

# Intermodulation: Improvisation and Collaborative Art Practice for HCI

**Laewoo (Leo) Kang**  
Information Science, Cornell  
University, Ithaca, NY  
lk423@cornell.edu

**Steven J. Jackson**  
Information Science, Cornell  
University, Ithaca, NY  
sjj54@cornell.edu

**Phoebe Sengers**  
Information Science, Cornell  
University, Ithaca, NY  
sengers@cs.cornell.edu

## ABSTRACT

This paper integrates theory, ethnography, and collaborative artwork to explore improvisational activity as both topic and tool of multidisciplinary HCI inquiry. Building on theories of improvisation drawn from art, music, HCI and social science, and two ethnographic studies based on interviews, participant observation and collaborative art practice, we seek to elucidate the improvisational nature of practice in both art and ordinary action, including human-computer interaction. We identify five key features of improvisational action – *reflexivity*, *transgression*, *tension*, *listening*, and *interdependence* – and show how these can deepen and extend both linear and open-ended methodologies in HCI and design. We conclude by highlighting collaborative engagement based on ‘intermodulation’ as a tool of multidisciplinary inquiry for HCI research and design.

## Author Keywords

improvisation; art practice; creativity; collaboration.

*“This conviction that direct deed is the most meaningful reflection, I believe, has prompted the evolution of the extremely severe and unique disciplines of the jazz or improvisational musician... Aside from the weighty technical problem of collective coherent thinking, there is the very human, even social need for sympathy from all members to bend for the common result.”*

- Bill Evans, liner notes to Kind of Blue [19]

## INTRODUCTION

The introduction of artistic methods and processes into academic research can enrich and enliven both research and art. In the HCI research community, art-based methods have begun to push and refigure core HCI notions of collaboration, design, and arguably computing itself (see, inter alia, [18,28,32,33]). Artists’ creative processes and

outcomes can help us to see and imagine opportunities and dimensions of technology and design that may elude more behavioral or engineering models [5,17,41]. In recent years, a range of artistic practices – from performance-based, to collective making, to adversarial engagement - have been highlighted as types of research methods that may draw on, widen, and extend interdisciplinary and experimental approaches [6,9,31,40,61].

This paper builds on this work to explore the forms of improvisational and open-ended learning commonly found in collaborative art and musical practices, and their potential as methods for HCI research and inquiry. Rather than casting improvisational art practices primarily as a step on the way to more systematic forms of thinking [39], as mysterious and personal matters of voice and expression [37], or as inscrutable sources of inspiration for more recognized forms of scholarly work, here we explore their potential as valid and generative research sites and activities in their own right. Our goal is to further understanding of the potential and nature of such artistic approaches to generating insight for HCI research. We do so by exploring existing theory and two sets of empirical studies based on the study team’s ethnography and collective art practice.

Derived from a Latin word meaning “unforeseen”, improvisation refers broadly to the practice of composing or inventing extemporaneously, through some kind of responsive and situationally-dependent departure from pre-formed plans or expectation [44,57]. More recently, the word has been used to indicate a process of “un-premeditated” composition or performance across a wide range of fields or endeavors. Outside the worlds of musical and artistic performance, the language of improvisation has sometimes been adopted to underscore the indeterminate and evolutionary qualities of everyday human behavior, and as such has begun to challenge and inspire work across a broad range of disciplines: from anthropology, economics and cognitive science; to architecture and urban planning; to mechanical and robot engineering [27,42].

HCI work to date has explored improvisation across several dimensions. This includes theoretical analysis around forms of complexity and uncertainty in human-computer interactions and the emergent and “circumstantial” character of human action [2,9,43,45,58]; and as a creative methodological approach wherein improvisational practices

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than the author(s) must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from [Permissions@acm.org](mailto:Permissions@acm.org).

CHI 2018, April 21–26, 2018, Montreal, QC, Canada

© 2018 Copyright is held by the owner/author(s). Publication rights licensed to

ACM. ACM 978-1-4503-5620-6/18/04...\$15.00

<https://doi.org/10.1145/3173574.3173734>

are employed in the service of ideation, discovery, and the elicitation of user preferences and worldviews [24,25,52,59].

This paper seeks to extend these lines of analysis in several key directions. Drawing from an integrated program of theory, ethnography, and collaborative art production, we argue for improvisation as (a) a form of active learning that fosters emerging creativity through tension between structure and freedom, and (b) a holistic and complex socio-material practice that transcends and transforms the experience and capabilities of individual creative actors. We identify five key features of collaborative improvisational practice – *reflexivity, tension, transgression, listening and interdependence* – and explain their relevance to other linear and open-ended methods in HCI and design research. Finally, we explain how a process of *intermodulation* can be one way to explore multidisciplinary creativity and knowledge for HCI design.

The paper that follows proceeds in five main stages. First, we review approaches to improvisation in art and music to understand how improvisation functions as an ordinary feature of human learning and collaborative creativity. Next, we review related HCI work that explores the nature of improvisation both theoretically and methodologically. We then report on two ethnographic and improvisational projects of our own. The first involves an extended interview and observational study with fifteen media artists and musicians who employ improvisation as central methods of creative work. The second, ‘Intermodulation,’ involves a series of collaborative improvisations undertaken in conjunction with three groups of amateur and professional musicians, culminating in a series of public audio-visual performances. In discussion, we outline five key dimensions of improvisational action, and explain how this understanding of improvisation can challenge and extend existing HCI theory and methods. The paper concludes by exploring the potential of improvisational methods for multi-disciplinary HCI inquiry.

### IMPROVISATION IN ART AND MUSIC

Improvisation as a process of emergent and un-scripted behavior is broadly accepted in the art and music fields, especially in contemporary art and jazz, as a way of producing more effective, open-ended, and sometimes participatory aesthetic and creative outputs. When individuals or groups are working in an improvisational mode, their actions do not follow a linear and predetermined plan, but are taken contingently in response to the emerging contours of real-time situations. Take for example, Picasso’s creative process, as captured in the film ‘The Mystery of Picasso [62],’ a five hour time-lapse video shot in Picasso’s studio. As Sawyer [56] describes:

*In his studio, Picasso is painting free-form, without preconceived image or composition; he is experimenting with colors, forms, and moods. He starts with a figure of a reclining nude, but then loses interest, and the curve of the*

