RISK AND EXPRESSION: PHYSICAL AND MATERIAL RISK STATES IN COMPUTATIONAL MUSIC PRACTICES

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RISK AND EXPRESSION: PHYSICAL AND MATERIAL RISK STATES IN COMPUTATIONAL MUSIC PRACTICES

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For my mom, my sister, and my niece,
whose steadfast and unconditional love
fly in the very face of this dissertation.

And for Eric, whom I love.

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SUMMARY

Risk, while an inherent property of traditional performance, is little understood in the world of digitally mediated performance. Technology has been a constant factor influencing creative musical practices, from the first flutes carved from bird bones to spliced magnetic tape to electrical synthesizer circuits. Musicians today often choose to incorporate or utilize digital and computational technologies into their creative processes, from augmenting and extending traditional instruments to the creation of entirely new ones. Though technological developments naturally run alongside novel artistic practices, processes, and products, the relatively recent uptick in the availability and affordability of digital and computational resources has provoked a swift and drastic shift away from highly physical modes of creation to ones less dependent on the direct connection between the hand of the creator and the music they create.

The research presented here investigates qualities of physical and material risk within musical performance practices and the value that such properties may hold for less physical engagements afforded by (or designed for within) computer music communities. This work will explore concepts of risk and expression in creative practices and assess the impact that facing the “unknown” has played in traditional and contemporary musical performance. By identifying the value that physical and material risk, uncertainty, and the potential for failure play in the creative process (namely through their facilitation of idiosyncratic problem-solving and personal acts of expression), we can potentially provide a compelling argument for the importance of such qualities in practices which do not naturally engage with them.

The central question that drives this research is whether or not physical and material risk states enable higher levels of perceived expressivity for performers through specific qualities of unpredictability and the potential for failure. Designing for risk and assessing the experiences of practitioners within the field of experimental media performance will contribute to a better understanding of the value of physical and corporeal materials within

digital practices and present potential guidelines for the creation and use of new instruments for creative musical expression.

CHAPTER 1
INTRODUCTION AND BACKGROUND

1.1 Risk and Expressivity

Risk can seem like a catastrophic term, evoking thoughts of fear, anxiety, and stress. It is all too easily associated with negative emotional, mental, and physical states, or conditions of pain and discomfort. However, risk offers a wealth of benefits to the creative experience as well, from prompting new methods of problem-solving to presenting opportunities for idiosyncratic expression. Risk exists on a spectrum: too low may be negligible, too high can result in a hindrance to creative activities. Further, risk can span multiple facets of the human condition: physical and material, social, intellectual, emotional, and beyond. All of these elements combine and contribute to what we experience.

The work presented here contends that higher risk states can be a productive impetus for new creative directions, pushing people outside of their comfort zones and setting conditions for expressivity. In the presence of an instrument that is stable and physically familiar musicians may rely on their prior experiences and existing expectations to guide them in their pursuits—to creative ends, or not. Conversely, if faced with an instrument exceedingly foreign or difficult, an individual may be creatively incapacitated by the unknown and uncontrollable. Somewhere in the middle of these extremes is the instrument that can be known intimately, yet behaves unpredictably; a state in which performers must apply their skills in novel ways without the safety nets of stability and routine to fall back on.

Experiences are subjective: what causes one person to feel fear and anxiety may, for another, be exciting and enjoyable. The question is not, "What role does risk play in the creation of "good" music?" but rather, "Does risk prompt new—or altered—modes of creativity and, if so, might higher risk states facilitate feelings of expressivity for a performer?"

The studies designed for this research draw directly upon the experiences of practitioners, allowing them to speak about their creative processes, values, priorities. Through comparative studies, artifact design, in-depth discussions, and the application of Thematic Analysis, I am able to share the perceptions and experiences of practitioners as they themselves describe. In doing this work I am able to demonstrate that high and low risk states do indeed have an impact on how improvising performers navigate a creative process of music making—sometimes to extreme degrees. By investigating the complex relationships between these hard-to-define physical qualities of musical performance and their potential role in an increasingly digital practice this work contributes to an understanding of an under-served issue of relevance to future work in computer music practices.

The overarching research questions driving this dissertation are:

1. Do qualities of physical (relating to the performer's body) and material (relating to the instrument/interface) risk play a meaningful role in the perception of expressive capabilities on the part of the performing musician?
2. If computational technology distances us from physical and material risk states, what impact does that have on the experiences of the computer music performer?

