has on stage experience. The profiles of the participants are such: (1) 25, M, bass guitar, indie/electronic, formal education, 13 years of performance experience. (2) 24, F, piano,

classical, self-taught, 16 years of performance experience. (3) 28, M, guitar, alt rock/no wave, self-taught, 10 years of performance experience. (4) 43, M, laptop, noisefunk, formal education, 36 years of performance experience. (5) 28, M, computer, electronic/house, formal education, 5 years of performance experience. (6) 26, M, drums/violin, rock, self-taught, 8 years of performance experience. Participants no.2 and 4 have also performed professionally. Participants were divided into two groups of three based on their backgrounds, experience and musical styles to do rehearsals and perform together.

4.2 Practice and Rehearsals

Each participant was met by the researcher for a brief explanation of the study, a short demo and introduction to C-Box and to complete the initial questionnaire for musical background information.Following this, participants were asked to practice with the C-Box everyday, record a video of themselves practicing and fill in a practice diary after each session. To fulfill the requirements of the practice, they were asked to finish at least six practice sessions on different days. The practice diaries were intendend to capture and track their personal approach, experience and level of expertise.

When the practice period ended, the researcher met with each group separately. Each group was asked to undertake two group rehearsal sessions, each including one rehearsal with network rules (*case-a*) and one without them (*case-b*), in order to capture the influence of these hidden constraints. Then, a short group discussion took place in which the network rules and differences between cases were explained by the researcher. Finally, the performers were asked to rehearse once more with and without network rules. The order of the cases were switched between the groups to eliminate any possible order bias. The participants were not directed to achieve, convey or express anything during the rehearsal or performance.

4.3 Performance with Audience

A performance night was arranged for both groups to perform with the prepared instruments in the same order that they did the rehearsals: *Case-a* and *case-b* from the first group, then *case-b* and *case-a* from the second. The performance night was publicly advertised and was audio and video recorded. An audience of 17 people attended.

During the study questionnaires were collected in the form of practice diaries and more focused questionnaires collected after the rehearsals and on the performance night. These questionnaires were aimed to understand participants' self-rated level of mastery, interaction with the instrument, personal approach to performing with it, exploration of affordances, style and group interaction. Semi-structured group interviews were also undertaken which were audio and video recorded, after rehearsal sessions and at the end of the performances. These interviews contained open-ended questions about participants' thoughts, feelings, collaboration, performance experiences, agreements/disagreements and musical approaches.

5. RESULTS
5.1 Diversity of Style and Difference between Individual and Group Playing

Affordances of this instrument were even more limited than the version used in the cube-instrument study [28], as it has a fixed synthesizer. This is one of the biggest physical constraints. The participants reacted to this limitation by focusing more on the techniques they could use on C-Box, as reported in the questionnaires. According to the observa-

Figure 2: A picture of the second group taken during the performance.

tions, they focused more on what the can play rather than how they can play it.

Individually, the participants showed a diversity in the playing styles. The influence of coming from different musical backgrounds and performing different kinds of music could be seen in their individual and group playing. According to the observations, participants with a classical music background focused mostly on the pitch and communicated through it such as playing sequence of intervals, short melodies etc. Noisefunk performer was mostly trying to create large envelopes of noise using a multiple finger technique he developed during practice sessions.

Players were observed using the individual video recordings taken during self-practice sessions as well as the video recordings of rehearsals and performances. Due to technical problems during the performance night, multi-cam recording failed and only one camera recorded the performances, capturing only part of the stage.

All of the participants sat during the self-practice sessions, rehearsals and the performances, therefore the posture variety was low. During the performance and the rehearsals, all the participants sat in a triangular shape without any directions and aligned themselves towards the center of this triangle. They kept the box on their laps.

It has been seen on the video analysis that some of the interaction techniques were more favored by some participants than others. For instance, the noise artist kept both hands on the sensor almost all the time, because that was causing the synth to get loud, distort and produce drone-like timbres. Four of the six participants reported that they learnt at least one new technique during the rehearsals. 1 participant reported something that he could not achieve using the affordances of C-Box: *"I would like the sensor just to be 4 times longer so I can control the pitch!"*

Participants agreed that they enjoyed the group playing much more. This appears to be due to the element of social interaction and exploration of what can be done with others. A performer can set her mind to play exactly the same gestures in the same sequence in every performance, but the music will most likely be different each time when there is a group around her and they unaware of her musical intention. Thus, the more interesting aspect of this study for participants was the group music: *"It was not very satisfying for me to play solo at home, because of the nature of the synth. So, the interesting thing was to play and create things with others."*

It was observed that there was a noticeable tension and movement in what was being played such as getting louder and more silent together. Some roles emerged, e.g. lead, percussionist etc. It has been reported in the interviews that the simplicity of C-Box created a cohesion, because the different techniques were audible and easy to reproduce

by others.

In the group performance, the most dominant modes of interaction were observed and the characteristics of the sounds were observed to be more effective than visual interaction. Individual timbre and loudness were observed to be the most dominant ways of influencing the whole group playing, because the timbral variations and loudness were more easily noticed and reacted to by the other players. These created the significant dynamic changes that shaped the structure. Video recordings and interviews indicate that the participants used eye-contact and body language very minimally to convey intention, ideas or a new direction. One common behavior was looking at each other at the verge of a resolution to an end, as they were trying to confirm with each other that they are finishing the session: *"Pitch was less apparent to me as the performance was highly atonal, and I felt that the tension and release in the performance came entirely from rhythm, dynamics and timbre."*

5.2 Non-networked vs. Networked Case and Their Influences on the Performance

One of the focuses of this study was understanding the influence of the hidden (network) constraints. Questionnaires, observations, semi-structured interviews and ethnographic analysis of the video recordings were used to explore the influence of hidden constraints as discussed below.