*woman’s leg reminds him of a matador’s leg as he flies through the air after being gorged by bull - so he paints over the nude and creates an image of a bull and matador. But this leads him to yet another idea; he paints over the bullfight image and begins work on a Mediterranean harbor - with water-skiers, bathers in bikinis, and a picturesque hilltop village. The free-form inspiration continues. Five hours later, Picasso stops and declares that he will have to discard the canvas - it has not worked. But time was not wasted- he has discovered some new ideas, ideas that have emerged from his interaction with the canvas, ideas that he can use in his next painting. Picasso says, “Now that I begin to see where I’m going with it, I will take a new canvas and start again.”*



**Figure 1. Pablo Picasso’s process in ‘The Mystery of Picasso’**

From a woman’s leg to a Mediterranean harbor to “I will take a new canvas and start again”, Picasso’s idea does not follow a linear progression or blueprint, but continuously changes through both purposeful and accidental interactions with the circumstances around it. Such uncertainty and non-linearity might appear at first glance random or without a plan, especially when considered from a traditional behavioral science or engineering perspective. But doing without preconceived images does not automatically imply doing without plans, or finding alternative solutions only when plans fail. As the film reveals, although Picasso does not work from a ‘master plan’ of the work, he is planning all the time, continually adjusting his behavior and creative ideas to the shifting circumstances around him.

In the music and art theory literatures, such improvisational activities have been understood in two broad ways. The first involves the musical and creative capacity to accommodate to emerging developments in the musical or artistic situation. This may emerge in response to unanticipated shifts in the material environment [26,44]: for example, as happened during the 19<sup>th</sup> century when the number of keys on pianos was dramatically increased and traveling pianists could not always anticipate which instrument they would encounter in upcoming concerts. Improvisation may also emerge as a response to unanticipated breakdowns or glitches: for example, when one or more piano strings broke

during performance (a frequent occurrence in the instruments of this era). Under such circumstances, musicians were required to develop alternative variations on the fly, bringing unexpected circumstance into alignment with the original plan of the music (and in cases of group performance, this adjustment would need to be accomplished *collaboratively*). Improvisation in this mode builds on the capacity for agile and flexible response to the vagaries of uncertain and unstable situations.

In other instances, musicians and artists may seek to exploit or create uncertainty as a mechanism of discovery and expression, making breakdown in effect a ‘feature’ rather than a ‘bug’. For example, jazz musicians may play exploratory and unplanned notes called ‘blue notes’ in search of new musical phrases and expressions, whether in composition or in live performance [38].<sup>1</sup> While this highlights a more adventurous and purposive mode of improvisation and involves forms of risk and uncertainty that hold the outcome in suspense, it remains for all that accountable: to the stipulation that the music continue to unfold in “logical, cogent and expressive ways” [7]; to the norms and conventions of distinct musical traditions, including the convention of violating convention, where this holds (e.g., punk rock); and to a certain threshold of coherence or fit to both audience expectation and other members’ sound. Thus, even where spontaneous and intuitive, improvisation may rest on deep structures of continuity and expectation that ensure the new phrase or concept remains broadly intelligible, even when surprising. This balance between novelty and tradition, structure and freedom, constitutes the essential tension that shapes and animates improvisational work.

In contemporary experimental music and media art, improvisational creativity has been explored through languages and practices ranging from indeterminacy and appropriation to bricolage and the ‘ready-made’ movement. Mid-century artists like John Cage and Nam Jun Paik explored the “situational” nature of aesthetics and creativity through a range of novel, often transgressive, works (see, *inter alia*, [11,12,48]). Cage’s idea of the “indeterminate score” emphasized the interaction of musical creativity with uncertain situations. Driven by the desire to “let things be themselves”, the role of the composer in this type of music is no longer to determine the musical outcome through a traditional notation system with a fixed and precise relation

---

<sup>1</sup> Jazz pianist Thelonious Monk for example was a master of the ‘blue note’, a ‘mis-struck’ note (a seventh in place of an expected octave, adjacent note pairs, etc.). While jazz historians have attributed this to Monk’s unusually flat hand technique (resulting in adjacent keys being occasionally struck together), this quickly became a distinctive and widely copied feature of Monk’s influential style, and an iconic feature and figure of jazz (along with the name of a leading New York jazz club and record label).

between notational symbol and sound; instead, the composer “determines” a set of rules which performers and audience members interpret to regulate and produce situated sound experiences [21]. Nam June Paik’s interactive art work (including ‘Participation TV [49]’) explored forms of “audience activity” embedded in television media, as well as the forms of “indeterminacy” producing unexpected feedbacks via on-going participation.

More recently, an emerging field of critical studies in improvisation [42,63] explores connections and patterns in improvisational practices across a broader range of practices and disciplines. Some researchers in this field have sought to connect and interpret improvisational practices according to behavioral science or engineering models, casting individual practices of creativity and improvisational action as a form of real-time planning and adjustment under languages like “error-correction” [50] or “monitoring-planning-executing” [51]. Others [46,55] have emphasized instead the nature of improvisation as an emergent *group* phenomenon in which improvisational actors react not only to changes in surrounding circumstances, but also intuitively participate and contribute to a kind of “group flow,” achieving (where successful) “interactional synchrony” at the collective and holistic level. This group flow emerges as an interactive property of the group, and is often named by participants and analysts alike in fleeting and elusive, even mystical, terms – chemistry, feel, style, etc.

#### IMPROVISATION IN HCI

In early HCI work informed by influences from behavioral science and engineering, human activity was often understood as a kind of purposive and goal-directed action unfolding through linear, instrumental, and broadly predictable progressions [8]. This perspective interpreted interaction as a series of action-reaction (or stimulus-response) couplings between individuals and environments with less appreciation for the active and emergent properties to be found in the circumstantial and material factors shaping and defining interactive situations. Such instrumental and mechanical understandings have however been challenged and extended through older and newer work in HCI theory and design methodology.

Suchman [58] for example has emphasized the *situated* character of human action and its dependency on emergent material and social contexts. Rejecting plan-based models of human cognition then prevalent in Artificial Intelligence and HCI, Suchman describes instead how circumstances co-create intelligent action, providing resources that help structure action without fully determining its course. Agre [2] builds on this insight to connect questions of determinate planning and action to the indeterminate properties of *situations*, which remain complex, non-transparent, never fully representable, and therefore genuinely uncertain. This recognition necessitates a shift from the model of “capital P” planning towards a “small p”

model built around moment-to-moment improvisations undertaken in response to the question of “what to do now based on how the world is now” [1]. Dourish et al [16] build on these understandings of improvisation to argue they apply to the everyday action of designing itself.