The value of this line of inquiry lies in the fact that we can ask it in a very specific space, one that has evolved from traditional, acoustic musical practices to include computational tools for creativity. The digital elements of musical expression embedded within contemporary practice have contributed to a dramatic shift in how we understand what it means to be musically expressive and creative. Given that the physical and material conditions of music-making are lessened by these technological mediations, we are presented with an opportunity to query the role of risk in a digital performance context.

1.2 The Experimental Music Community

Because the questions being posed here are geared toward understanding how digital tools for creativity have impacted the roles of physical and material risk states, this work is grounded in the specific domain of computer music. Computer music practices (CMPs) have analog roots extending as far back as human history; traditionally speaking, musicians have engaged with *physical* instruments for music production, honing their craft through a dedication to one specific instrumental practice over the course of a lifetime. The musician would develop intimate knowledge of every part of their instrument, and the connection between body and music was incredibly direct, even from the beginning: air exhaled through a hollowed-out bird bone, hands laid on animal hide stretched over shells. Today we see a new way of making, where music can be coded, articulated virtually, or even produced by brain signals alone. Computational technology has changed what it means to play an instrument: "physical" and "material" no longer function within the same boundaries, nor do they play the same roles. To conduct research within the computer music community, then, is to examine the value of physicality and materiality in creative musical expression and query how computational disembodiment from these qualities shifts what we understand about the musical experience.

Musical practices that involve the creation of novel instruments and interfaces involve a unique mix of varied stakeholders, some with traditional roles (e.g. composer, musician) and others with backgrounds in fields such as design, fine arts, and engineering. In order to question the shifting role of risk in CMPs we must address specific communities: the composers, creators, and performers within the field of computer music who commonly merge and shift between roles. The NIME (New Interfaces for Musical Expression) and ICMC (International Computer Music Conference) communities engage with Digital Musical Instruments (DMIs) and interfaces which build upon existing musical traditions in experimental and exploratory ways. These communities offer an appropriate platform for discourse surrounding research in risk and expression for several reasons, including existing interest in elements of chance and unpredictability in musical composition and system design, the creation of bespoke interfaces for performance, and a history of examining and engaging with expressivity through design, theory, and praxis.

Computer music communities also provide an opportunity to explore issues of risk and expressivity through their merits of openness, spirit of experimentation, and engagement with creative and design practices. The research undertaken here has implications not only for how we can better understand existing practices among improvising musicians, but also for the design and use of new tools and technologies in the future.

While many different forms of risk will be examined in later sections of this work, it is important emphasize the importance and value of examining risk's relationship to expressivity through an engagement with the community itself. As will soon be discussed, risk (as a general state) has always been a quality of live performance, and remains as such. The specifics regarding how risk manifests, however, change with cultural, technological, and aesthetic evolutions over time. Computer music today reflects particularly stark and (relatively) rapid shifts in terms of what we have known as "traditional" methods of musical composition, instrumentation, and performance—a history spanning centuries. The increased flexibility of musicians' roles and identities (composer, luthier, performer, and audience) have certainly contributed to a shift in the ways that practitioners engage in "risky" behavior. However, it is the incorporation of digital and computational elements within this creative practice that presents a rich locus for engaging in a discourse regarding the specific categories of risk which are of most relevance to this dissertation: physical and material. Between the modified form factors which are embedded in much of the design and engagement with DMIs and the procedurality introduced into the creative musical process by computational technology, physical and material risk states in CMPs provide a compelling point of entry into questions about where the futures of risk and expression may lie.

CHAPTER 2

CENTRAL RESEARCH QUESTIONS

One must be able to define and identify specific categories of risk, extrapolate qualities of risk into a design space, and quantitatively and/or qualitatively measure perceptions of expressivity in creative practices in order to fully investigate issues of risk and expressivity. Therefore, the studies presented in this work will each address a critical subset of the main research questions, namely:

1. RQ1: How is risk incorporated into computational musical practices?
2. RQ2: Does a higher physical and/or material risk state lead to higher levels of expressivity perceived by a performing computer musician?
3. RQ3: What value might applying these risk qualities to new computational musical instruments have for musicians?

RQ1 will be addressed in Chapters 3 and 4, where existing paradigms for risk will be explored. Risk will be discussed as a component of general performance practices, and physical/material risk in particular will be identified within traditional and contemporary music practices. We will also examine the complications that arise when attempting to measure and/or evaluate risk in CMPs, particularly though Human-Computer Interaction (HCI)-inspired methodologies and other quantitative techniques. In Chapter 5 several issues are laid out in the interest of illustrating the need for qualitative methodologies that can reflect and engage with deeper, "thicker" understandings of subjective experiences.