The questionnaires indicate that participants found the non-networked case more liberating, where the networked one was sometimes perceived as obstructive, for example: *"Non-networked was freedom to express ideas, so I could actually focus on my rhythmic structure and take turns with my own decision."*

Overall, participants found the networked version mostly very limiting. Most of them reported that it brought structure and dynamics, but it often disrupted what they want to do. One participant felt that it was more like playing a game.

In contrast, 3 participants stated that the networked version made the performance more connected between the performers: *"Rules made it easier to interact, because it made all the relationships between techniques and sounds more transparent, ... coherent."*

Participants also reflected upon what happened on stage between one another. The solo rule was found to bring coherence, but because of the fact that it was rather forced, it did not align with what was in participants' minds: *"The solo sections forced focus on one performer and resulted ultimately more attention and interaction. However, sometimes what system brought didn't coincide with other performers' intentions."*

The participants almost totally ignored the beat rule both during the rehearsals and the performances. Even after they understood how it worked, they did not react to it or use it as a way to modify their musical intention. Interviews also showed that they found the beats unimportant as they were easy to ignore.

The interviews also showed that they found the network constraints imposing and obstructive. They reported that it lead to more structured and varied composition: *"I don't do percussions at all, so when I'm cut out, only thing I can do is something percussive and it is a mental leap! Maybe more engaging, but sometimes, I just want to continue to play, but it may not let me!"* Two of the participants agreed that they thought the networked case was better for the audience, since it yielded a more structured form of musical material.

Regarding the C-Box, most of the participants reported that they found the timbre variation very limited as they could only distort it and change the tune of the additive synthesizer a tiny bit by pressing too hard. One participant particularly wanted to be able to control the pitch better: *"I would like the sensor just to be 4 times longer, so I can control the pitch."*

Interestingly, the analysis of the video recordings and the interviews showed that the players' loudness were synchronised, when the system was non-networked. From individual loudness levels of each C-box log, it could be seen that the loudness of the individual players was increasing and decreasing in accordance with the overall average loudness. However, in the networked case, this seemed much less apparent, because the solo rule was being triggered and participants then played along with it. Often times the players mimicked each other for the rhythmic parts. Also when a player started to do something very different, this was reflected by other players as they changed their gestures after a short period of time.
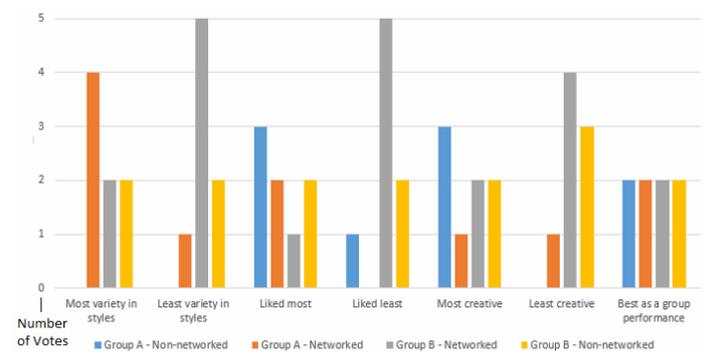
5.3 Audience Feedback

Figure 3: The results of audience questionnaires.

An audience of 17 people attended the performances in a performance space with a total capacity of 30. A short audience questionnaire was left on each chair so that feedback could be provided voluntarily. The questions and comment sections were aimed at obtaining feedback about the audience perception of the styles, coherence, creativity of the musicians, and whether the spectators liked the constraints of the C-Boxes (see **Figure 3**). Only 8 of the questionnaires were completed fully, however, common feedback about the constraints was that *"the non-networked case felt more planned"* and the networked case was perceived as *more unstable.*

6. DISCUSSION

Nijs et al. argue that the experience of a musical instrument becoming part of the body is necessary for expressive communication of musical meaning [22]. Arguably, there were two reasons that the *appropriation* [28] and embodiment did not happen in the study reported here: *i*) the amount of time the performers had to practice (one week) and *ii*) the design of the instrument itself which some performers reported could be improved by having more elaborate timbral control.

Another contributing factor may be that all the instruments are exactly the same and are not flexible or malleable to each performer's unique capabilities and background. As Buxton argues [8], a one-size-fits-all general purpose interface design approach does not let the musicians use their talent to a full extent. On reflection, the instrument designs should have reflected players' diversities.

We observed that in the domain of free improvisation

346

it is counter-intuitive to restrict the performers' freedom with forced unnatural interventions. If the constraint is something really abrupt, such as the *solo rule*, or abstract, such as such as the playing of beats top-down, it results in frustration instead of challenge for the performers. Instead, the constraints should be designed and implemented in more ecologically valid ways.

According to the observational analysis and the interviews, the most dominant modes of interaction in the group performance depended on the performers' musical backgrounds and interface constraints. Performers focused more on the timbre and loudness of each other's contributions in order to shape the main compositional structure of the performance, whereas pitch and rhythm were the main cues for musical phrasing among the individual performers due to the design of the instrument: Having a pitch range almost as wide as of a guitar, allowing sharp attacks, limited timbre and effortless pitch control. Furthermore, it may be that introducing both transparent limitations on a physical level and hidden constraints as musical rules results in a form of cognitive overload for performers.

7. CONCLUSION

Results of this study indicate that network constraints can lead to more structured improvisation, although the resultant music may not fit with performers' true intentions. Furthermore, it was found that when series of beats are introduced to guide the performers into a collective convergence, it is likely to be ignored, because it is perceived by performers as being out of context.

In this study, we relied heavily on self-reporting by the participants. More objective methods of analysis should be explored for future research such as analysis of the patterns of interaction between performers.

8. ACKNOWLEDGMENTS

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