These theoretical insights have been mirrored in turn by diverse methodological explorations in HCI research and design (see, inter alia, [10,24,29,45] ) that highlight the advantages of learning through open-endedness, situated engagement, and artistic collaboration. For example, in research through design [59], a generative and inductive research approach necessitated by the “wicked problems [53]” designers face, open-endedness is actively employed as a resource for discovery and surprise. Critical making [52] highlights learners’ situated experiences and insights derived from hands-on activity and material engagement with DIY electronics. This approach promotes the integration of critical thinking and physical making for reconnecting our experience with technologies to conceptual critique. Meta-design [25] also highlights the emergence of knowledge and insight in collective design practices in which users, designers and other uncertain factors collectively interact and ‘co-evolve’.

Despite these parallels, there remains some confusion and disagreement around how to articulate and evaluate the forms of improvisational knowledge and practice that spring from these generative inquiries [15,60]. Gaver [23] explains that the knowledge from such inductive inquiry is likely to be “provisional, contingent, and aspirational”, and may not fit well within a traditional scope of evaluation where standardization and generalization are considered critical to a research contribution. Höök et al. [30] describe such contingent and situated knowledge as “first-order knowledge”, and argue that this can become a more generalizable form of knowledge (“second-order knowledge”) by capturing and studying the specificity and richness of design processes beyond anecdotal evidence.

As a way to articulate and evaluate such contingent knowledge, some researchers also suggest considering documentary artifacts and intermediate design products produced during the improvisational process as important research results that can point, albeit indirectly, to emergent forms of knowledge and creativity. To this end, Bardzell et al. [3] suggest using a set of ‘mediums’ for documenting process, and highlight the performativity of this rich documentation for reflective knowledge construction. Gaver and Bower [22] propose ‘annotated portfolios’ where a series of design works become productive as research by linking them to processes of theory formation in writing. Zimmerman et al. [60] describe how knowledge from design practice may be “implicit” and reside within the designed artifact. Bardzell [4] similarly describes the role and importance of designed artifacts as knowledge producer, both for those who encounter them and those that

design them. Odom et al. [47] recommend identifying these explicitly as ‘research products,’ to call out their epistemic functions and extend HCI notions of the prototype.

Taken collectively, these insights suggest that the forms of improvisational action central to (much) art and music also appear not only in the use of systems (as designed, built and studied by HCI scholars) but also in their design. This general recognition has given rise to a range of new methods and approaches based on open-endedness, situated engagement, and group emergence, attributes which can fairly be called improvisational. Recent literatures have begun to suggest ways in which knowledge from improvisational research can be made more accessible and generalizable, both through processes of deliberate documentation and reflection, and the consideration of a range of intermediate artifacts. However, there is still limited understanding of how improvisation works as a mode of research, and what features of improvisation actually enable learning and creativity. Such concerns also involve issues within the wider HCI community around the evaluation of improvisational and art-based research approaches. To better understand these questions, the following sections introduce two empirical studies – one ethnographic, one participatory and performative – around art-based instances of collaborative improvisation.

#### STUDY 1: MEDIA ARTISTS AND MUSICIANS

In this section, we report findings from an interview-based ethnography study conducted from 2013 to 2016 with fifteen multi-media artists and musicians who engage processes of improvisation for producing their creative works. The purpose of this study was to understand the motivation, process, and value of improvisation from an actors’ point of view. Interviews followed a semi-structured format organized around questions about their improvisational process, results and experience. Most lasted between one and two hours. All interviews were conducted in person and combined with studio visits and/or observations of public exhibitions. Interviews and observational data were later transcribed, reviewed, and coded according to grounded theory [13] principles.

All of the artists and musicians in our study described the process of improvisation as an approach to playing and producing creative works. They describe their improvisation as neither random nor pre-determined activity, but as situated action in contexts of on-going reflection. Keith MacDonald, an American jazz Pianist interviewed in Klemp et al’s jazz study [38], describes his improvisation as real-time “reaction in phrase”

*Everything is a reaction to what was just done. When I improvise, I think in phrases. If one of these phrases is interrupted, I abandon the past idea and develop the new one.*

In our own interview, one multi-instrumental musician explained her improvisation process as one that “responds” to “different contexts.” As she explained:

*When I'm performing in a chapel, I'm not going to have bar noise, or a cappuccino maker, or people talking. There is a sacredness, and so the tension can be created in that performance in silence, because the music is very hollow and so the tension is like, 'when is she going to play the next chord?', and you feel the tension in the emptiness.*

One multi-media artist who produces steampunk-style clocks by assembling diverse outdated materials, described that his process of making artworks often proceeds by finding and taking apart a particular old technology like a mechanical typewriter or cash register. He explained that the complex inner mechanism and old aesthetic of these materials continuously inspire what he makes. He described his making process in his studio this way:

*I think the more things I have been taking apart, the more I have been inspired to what I have been doing now. I mean you know, when you take apart a typewriter, I mean, it's amazing. What some of these people did with, you know like, the old cash register before an electronic?*

Some group musicians also explained how their personal musical ideas often developed through real-time interactions with other members' sounds. One electronic musician explained this as a process of feedback or “mutual adjustment,” as distinct musical expressions were blended and evolved in performance. As the musician describes:

*Therefore, you're going to have this feedback. In other words, the musician is adjusting from the right hand side to the left hand side, as they're listening, Both of them at the same time are adjusting to each other. You've got to have some sort of loop back. Feedback.*

Several interviewees described the “tension” stemming from the uncertainty of improvisational process – the ever-present threat of unwanted dissonance and breakdown – as a source of both fragility and potential failure, but also energy and creativity. One musician described her efforts to harness this tension, explaining how she intentionally invites “unpredictable elements” and “uncontrollability” into her music to challenge herself to avoid staid and too easily anticipated outputs. She offered the example of a musical device called the ‘Blister’ [14], a DIY synthesizer that creates random and chaotic electronic sound.

*When I play by myself I know exactly what I'm going to get, and so by incorporating Blister there's this element of tension, or volatility, and so I'm not entirely sure what's going to come out, which I can then respond to, because I like that tension in performance.*

In addition, some interviewees described a sense of joy or achievement in improvisational processes when unexpected musical expressions and artistic ideas emerged from the

situation. One percussionist in the band explained how the creation and relaxation of such tension leads to “surprising” group experiences. As the musician described:

*I love space where it creates tension, where it's just, it does not use enough space in between, taking a breath and waiting. There was something that happened today and I was like, 'it creates a tension, I love it.' It was just really like, 'Are we doing another one? Should I stop? Okay, it will be like a big surprise.'*

The artists and musicians reviewed above demonstrated a range of experience about improvisation from a practitioner perspective in media art and music. Reflecting the theories explored previously, participants explained how their creative processes develop through interaction and engagement with diverse on-going environmental factors like phrases, space, materials and other members. Some of them reported that they intentionally exploit uncertainty as a mechanism of discovery that transgresses pre-planned structures and avoids easily anticipated outputs. In addition, some point out the nature of “tension” in this practice, which promotes surprising group discovery.