RQ2 is realized through two studies (detailed in Chapters 6 and 7) that compare and contrast performers' experiences with predictable, low-risk instruments and unpredictable, high-risk ones. Data gathered through improvisational performances, interviews, and reflection activities give insight into performers' perceptions of expressivity, shifts in their creative and improvisational processes, and experiences in high- and low-risk states. The application of qualitative analysis methodologies will leverage this first-person data to provide an understanding of the relevance of risk in expressive endeavors.

RQ3 is addressed through the culmination of the studies and subsequent data analysis, driven primarily by a Thematic Analysis (TA) methodology, detailed in Chapter 8. The study findings are of interest to those in the CMP community who wish to design, compose for, and perform with novel instruments in ways which encourage expressive capabilities through heightened risk states, and while this work can not argue for increased generalizability or appropriateness for *all* cases, it does work toward the following goals:

1. Methodological: TA allows us to better understand the "whole body" experience of an experienced musician in CMPs through direct, one-on-one user studies. Rather than attempt to evaluate the "success" or "failure" of an artifact or performance, the work undertaken here contributes to a better understanding of the role that a qualitative element (physical/material risk) plays in emerging digital practices.

2. Representation and Applicability: Data gathering techniques informed by TA empower practitioners to become the "experts" of their own experiences, legitimizing their thoughts, feelings, and beliefs as valid and worthy of contributing to the discourse. By including practitioners who work with a variety of instruments/interfaces and identify as different "stakeholders," this research speaks to as wide an audience as possible: designers, composers, musicians, makers, engineers, and others in CMPs.

This work does not present findings that can be neatly packaged and taken away for application in CMPs. There are no quantitative measurements for physical qualities that can be made to be "risky," nor are there prescriptions for practice that can be tallied at categorical point values. What this research does is query the role that physical and material risk play in expressive music-making practices and emphasize the value of such qualities in a discipline that is increasingly digitized. This allows for certain suggestions to be made regarding future design strategies (see Chapter 11), but the ultimate goal of this work is to provide a deeper understanding of physical and material risk conditions that may be of value to digital practitioners.

CHAPTER 3
LITERATURE REVIEW

3.1 Risk in Creative Practices

As creative practices call for the adaptation of the practitioner to current affairs, issues, and interests, so to do our tools inevitably evolve alongside us. Acts of creativity reflect not only tradition and heritage but also the affordances of the interfaces available for production. Creative practices, therefore, actualize both the rich histories of practice and the culture of the here-and-now—and even possible futures. The concomitant development of art and technology, which has only relatively recently turned digital, begs new questions of risk and expression. What are we risking when we live-code music on a laptop? How does technology shift or change what failure is, and what shape error takes? These issues are under-examined in our digital culture and call for deeper investigation.

We begin with an examination of risk and creativity in very broad strokes and systematically hone in on the ways in which creative practitioners engage with their practices (through evolving tools and technologies) over time. When we arrive at a discussion of contemporary computer music it should be clear that, while risk remains a constant factor in live performance, our notions of what risk is (and how we experience it) change drastically.

Experimental musical practices provide a specific activity and community through which to productively engage with questions of expression and its relationship to risk. The ontology of such practices are entrenched in traditional approaches to music-making, but the practice has also grown to embrace and engage with new modes of creativity (computational creativity in particular) and digital fabrication. In order to better understand the ways in which digital and computational technology have impacted notions of risk and expression one must first address what risk has looked like before such tools proliferated through the contemporary music scene, both in creative practices in general and musical practices specifically. This begins with a wider view of risk as a historical element of performance and then narrows—first to risk within musical performance in general, and then to experimental musical practices in particular. Following this trajectory, we can arrive at a discourse about how computational technology shifts the ways we define and engage with these concepts.

3.1.1 High-Risk History

Though this research looks specifically toward experimental music practices, the question of risk in creative activities has a much larger scope involving practitioners across varied disciplines. Prior to the advent of cheap, accessible digital technology, risk was an analog quality of performance spectacle: tightrope walkers at great heights, sword-swallowers and their blades, fire-walkers and their flames. The oldest relationships between risk and entertainment are fairly clearly drawn: the higher the rope, the more we clamor to appreciate the skill of the tightrope walker perched precariously above us; the sharper and longer the blade, the more amazing its ingestion. Taking greater risks in such high-stake scenarios can come only from a place of mastery and experience (natural selection is an efficient culler of unskilled tightrope walkers, presumably), and what is the appeal of a performance if not to observe the abilities of talented human beings?