## STUDY 2: INTERMODULATION <sup>2</sup>

Motivated in part by the findings of our interview study, members of the study team decided to study improvisation through participation in two collaborative art projects (Intermodulation I & II), which culminated in a series of public audio-visual performances in Ithaca, New York between 2015 and 2017. In these projects, the first author was engaged primarily as a multimedia artist, providing interactive artworks to accompany the performances of electronic and experimental musicians, as well as (auto-) ethnographer, studying the process and results of these collaborations. The second author participated mainly in the form of ethnographic observation and interviews around the collaborative results. The main purposes of the study were to understand features of improvisation through first-hand experience, to track how HCI- and design-related creativity emerged and developed through collaborative and improvisational processes, and to share these empirical findings through analysis of ethnographic materials, rich documentation and produced artworks.

To this end, collaborations were captured through an extensive process of documentation and reflection, featuring a rich combination of still photography, video, audio recording, and field notes. Participants (including members of the study team) were also actively interviewed before, during, and after the collaborations, following a semi-structured format organized around questions related

<sup>2</sup> The term comes from two sources: a famous jazz duet by Bill Evans and Jim Hall recorded in 1966 [20]; and a concept from electrical engineering explaining the forms of newly-emerging signals when two or more different signals are merged into one non-linear system [54].

to motivation, process, discovery, and experience. Most interviews lasted between one and two hours, and were conducted as individual interviews or broader ranging group discussions in which non-study team participants also presented questions and themes back to the authors. All interviews, videos and field note data were subsequently transcribed, reviewed, and coded by the authors. In addition, this work led to the development of three Arduino- and Processing-based installation art pieces – Breaking AndyWall, echo() and Intermodulator – designed to interact in real-time with the collaborating musicians. More on these pieces and other supporting materials from the study may be found in its project website (<http://cornellhci.org/intermodulation>).

### Intermodulation I, 2015 ~ 2016

The first Intermodulation began in November 2015 and eventually produced two audio-visual performances in late 2015 and early 2016. These performances involved two groups of musicians: ‘The Electric Golem’ [64], a New York-based improvisational electronic music duo that releases and performs their music in international venues; and cellist Min Park, a classical musician with diverse experience in both solo and orchestral performance.



Figure 2. Intermodulation I, 12/18/2015

The initial idea of the event was triggered from a casual meeting in early December 2015 when the first author was testing the prototype of his new artwork, ‘echo() [36],’ with a member of The Electric Golem. The artwork was made up of B/W tube screens and other light sources that interacted with the volume of the sound picked up through the microphone. While testing this installation with their voice and other instruments’ sounds, such as guitar and harmonica, they accidentally discovered the artwork’s potential as a live music visualizer. This unintended finding led them to plan an audio-visual concert where musicians can play music along with the final version of echo(), now upgraded to detect and visualize both volume and pitch.

This initial plan evolved to inviting more musicians and adding a second installation piece, ‘Breaking AndyWall [34],’ which progressively decomposed images of famous artworks in response to fluctuations in pitch and volume.

The first public event, Intermodulation, was presented on 12/18/2015 in the first author’s art studio with approximately 50 audience members in attendance. The evening proceeded in two parts. In the first, the Electric Golem played one piece of their music, ‘The Heart of the Golem,’ for 28 minutes, along with echo() and Breaking AndyWall. Images from Breaking Andywall were projected high on the wall, and shattered progressively into pixels in response to the volume and pitch of the sound. The other installation, echo(), was installed on the floor, with the installed screens generating a pattern of moving characters driven by the volume and the frequency of the sound. In the second part, Park played four classical cello compositions, accompanied only by the echo() installation. In this setting, echo() produced four different patterns that hadn’t been seen previously. Of the six screens in the installation, one was installed facing Park for him to observe live interactions with the installation.

### Intermodulation II: 2016 ~ 2017

Our second case centers on a collaboration with Annie Lewandowski [65], a composer, improviser, and multi-instrumentalist whose work is situated between the worlds of improvisation and independent rock music. Lewandowski leads an experimental trio, Powerdove, that records and tours throughout the United States and Europe. Collaborations between Powerdove and the first author’s audio-visual media piece ‘Intermodulator’ resulted in four public performances from November to May 2016-2017.



Figure 3. Intermodulation II, 11/10/2016

The initial idea of this collaboration was triggered in an interview with Lewandowski during our initial round of ethnographic study in July 2016. During the interview, the first author shared an early prototype of his new artwork ‘Intermodulator’ [35], a sound-responsive installation comprised of opposing box fans and backlights. In this installation, the speed of the individual fans and the brightness of the backlight respond to the pitch and volume of input sounds. When a certain resonance and balance are achieved, the opposing fans produce a seemingly stationary

or ‘moiré’ effect, an illusion produced from the visual interference of two oppositely rotating objects.

At the time, the installation had not been fully developed either technically or conceptually, and only one set of fans and lights was functioning to produce the moiré effect. When Lewandowski played with the effect of her voice on the prototype, interesting correlations between the pitch and timbre of her voice and the effect of the installation were discovered, and an agreement was reached to include it in an upcoming Powerdove concert.

The first result of this collaboration was presented during Powerdove’s North American tour on November 10, 2016. During the course of the 1.5 hour concert, the Inter-modulator was installed in the background of the stage, and produced interactive visual images responding to the volume and frequency of sound sources including Lewandowski’s vocals, other member’s instruments, and audience engagement and applause. Although one set of fans was designed to be installed facing Lewandowski and the other band members to allow them to interact live with the installation, limited stage space demanded in the end that all fans were installed in the background. All pieces performed in the concert – as with Powerdove’s live performance more generally – followed a pattern of collective improvisation, though built around known originals from the group and in some cases previously recorded pieces. In later interviews, one of the Powerdove members described such collective improvisation as a process of “developing dialogue” in real time.

#### **Motivation, creativity and collaboration in improvisation**

In both Intermodulation I and II, goals and expectations of the collaborations were not pre-arranged in detail but emerged and evolved over the wider course of the interaction. Because the artworks were still under construction through the initial stage of collaboration and were tweaked and revised all the way to the end, it was difficult for either musicians or artist to think towards final results in a fully determinate way. Other important factors such as performance spaces, stage settings, and playlists also remained ‘undecided’ in the initial stages of collaboration, and took form and shape only as the process emerged.

In later interviews, participating musicians described their motivations and willingness to participate in these uncertain and somewhat time-consuming projects. One commonly expressed motivation was a certain “curiosity” and “excitement” around interacting and experimenting with other genres of art. Lewandowski for example reported a deep curiosity about how the Inter-modulator would interact with the Powerdove sound. This led into a wider discussion of “curiosity for the other” as a central feature of her approach to experimental collaborations. As Lewandowski explained:

*I guess that's why I'm an improviser, is that I like drawing the other near. I learned that a lot from my teacher when I was in graduate school. He's so great at that. He'll play with anybody because he's just got this curiosity about the other. That maybe drives my work also. It's just this otherness, and then what does it mean?*

On the other hand, some participants emphasized points of connection and similarity with potential collaborators, whether mutual friends, similar aesthetic or working styles, or an almost ineffable ‘feeling’. As one member of The Electric Golem explained:

*It usually starts from something very much in common like maybe your childhood friends, maybe you've just become socially... you have friends, or maybe you're in school together. Maybe our kids play together. There is something in common that brings you together that you start building a relationship socially. Then you start seeing the possibilities.*

In addition, some participants reported situations where unexpected artistic and musical expression emerged and developed through engagement with ongoing environmental factors. For example, both members of The Electric Golem gazed frequently at the visual image of the artwork while performing during the first Intermodulation concert. In a later interview, they explained that the visual response from the art piece was “invoking” them to produce new musical expression. As one of them described:

*When I saw, for instance, the Marilyn Monroe picture fragment, which was produced by certain sounds that we were making, it made me think of certain sorts of sounds that would go with that type, glitching type sounds. High frequencies, I was thinking. The visual image was invoking me to produce certain sorts of sounds.*



**Figure 4. The Electric Golem interacting with the artwork**

The first author also reported situations that challenged and inspired him to produce unexpected creativity and solutions. For example, during the rehearsal of Intermodulation I, he accidentally confronted a technical error in the Breaking AndyWall system, which produced an

unintended color-inversion glitch. This led to a revamp of the technical system that actively employed this glitch as a visual effect in subsequent collaborations (Figure 5). As described in his fieldnotes:

*Because 'Breaking AndyWall' was originally designed to interact with the audience' hammer smashing, it started producing a lot of unexpected graphical glitches when I first converted it to interacting with live sound. But somehow I thought it could be quite cool if I used that error to visual effect.*



**Figure 5. The subsequent performance of Intermodulation I**

On the other hand, Min Park, the classical cello player interacting with `echo()`, explained that his musical and creative expression was barely affected in this series. In video analysis, we observed how Park's eyes remained fixed on the musical score rather than the art work going on in front of and behind him. In a subsequent interview, Park explained that he considered the artwork not as a communicative actor or partner, but as a "backup dancer" that was "totally dependent" on his play. As Park explained:

*I know how it works. It was very easy to play, because they would react to me and they're totally dependent on me. I'm not dependent on them for anything.... I think the audience wouldn't think that the objects shared the same hierarchy with me. I feel like the audience would only perceive these objects to be more kind of backup dancers.*

In the later audience interview, the audiences commonly explained that these interactive artworks appeared to be not simple visual supporters by mentioning their perceived roles as "performers" or "interactive actors". As one audience member described:

*I was also intrigued by the technical part of their expertise, which I wasn't familiar with. I enjoyed that a lot. This is like how we perceive the performers, with their technical thing kind of exposed before me."*

The members of Powerdove also report that their musical expressions were not immediately affected by the interactive installation in the first concert, mainly because they were immersed in their own improvisational actions.

Members mostly concentrated on their own playing and interactive musical conversation with each other without communicating with the light installation. This outcome stemmed in part from the particular stage setup, with the installation installed to the rear of the stage and out of the musicians' normal range and orientation of vision. However, members of the group reported discovering new ideas about working with the installation after watching video of the concert showing how the installation interacted with concrete and specific sounds. This led in turn to subsequent collaborations in which the installation was reworked to face the musicians (Figure 6).

Several participants also commented on the importance of "listening" in such improvised collaboration, as a way of managing uncertain and problematic situations as well as promoting creativity. In *Intermodulation I*, a member of *The Electric Golem* reported moments of dissonance or repulsion where his musical interaction felt disconnected with the artwork. To cope with such moments, he was required to "synchronize" and "listen" in a new way:

*There were a couple of times when I looked up at the Breaking AndyWall piece and I felt it wasn't ... It didn't feel like it was part of me...I did notice that, yeah. I'm also having to synchronize with another performer, with Jim. I've not only got the light there, but the main person I'm orientating to is the sound. Listening to what Jim is doing 'cause that's what we obviously do most of the time.*

Lewendowski also describes the practice of listening as not only a means of coping with uncertainties and overcoming breakdowns, but also a way to develop her own creativity interdependently "in relationship with other people." As she explains:

*The whole idea was that if you just stop and listen that listening will be your guide... The qualities that you want in a good improvisation are also the qualities that you want to develop in yourself and in your relationships with other people. There's a feeling there that you want friends who are good listeners and can respond. You want to be a good listener. It connects more largely to just being a human in the world*

From this two-year long participatory study based on improvisational collaboration and art practice, we witnessed and experienced many pleasures and difficulties similar to those described by the improvisational artists and musicians in our earlier ethnographic study. Our study showed how emerging situational factors, like unexpected images, challenging stage setups or unexpected technical errors, produced emotional and intellectual tensions, both welcome and unwelcome, which in turn invoked learning opportunities that set collaborative processes onto different and unexpected paths. In addition, our study demonstrated a form of improvisational collaboration not driven by pre-arranged and agreed-upon goals, but by a kind of mutual flexibility, openness, and "curiosity" around connection

with both similarity and otherness. In both its successes and failures, our work underscored the centrality of “listening” as a means of coping with uncertainty and developing relational creativity. Conversely, it showed how attachment to predefined scripts and plans – for example, our cellist’s adherence to the score – may challenge and limit possibilities of listening. Finally, our study illustrated certain kinds of tension between improvisational activities and forms or genres of work oriented to controllability and the linear execution of pre-assigned goals.



Figure 6. A subsequent performance of *Intermodulation II*

## DISCUSSION

The above sections described the motivation, process and result of studying improvisation through theoretical review, ethnographic study and collaborative art-making. To explore improvisation as a possible site and tool for HCI and design research, we now use results from this integrated study to describe (a) key features embedded in improvisational practice, and (b) how an understanding of improvisation built around these features can deepen and extend approaches to creativity and collaboration in wider HCI theory and methodology.