3.1.2 Performance Art

Beyond these more overtly dangerous fringe activities, risk-taking has long been an important element of performative art. British actor and academic Steve Dixon identifies the appeal of risk and liveness in performance, stating, “There is a different tension and vulnerability in live performance, a sense of danger and unpredictability that affects the adrenalin and nerves of both the performers and the spectators—at least at the outset, even if it is not always maintained." [1] Many of the well-known performance artists of the '60s and '70s provide rich examples of risk-taking through danger and destruction of objects, expectations, and norms. In his 1962 piece, *12 Piano Compositions for Nam June Paik*, composer George Maciunas instructs the pianist in a number of highly unusual steps, including: "Place a dog or cat (or both) inside the piano, play Chopin, stretch the three highest strings with a tuning key till they burst, place one piano on top of another." Similarly, in his work *Solo for Violin* (1962) he "proposes that an old classic be played on a violin and that where pauses are notated the violin is to be maltreated—by scratching the floor with it, dropping pebbles through the f-holes, pulling the pegs out, and so on." [2] In many ways such musical works were (and are) a response to centuries of tradition, a way to confront and push beyond convention and expose new sonic possibilities.

The rise of marginalized and experimental art in the '60s and '70s was wide-spread and particularly observable in performance art. Vito Acconci's 1970 piece, *Trademarks*, saw the artist repeatedly bite his own naked body, while Chris Burden's 1971 performance of *Shoot* ended with him being shot in the arm by a rifle-wielding collaborator. Film historian J. Carlos Kase uses these and many other performances of the '60s and '70s as examples of risk-taking as a vehicle to engage with many prominent issues of the time: "These planned encounters with sometimes unpredictable and indeterminate forces of potential violence called attention to lived bodily experience by testing its physical, carnal limits." [3]

Risk to the physical body of the artist does not only engage with human limitations and the notion of the "self" as simultaneous artist and canvas, but also becomes a powerful weapon for confronting cultural power structures and societal norms *through* the body. The work of Carolee Schneemann and Marina Abramović, for example, often challenge the passive nature of the audience-as-voyeur, placing them in the active role of spectator and participant. In what is perhaps her most well-known example, *Interior Scroll* (1975), Schneemann stood naked atop a table and unfurled a scroll from inside her vagina, reading aloud the text of a conversation between herself and a film critic who refused to watch her films. Through her body, Schneemann exposed the viewer to her own trauma and struggle, an identity oppressed within a culture that systematically disempowered women. One of many qualities of Feminist performance art of this time involved taking that which was suppressed and objectified—the physical body—and reclaiming it in the face of the spectator. Schneemann illuminates this dynamic in her reflections on the performance of *Interior Scroll*:

> "I didn't want to pull a scroll out of my vagina and read it in public, but the culture's terror of my making overt what it wished to suppress fueled the image; it was essential to demonstrate this lived action about 'vulvic space' against the abstraction of the female body and its loss of meaning." [4]

In Abramović's work, *Rhythm 0* (1974), she invited spectators in a gallery space to use any of 72 different objects on her body, from the innocuous (a rose, honey, grapes) to the deadly (razor blades, nails, and even a loaded gun). Though the 6-hour performance began tamely, spectators escalated their behavior steadily, from forcing her to kneel and be subjected to abuse to cutting her throat with razors and holding the gun to her neck. Of the experience, Abramović recounts:

> "What I learned was that...if you leave it up to the audience, they can kill you...I felt really violated: they cut up my clothes, stuck rose thorns in my stomach, one person aimed the gun at my head, and another took it away. It created an aggressive atmosphere. After exactly 6 hours, as planned, I stood up and started walking toward the audience. Everyone ran away, to escape an actual confrontation." [5]

Her related works, *Rhythm 2, 5,* and *10* similarly positioned her body as subject and medium:

> "In *Rhythm 5* (1974), Abramović lay down inside the blazing frame of a wooden star. With her oxygen supply depleted by the fire, she lost consciousness and had to be rescued by concerned onlookers. In *Rhythm 10* (1973), she plunged a knife between the spread fingers of one hand, stopping only after she had cut herself 20 times. Having made an audio recording of the action, she then played back the sound while repeating the movements—this time trying to coordinate the new gashes with the old." [6]

Performances by artists such as Schneemann and Abramović effectively weaponized risk—the risk of exposing and exploiting the spectator's discomfort, fears, prejudices, and passivity, and the risk of baring the most intimate parts of the body for the world to see—as a visceral way to make the invisible (or disregarded) known.