### Five Key Features of Improvisation

#### *Reflexivity*

As we have seen, improvisation is best understood neither as purely random nor as the simple realization of a pre-defined plan, but as a constructive and *reflexive* learning process through which learners’ cognitive, collaborative, and creative processes are continuously reconstructed in concert - and sometimes in counterpart - with shifts in the on-going environment. This learning takes place not through arms-length reflection, but as a constant, active, and reflexive restructuring of experience and work. In improvisation, creativity and knowledge depends on processes of trying through reflective explorations that in turn give rise to changes in the environment which then challenge and invite further exploration, and so forth.

#### *Transgression*

Beyond a simply responsive action that passively adapts itself to unexpected situations, improvisation may also

follow from and involve *transgressive* actions through which a practitioner actively invites and creates unforeseen and uncertain factors as a mechanism of discovery and expression. The musicians and artists in our study intentionally play unplanned notes or invite unpredictable elements in the situation to develop new musical expressions. Improvisational practice may therefore be employed not only to resolve or respond to situational problems, but to actively lead and disrupt given situations, upsetting the ‘set-up’ of expectation and predictable outcomes in ways that challenge performers and audience members to arrive at new and un-premeditated outcomes.

#### *Tension*

Our study shows that a practitioner’s balancing between structure and freedom constitutes an essential (if sometimes uncomfortable) *tension* that can call forth unexpected moments of creativity, learning, and surprise. This tension can include both affective (or emotional) and intellectual components, generated from the uncertainty and unfamiliarity inherent in improvisation and collaboration. While this tension makes the process of work riskier and less stable, it offers compensation in the form of un-premeditated creativity and “surprising” results. At the same time, it ensures a certain kind of continuity or accountability; as the musicians and artists in our study suggest, good improvisation is not only spontaneous and intuitive, but also rests on a certain threshold of continuity and expectation that ensures the new phrase or concept remains broadly intelligible to the old.

#### *Listening*

Our study also points to the centrality of collaborative *listening* as an essential element of improvisational practice. Such listening is not limited to sonic or dialogic exchange between participants, but includes also a more holistic and integrated process whereby practitioners engage and synchronize, both logically and intuitively, with collaborators, materials, and other circumstantial factors in the situation. As the participants in our study consider diverse environmental factors including media artworks, stage context, and other members musical expression, improvisational practitioners generate new or amended forms of idea and skill in concert with the environment around them. Such acts remind us that improvisation is not an inwardly-focused process restricted to reworking one’s own artistic expressions, but an emergent and outwardly-listening one built around coherence and accountability to the changing circumstances of surrounding environments.

#### *Interdependence*

Finally, our study emphasizes the *interdependent* nature of improvisation, in which participants’ cognition and behavior are co-constructed in relationship with other actors and the environment. As musicians develop their own expressions depending on each other’s sound, their creative thoughts and expressions in improvisation are neither clearly separable nor independent. Instead, they are constituted and maintained in an interdependent

relationship where cognitions, emotions and artistic expressions are modulated across each other –what we here call intermodulation. As a broken typewriter, Blister, and the artworks provoke the participants’ real-time expressions, this process of intermodulation happens not only between human actors, but also in concert with the non-human ‘performers’ around them.

### **Improvisational Creativity and Collaboration for HCI**

As described and analyzed above, improvisational practice is an active and sophisticated learning process comprised of complex and interrelated elements and interactions. As such, it builds on and contributes back to questions around creativity and collaboration in open-ended as well as more linear modes of HCI research.

#### *Emerging Creativity and Knowledge in Tension*

The understanding of improvisation developed here reveals how creativity and knowledge may be achieved not only through linear or highly structured models, but also emerge interactively in particular situations through a researcher’s improvisational engagements with his or her surrounding environment. Although this open-ended approach may be less suited for studies oriented primarily to generalizability, standardized usability, or efficiency, it can be advantageous for exploring complex and circumstantial problems of system and design that may elude more linear and structured approaches. As theories of research through design, critical making, and meta-design also suggest, this way of learning is not only advantageous for producing artistic works, but can also help HCI research explore new opportunities for and dimensions of technology and design. Although such emerging creativity and knowledge may appear as “first-order” or “provisional” knowledge in early stages of research, it may become more specific and sharable over time through a researcher’s deliberate reflection, rich documentation and presentation, and deeper consideration on a series of produced artifacts.

What our study contributes to this discourse is that the ‘tension’ produced between open-endedness and structure can be one source that naturally calls such emerging creativity and knowledge into being. As the above features describe, improvisational practice (at least of the sorts studied here) is neither fully ‘free’ nor entirely disciplined and controlled, but rather occupies an in-between space where the practitioner’s transgressive action strikes a precarious balance with existing structures and frameworks. By actively listening to and engaging with other stakeholders as well as the ongoing material environment, the practitioner can transform such tension into aesthetic experience (experienced as moments of flow, delight, or surprise), and develop his or her own creativity in inter-dependent relationship with others.

#### *Collaboration as Holistic Socio-Material Practice*

Better understanding of the intricacies of improvisation may also help HCI extend notions of collaboration to more holistic and complex socio-material practices. As the

features of listening and interdependence highlight, one’s cognition and behavior in collaborative improvisation can never be separated from others’ activities and surrounding material environments, but are co-constructed with them through active cross-engagement. Similar to meta-design’s idea of “co-evolution”, this mode of collaboration promotes forms of ‘group emergence’ that generate results, insights and problems unavailable to individual actors, or without the influence of the (specific) material environment.

Our study highlights that this group opportunity arises not only in the process of building harmonic and stable relationships between those who share similar interests, but also through exploring and engaging with other actors’ differences and unfamiliarity, which may periodically give rise to kinds of interference or ‘blue-notes’ grounded in unmixable, discrepant or otherwise incomprehensible properties. As the ideas of ‘tension’ and ‘intermodulation’ describe, learning opportunities in improvisation often emerge and develop through fragile and precarious interactions where separate individualities are continuously transgressing and adjusting to each other to construct a new harmonic equilibrium across differences. Such a perspective makes clear that otherness and unfamiliarity in improvisational learning is not so much a problem to be avoided, but rather a challenge to be embraced in the ongoing working out of both individual and collaborative voice and creativity.

### **CONCLUSION**

This paper explores the value and possibility of improvisation and collective art practice as a mode of HCI research and inquiry. As the theories and cases reviewed above make clear, the core engine that enables improvisation is neither a predetermined plan nor sheer extemporaneousness (or put simply, just ‘making stuff up’). Instead, it is enabled through processes of dialogue and intermodulation that continually arbitrate between freedom and structure, similarity and otherness, tension and relaxation, and self-conviction and external validity. From this complex and precarious interaction, the subject ‘I’ can be stimulated to emerge from his or her existing narrowness in the world, and develop creativity and knowledge in a mutually reciprocal way with others. This paper identifies five key features that enable such learning opportunities, and explain how these can deepen and extend notions of creativity and collaboration in HCI and design. Our work has attempted to provide one useful model of multidisciplinary research wherein musicians, artists, and HCI researchers learn to come together – “to bend for the common result” – to achieve outcomes, insights and ideas unavailable to each individually.

### **ACKNOWLEDGMENT**

The authors wish to thank and acknowledge the avid participation and imagination of our collaborating musicians – The Electric Golem, Min Park, and Powerdove – without which this work would have been impossible.

## REFERENCES

1. Philip E Agre, and David Chapman. 1987. Penglimentation of a Theory of Activity. *aaai.org*.
2. Philip E Agre. 1997. *Computation and Human Experience*.
3. Jeffrey Bardzell, Shaowen Bardzell, Peter Dalsgaard, Shad Gross, and Kim Halskov. 2016. Documenting the Research Through Design Process. In *Proceedings of the 2016 ACM Conference on Designing Interactive Systems - DIS '16*, 96–107. <https://doi.org/10.1145/2901790.2901859>
4. Jeffrey Bardzell, Shaowen Bardzell, and Lone Koefoed Hansen. 2015. Immodest Proposals. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems - CHI '15*, 2093–2102. <https://doi.org/10.1145/2702123.2702400>
5. Estelle Barrett and Barbara Bolt. 2007. *Practice as research: approaches to creative arts enquiry*.
6. Steve Benford, Chris Greenhalgh, Andy Crabtree, Martin Flintham, Brendan Walker, Joe Marshall, Boriana Koleva, Stefan Rennick Egglestone, Gabriella Giannachi, Matt Adams, Nick Tandavanitj, and Ju Row Farr. 2013. Performance-Led Research in the Wild. *ACM Transactions on Computer-Human Interaction* 20, 3: 14:1-14:22. <https://doi.org/10.1145/2491500.2491502>
7. Paul Berliner. 1994. *Thinking in Jazz: The Infinite Art of Improvisation*. <https://doi.org/10.2307/899035>
8. Wiebe E Bijker, Thomas P Hughes, Trevor Pinch, and Deborah G Douglas. 2012. *The social construction of technological systems: New directions in the sociology and history of technology*. MIT press.
9. J Bowers. 2002. Improvising machines: Ethnographically informed design for improvised electro-acoustic music. *ARiADATexts* (4).
10. John Bowers, Robyn Taylor, Jonathan Hook, Dustin Freeman, Charlie Bramley, and Christopher Newell. 2014. HCI: human-computer improvisation. In *Proceedings of the 2014 companion publication on Designing interactive systems*, 203–206.
11. John Cage. 1952. 4'33''(Four thirty-three).
12. John Cage and David Tudor. 1959. *Indeterminacy: New Aspect of Form in Instrumental and Electronic Music: Reading*. Folkways Records.
13. Kathy Charmaz and Linda Liska Belgrave. 2007. *Grounded theory*. Wiley Online Library.
14. Taylan Cihan. 2013. *Blister*. <https://vimeo.com/56305601>
15. Peter Dalsgaard and Peter. 2016. Experimental Systems in Research through Design. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems - CHI '16*, 4991–4996. <https://doi.org/10.1145/2858036.2858310>
16. Paul Dourish, Annette Adler, and Brian Cantwell Smith. 1996. Organising User Interfaces Around Reflective Accounts. In *Reflection '96*, 235–244.
17. Ernest A. Edmonds, Alastair Weakley, Linda Candy, Mark Fell, Roger Knott, and Sandra Pauletto. 2005. The studio as laboratory: Combining creative practice and digital technology research. *International Journal of Human Computer Studies* 63, 4–5 SPEC. ISS.: 452–481. <https://doi.org/10.1016/j.ijhcs.2005.04.012>
18. Ernest Edmonds and Linda Candy. 2002. Creativity, art practice, and knowledge. *Communications of the ACM* 45, 10: 91–95. <https://doi.org/10.1145/570907.570939>
19. Bill Evans. 1957. Improvisation in Jazz. *Kind of Blue*.
20. Bill Evans and Jim Hall. 1966. *Intermodulation*.
21. SM Feisst. 2009. John Cage and improvisation: an unresolved relationship. *Musical improvisation: Art, education, and society*.
22. Bill Gaver and John Bowers. 2012. Annotated portfolios. *interactions* 19, 4: 40. <https://doi.org/10.1145/2212877.2212889>
23. William Gaver and William. 2012. What should we expect from research through design? In *Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems - CHI '12*, 937. <https://doi.org/10.1145/2207676.2208538>
24. Elizabeth Gerber and Elizabeth. 2007. Improvisation principles and techniques for design. In *Proceedings of the SIGCHI conference on Human factors in computing systems - CHI '07*, 1069. <https://doi.org/10.1145/1240624.1240786>
25. Elisa Giaccardi and Gerhard Fischer. 2008. Creativity and evolution: a metadesign perspective. *Digital Creativity* 19, March 2015: 19–32. <https://doi.org/10.1080/14626260701847456>
26. Hermann Gottschewski. 2007. The Provisum and the Improvisum in Musical Performance. *Yonsei Music Research* 14: 13–22.
27. Guy Hoffman and Gil Weinberg. 2010. Gesture-based human-robot jazz improvisation. In *Robotics and Automation (ICRA), 2010 IEEE International Conference on*, 582–587.
28. Hrönn Brynjarsdóttir Holmer, Carl Disalvo, Phoebe Sengers, and Thomas Lodato. 2015. Constructing and constraining participation in participatory arts and HCI. *International Journal of Human Computer Studies* 74: 107–123. <https://doi.org/10.1016/j.ijhcs.2014.10.003>
29. Jonathan Hook, Guy Schofield, Robyn Taylor, Tom Bartindale, John McCarthy, and Peter Wright. 2012. Exploring HCI's relationship with liveness. In *Proceedings of the 2012 ACM annual conference extended abstracts on Human Factors in Computing*