3.1.3 Analog Risk

We can see an acknowledgement and incorporation of the error and failure inherent to the technological tools being used by the artist as early as the '20s and '30s in experimental film pieces that position traditionally-avoided artifacts (e.g. scratch marks, dust, leader tape) as formal compositional elements of a work. Len Lye, Norman McLaren, and Stan Brakhage are among early experimental filmmakers set to scratching, burning, and otherwise manipulating the physical materials of their art as a way to work with an expanded and extended visual and sonic palette (often termed "direct-animation" or "drawn on film"). The '60s and '70s saw a continuation of such subversive work, such as Nam June Paik's *Zen for Film* (1964), which runs 14 minutes of blank film through a projector, exploiting the accumulation of dust and scratches as content rather than detritus. A similar work, *Magnet TV* (1965), applies a magnetic force (normally considered detrimental or damaging to television hardware) as a means to generate imagery.

The eventual proliferation and transition to digital playback technologies did not stop artists from engaging with physical materials. Japanese artist Yasunao Tone's "Wounded CDs" from the '80s and '90s, for example, carry the techniques of scratching and defacing analog materials over to digital media. By applying pieces of tape, gouging, and scratching the CD itself Tone was able to re-compose (or *de*-compose) the music encoded on the disc: "Although some of the binary data was being blocked, the machine still attempted to piece together the rest. So instead of shutting down, or skipping over any damaged audio, the CD scanned the audio as true, though it would not sound anything like the music contained on the disc." [7]

Figure 3.1: Example of Tone's *Wounded CDs*. Photo by Gary McCraw.

While many artists explored the exploitation and application of mistakes and artifacts through an active "misuse" of their working materials, material risk was also a focus of so-called "auto-destructive" artists who harnessed the toll that time takes on everyday objects as a way to confront notions of war and destruction, among other things. These works that embraced the fragility and transient nature of all matter have been lost, in large part, to time—often as a part of their very conception. In his infamous 1959 manifesto, *Auto-Destructive Art,* Gustav Metzger describes such work:

> "Auto-destructive paintings, sculptures and constructions have a life time varying from a few moments to twenty years. When the disintegrative process is complete the work is to be removed from the site and scrapped." [8]

Metzger's work exemplifies this tenet clearly; In his *Acid action painting* (1961), three nylon canvases were doused in acid to the point of disintegration, and his *Construction with glass* (1961) saw several sheets of glass suspended tenuously above a concrete slab by tape, each falling to destruction over time. [9] These are just a small sampling of works that embraced the unpredictability and fallibility of materials for artistic expression.

3.1.4 Enter the Digital

As digital technology enters creative practices, risk moves from a purely physical phenomenon to something that is less tangible and more theoretical. New media culture is steeped in issues of privacy, security, and transparency, and also places the human body in a state of new change. Our future is one open to biological modifications, cyborg-ification, and extended capabilities. Australian performance artist Stelarc notoriously utilizes his body as a medium for exploring transhumanism at the intersections of technology, science, and the human body. For Stelarc, technology and the body evolve alongside each other, and as we adopt new hardware and software that extends the limits of our corporeal experiences, what it is to be "human" or "non-human" increasingly becomes obsolete. Technology "constructs our human nature" and is as much an appendage of our body as the arms and legs we were born with. [10] To explore these issues, Stelarc famously risks his own body, swallowing statues to use his stomach as a display case (*Stomach Sculpture* (1993)), attaching a third ear to his arm (*Ear on Arm* (2003-2011)), and suspending himself by piercing his skin with large hooks (*Suspensions*).

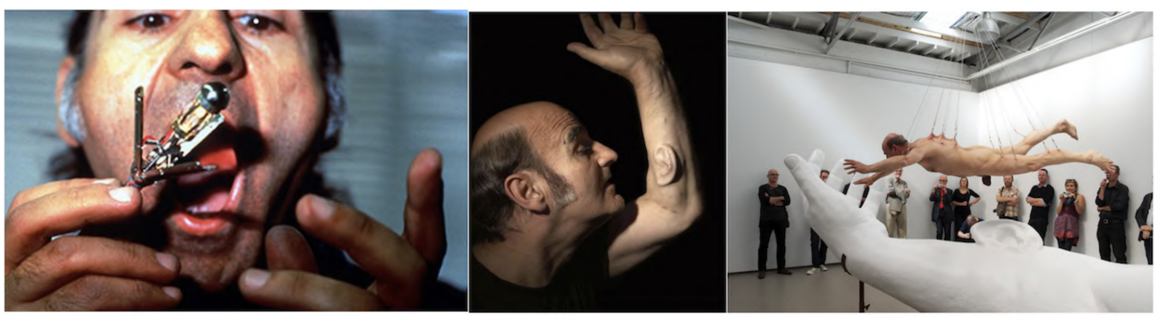


Figure 3.2: Left to right: *Stomach Sculpture*, photo by Anthony Figallo; *Ear on Arm*, photo by Nina Sellars; *Ear on Arm Suspension*, photo by Claudio Oyarce. From artist's website: www.stelarc.org