- Systems Extended Abstracts - CHI EA '12*, 2771. <https://doi.org/10.1145/2212776.2212717>
30. Kristina Höök, Peter Dalsgaard, Stuart Reeves, Jeffrey Bardzell, Jonas Löwgren, Erik Stolterman, and Yvonne Rogers. 2015. Knowledge Production in Interaction Design. In *Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems - CHI EA '15*, 2429–2432. <https://doi.org/10.1145/2702613.2702653>
  31. Steven J. Jackson and Laewoo Kang. 2014. Breakdown, obsolescence and reuse. In *Proceedings of the 32nd annual ACM conference on Human factors in computing systems - CHI '14*, 449–458. <https://doi.org/10.1145/2556288.2557332>
  32. Giulio Jacucci, Mira Wagner, Ina Wagner, Elisa Giaccardi, Mauro Annunziato, Nell Breyer, Jonas Hansen, Kazuhiro Jo, Stijn Ossevoort, Alessandro Perini, Natacha Roussel, and Susanne Schuricht. 2010. ParticipArt: Exploring participation in interactive art installations. In *9th IEEE International Symposium on Mixed and Augmented Reality 2010: Arts, Media, and Humanities, ISMAR-AMH 2010 - Proceedings*, 3–10. <https://doi.org/10.1109/ISMAR-AMH.2010.5643313>
  33. P.a Jennings, E.b Giaccardi, and M.c Wesolkowska. 2006. About face interface: Creative engagement in the new media arts and HCI. *Conference on Human Factors in Computing Systems - Proceedings*: 1663–1666. <https://doi.org/10.1145/1125451.1125757>
  34. Laewoo (Leo) Kang. 2016. Breaking AndyWall: Transgressive and Playful Exploration on the Dynamic Role of Users in Art and Design. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems (CHI EA '16)*, 3855–3858. <https://doi.org/10.1145/2851581.2891100>
  35. Laewoo (Leo) Kang. 2018. Intermodulator: interactive audio-visual system for collaborative improvisation. In *Proceedings of the 2018 CHI Conference Extended Abstracts on Human Factors in Computing Systems (CHI EA '18)*.
  36. Laewoo (Leo) Kang. 2017. Echo (): Listening to the Reflection of Obsolete Technology. In *Proceedings of the 2016 ACM Conference Companion Publication on Designing Interactive Systems*, 305–308.
  37. Scott Barry Kaufman and Carolyn Gregoire. 2016. *Wired to create: Unraveling the mysteries of the creative mind*. Penguin.
  38. Nathaniel Klemp, Ray Mcdermott, and Jason Raley. 2008. Plans, Takes, and Mistakes. *Critical Social Studies*, 1: 4–21.
  39. Don Koberg. 1981. *The all new universal traveler: A soft-systems guide to creativity, problem-solving, and the process of reaching goals*. William Kaufmann Inc.
  40. A. Baki Kocaballi and Yeliz Yorulmaz. 2016. Performative Photography as an Ideation Method. In *Proceedings of the 2016 ACM Conference on Designing Interactive Systems - DIS '16*, 1083–1095. <https://doi.org/10.1145/2901790.2901911>
  41. Patricia Leavy. 2010. Method meets art: Arts-based research practice. *Counselling and Psychotherapy Research* 10, 1: 76–77. <https://doi.org/10.1080/14733140903226453>
  42. George E. Lewis and Benjamin Piekut. 2016. The Oxford Handbook of Critical Improvisation Studies, Volume 1.
  43. John McCarthy and Peter Wright. 2004. Technology as experience. *interactions* 11, 5: 42. <https://doi.org/10.1145/1015530.1015549>
  44. Timothy J. (Timothy James) McGee. 2003. *Improvisation in the arts of the Middle Ages and Renaissance*. Medieval Institute Publications, Western Michigan University.
  45. Don Norman. 2013. *The design of everyday things: Revised and expanded edition*. Basic Books (AZ).
  46. T Nunn. 1998. Wisdom of the Impulse On the Nature of Musical Free Improvisation Part 2. *Pdf julkaisu International Improvised Music Archive*.
  47. William Odom, Ron Wakkary, Youn-kyung Lim, Audrey Desjardins, Bart Hengeveld, and Richard Banks. 2016. From Research Prototype to Research Product. *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems - CHI '16*. <https://doi.org/10.1145/2858036.2858447>
  48. Nam June Paik. 1965. *Zen for Film*.
  49. Nam June Paik. 1969. *Participation TV*.
  50. J Pressing. 1988. Improvisation: methods and models. *John A. Sloboda (Hg.): Generative processes in*.
  51. Geber Ramalho and Jean-Gabriel Ganascia. 1994. Simulating creativity in jazz performance. In *AAAI*, 108–113.
  52. Matt Ratto. 2011. Critical Making: Conceptual and Material Studies in Technology and Social Life. *The Information Society* 27, 4: 252–260. <https://doi.org/10.1080/01972243.2011.583819>
  53. Horst W J Rittel and Melvin M Webber. 1973. Dilemmas in a general theory of planning. *Policy sciences* 4, 2: 155–169.
  54. Francis Rumsey and Tim. McCormick. 2006. *Sound and recording : an introduction*. Focal Press.
  55. R. K. Sawyer. 2006. Group creativity: musical performance and collaboration. *Psychology of Music* 34, 2: 148–165. <https://doi.org/10.1177/0305735606061850>
  56. R. Keith Sawyer. 2000. Improvisation and the Creative Process: Dewey, Collingwood, and the Aesthetics of

- Spontaneity. *The Journal of Aesthetics and Art Criticism* 58, 2: 149. <https://doi.org/10.2307/432094>
57. R. Keith (Robert Keith) Sawyer. 2011. *Structure and improvisation in creative teaching*. Cambridge University Press.
58. Lucy Suchman. 1987. Plans and Situated Actions. *Cambridge University Press*: 224. <https://doi.org/10.1002/asi.20714>
59. John Zimmerman, Jodi Forlizzi, and Shelley Evenson. 2007. Research through design as a method for interaction design research in HCI. In *Proceedings of the SIGCHI conference on Human factors in computing systems - CHI '07*, Paper 41. <https://doi.org/10.1145/1240624.1240704>
60. John Zimmerman, Erik Stolterman, and Jodi Forlizzi. 2010. An analysis and critique of *Research through Design*. In *Proceedings of the 8th ACM Conference on Designing Interactive Systems - DIS '10*, 310. <https://doi.org/10.1145/1858171.1858228>
61. Adversarial Design. Retrieved September 17, 2017 from <http://dl.acm.org/citation.cfm?id=2341007>
62. Festival de Cannes: The Mystery of Picasso (In Competition). *festival-cannes.com*.
63. Critical Studies in Improvisation. <http://www.criticalimprov.com/>
64. The Electric Golem. <http://levelgreen.com/electricgolem/>
65. Annie Lewandowski (Powerdove). <http://www.annielewandowski.com/>