Digital hard- and software also inject new potentials for failure, error, and unpredictability into creative processes. In her article titled *The Aesthetics of Failure: "Post-Digital" Tendencies in Contemporary Computer Music*, Kim Cascone affirms, "Indeed, "failure" has become a prominent aesthetic in many of the arts in the late 20th century, reminding us that our control of technology is an illusion, and revealing digital tools to be only as perfect, precise, and efficient as the humans who build them." [11]

The glitch movement of the 1990s (though "glitch," as a term, can and is applied to work such as that described in the previous section) captures Cascone's sentiment well. Like the analog work before it, glitch artists reclaimed what was widely considered to be a mistake or error and built an entire art movement around it. Digital artifacts and errors that occur when working with audio and visual files were captured and even purposefully created by these artists on both the hard- and software level, resulting in work that showcases and glorifies the boundaries of digital technology.

3.1.5 The Digital Takeover

Even purely digital creative entertainment experiences are seeing movement toward heightened risk states. Video games have historically been a rather disembodied experience, with most physical interactions constrained to hand-held controllers or joysticks. There have, of course, been forays into fuller-body engagement such as the 3-dimensional Gametrak controller made popular in the early 2000s, dance mats (popularized by the 1998 hit Dance Dance Revolution), or newer wearable vibro-tactile garments.

Figure 3.3: Left to right: Gametrak controller, photo from www.tanga.com; KOR-FX haptic gaming vest, photo from www.korfx.com; Dance Dance Revolution mat, photo from www.wikipedia.org

In more recent years, however, developers have begun to look past bodily engagement simply as a way to interface with a game, toward embracing the idea that higher risk states may increase immersion, enjoyment, and engagement. UK-based company Mindwire developed and released the 2008 *V5* device, which translates digital stimuli (e.g. getting shot, crashing a car, or being punched) into physical jolts of electricity delivered to different parts of the player's body. For founders Wrightson and Williams, immersive gaming is more than a rumble from a controller or accelerometer-driven golf swing; it is also about raising the stakes for players and giving them something to "lose." As they quip, "How much better would games such as Mortal Kombat or Streetfighter be if you were ELECTROCUTED each time you were hit!" [12]

Artist and video game designer Eddo Stern and software developer Mark Allen took this application of physically risky technology to the field at the 2001 Tekken Torture Tournament. At this competition 32 gamers wore bands around their arms which would deliver electrical shocks whenever their on-screen avatars were injured.

Figure 3.4: Shock arm bands worn by participants at the Tekken Torture Tournament, 2001. Photo from www.eddostern.com

By implicating the physical body of the game-player in the virtual action of the game itself, the conceptual disconnect between real and simulation can be bridged (at least to some extent). While it may initially seem unappealing to submit yourself to intense electrical shocks, this added physical component seems to strengthen the emotional and psychological investment that a player experiences. In-game consequences—which can seem trivial when considered logically—become more palpable, and these heightened "stakes" can change what a player is willing to risk during gameplay.

3.1.6 Risk in Design and Craft

Because we are investigating risk as a quality of performance in computer music practices we must consider one additional field of study that is highly relevant the the activities of the community. The design, construction, and use of DMIs is in many ways informed by HCI and engineering; however, it also shares a space with design and crafting communities. Because computational tools for creativity propagate throughout all manner of artistic practices involving artifact construction, design and craft reflect certain shifting techniques and values among practitioners who, by trade, work with physical materials and who have been required to adapt to digital technology within their workflow.

In his book titled *The Nature and Art of Workmanship*, professor of furniture design David Pye elucidates the crucial role of risk in the creation of design artifacts, where it helps to draw a meaningful line between workmanship and manufacturing. For Pye, you can determine whether or not the workmanship is risky or certain by asking if the result is predetermined and unalterable once production begins. If so, it is workmanship of certainty. If the worker can spoil or ruin the product or process at any point in time, it is workmanship of risk. As he delineates, "The quality of the result [of workmanship] is continually at risk during the process of making." [13]

Spontaneity and improvisation find their place in Pye's list of the three aesthetics of workmanship alongside *successful evidence of intention* and *diversity of output*. In the art of workmanship the workman seeks "to diversify the forms themselves by allowing slight improvisations, divagations and irregularities so that we are continually presented with fresh and unexpected incidents of form."[13] In other words: if the person doing the creative work is improvising with unfolding material qualities—risking the unknown, the unpredictable—they reach something beyond manufacturing to conveys a sense of artisanship and expression through their work.

Anthropologists Tim Ingold and Elizabeth Hallam present concepts of agency in craft practices that similarly point toward unpredictable and uncertain relationships between people and materials, thoughts, actions, and/or situations. For them:

> "No system of codes, rules, and norms can anticipate every possible circumstance. At best it can provide general guidelines or rules of thumb whose very power lies in their vagueness or non-specificity. The gap between non-

> specific guidelines and specific conditions of a world that is never the same from one moment to the next not only opens up a space for improvisation, but also demands it, if people intend to respond to conditions with judgment and precision." [14]

Ingold and Hallam evoke de Certeau's concept of *tactical maneuverings* as exemplified by the metaphor of walking through a busy street. Pedestrians doing such must continually negotiate their path, improvising their choices based on updating circumstances. They posit that creativity is inherently improvisational, individual, and present in-the-moment, turning their focus to creativity as process rather than product. [15]

Philosopher and cultural historian Larry Shiner confirms these views in his approach to craft, for which he requires that the body and mind are working together within and through a physical medium. Like Pye, Shiner emphasizes the process of uncovering the unknown: "The craftsperson seldom has a completely worked-out design in mind, but pursues a rough idea through a dialogue of discovery with the material." [16] Shiner goes on to address the issues that incorporating new technology into crafting practices can cause, stating that, "When the designer or craftsperson combines digital design with digital fabrication, the body's contact with "materials" is so radically diminished that the flow of tacit knowledge normally gained through physical contact and feedback from alterations in the material becomes primarily visual and intellectual." [16]

Shiner touches on one of the unique conditions we find ourselves in now that computational technology has moved into the post-digital age. Once, digital technology was expensive, exclusive, and difficult to master—it became the *object* of much experimental art being produced (look what this amazing new technology can do!). Now, the laptop is naturally embedded in all manner of creative processes and functions as *support* rather than *subject*. As artist and curator Benjamin Weil puts it, "As digital tools become as readily accessible as the pencil or clay, mastery tends to be about pushing technology to the back of the stage, where it really belongs." [17]

3.1.6.1 Design and Craft in CMPs

There are many examples of cross-pollination between music, craft, and design—it could be argued that this overlap extends back as far as music itself, considering the prevalence of highly-ornate instruments across history. However, the concept of instrument as a designed *sculptural* object was particularly notable in the '60s; American composer Harry Partch (self-described as a "philosophical music-man seduced into carpentry") is a good case study for such activities, stating of his work that he gave the "imaginative and sculptural forms of [his] instruments...as much time [as he did] to intonation." [18]

Figure 3.5: Left to right: Partch's *Gourd Tree* (1964); *Eucal Blossom* (1964). Photos by Steven Severinghaus

Other artists and musicians take the instrument-as-sculpture philosophy to extremes, with focuses on "sound sculpture" and abstract representations of music-through-design. In contrast to work such as Partch's, these crafted object are not meant to be played so much as they embody the *concept* of sound through their presence in space. As cultural studies scholar Vadim Keylin says of sound sculpture:

> "Technology itself is what constitutes the artwork, while music remains a possibility to be actualised in interaction with the listener. Musicality thus becomes a quality of the material to be considered by the sculptor, alongside such things as colour, density, structure, etc. At the same time music itself is treated as a function of sculptural form that unfolds in temporal dimension." [19]

Examples of such an abstraction of musical instrument design can be seen in work such as sculptor-cum-musician Harry Bertoia's "sonambient" works (circa 1960-1980) and composer/artist Christian Marclay's *Glass Drumsticks* (2000).

Figure 3.6: Bertoia's *Untitled* sonambient sculptures (left, center), photos from harrybertoia.org; Marclay's *Glass Drumsticks*(2000) (right). Photo from MoMA.org

In Bertoia's work we see sculptural objects which are first and foremost visual and structural, but that are also inspired by (and producers of) expression through music. Though Bertoia's work "does not commit itself to a composed music piece", of his designed objects one can assert that "a certain musical structure is always present within the sculptural form." [19] Despite their static nature of his structural objects, the kineticism of design and focus on sonic phenomena place Bertoia's work in a space that is actively musical.

Conversely, Marclay presents us with a musical object rendered musically "useless" by way of its material fragility. The drum stick (perhaps the most physically abused instrumental tool) is cast in glass—though its utility is entirely stripped away, the object still manages to evoke a sonic landscape. We can not help but wonder what the sound of a glass stick hitting a drum head might sound like, even as it would crack and shatter in the musician's hands.

Each of the works above evoke musicality through the design and manipulation of physical materials as a way to directly or indirectly confront the roles of materiality and sonification through physical artifacts. Included in this are notions of risk, failure, and agency—as Keylin states:

> "Sound sculpture can be situated alongside other trends of the twentieth-century musical experimentation, as it shares a number of issues with them. In fact, the

materiality of music discussed above is one such issue that is dealt with in different ways in instrumental theatre or musique concrete. Another one is that of indeterminacy, questioning the composer's agency by delegating it to someone or something else." [19]

3.1.7 Conclusion

The brief overview provided here makes clear the proposition that there is a certain value in the risk undertaken in many established fields such as design, theater, craft, and performance. Each example gives insight into the ways in which designers and craftspeople engage with risk, either conceptually or materially, through the nature of their practice. Part of what makes an object valuable, or a performance striking, is the fact that the creator is continually improvising actions to mitigate the unfolding unknown. They are risking something of the materials and of themself: collapsing the cup, forgetting the line, damaging reputation or monetary investment—perhaps even making the choice to *embrace* the mistake: a fingerprint in the clay, a scratch on film. The creator reflects in real-time and engages in a dialogue with materials in a continual feedback loop.

3.2 Risk in Traditional Musical Practices

> "Do you know why I don't play ballads any more? Because I like to play ballads so much."
>
> *Miles Davis, to Keith Jarrett* [20]

This brief discussion of risk as a general component of performance practices at large allows us to hone in on how risk has played a role in musical practices more specifically. Because this work is interested in improvisational musical performance it is natural to look to jazz—one of the most well-known improvisational musical traditions—for inspiration. Jazz has been a fertile genre for study for decades, and we can find particularly relevant support for risk's connection to expression in the work done in the field of creativity and cognition (addressed further in Section 3.4). However, it is relevant to discourses in many fields.

3.2.1 Risk and Improvisation

In his paper, *Coda–Creativity and Improvisation in Jazz and Organizations: Implications for Organizational Learning*, experienced jazz pianist and behavioral researcher Frank Barrett draws upon the expertise and experiences of master jazz musicians as a model for understanding system organization. For Barrett, both jazz musicians and system managers embody "diverse specialists living in a chaotic, turbulent environment; making fast, irreversible decisions; highly interdependent on one another to interpret equivocal information; dedicated to innovation and the creation of novelty." [21]

Many jazz musicians confront unpredictability and self-imposed challenges in their artistic process. For example, jazz guitarist Kurt Rosenwinkel "retunes his guitars in unfamiliar patterns, a practice he describes as "voluntary self-sabotage"." [22] In Barrett's study of multiple well-known figures in the jazz tradition several themes emerge which support the premise that higher risk states can be essential driving forces in areas of creativity, innovation, and expression. He uses John Coltrane and Miles Davis as key figures who engage in what he terms *provocative competence,* one of seven characteristics unique to jazz that enable improvisation and innovation. These virtuosic players knew their skill level and natural abilities were such that, if left unchallenged, they would result in performances that were overly "safe." The safest route through a performance may seem to be the easiest or most natural (and is, additionally, the most likely to appeal to listeners looking for the most straightforward demonstration of skill and virtuosity); however, for these heavyweights of the jazz world, "safe" was unfulfilling, un-challenging, and against the spirit of jazz itself. Coltrane and Davis purposefully handicapped themselves in order to provoke better, more inspired performances at the cost of their own comfort:

> "Saxophonist John Coltrane is well known for deliberately playing songs in difficult and unfamiliar keys because "it made (him) think" while he was playing and he could not rely on his fingers to play the notes automatically...Miles

> Davis had a talent for creating incremental obstacles and nurturing small disruptions that provoked his musicians to experiment with new actions that yielded new levels of creativity." [21]

Davis had no qualms about imposing higher risk states on his bandmates, either: "Miles Davis told his musicians, "I pay you to practice on the bandstand," and believed that this made the music as "fresh" and "honest" as it can possibly be." [23] "Many band leaders limit rehearsals and tell their band members to not talk about the performance; they believe that this forces musicians into maximum spontaneity." [24]

Embracing a higher risk state in order to prime a situation for increased expression is a daunting, yet necessary act for many skilled improvisers. Psychologist Keith Sawyer illustrates this concept with an example from pianist Keith Jarrett, recounting:

> "He cannot rehearse in advance of an improv concert, because hearing himself play will interfere with his musical voice. He says, "I have the need not to hear piano music before I improvise on the piano. So what does that mean? It means I can't practice. So what does that mean? Sometimes, it's been a month or two that I have not touched the piano and then I go and do a concert."" [24]

To many musicians in less improvisatory genres the concept of not practicing with one's instrument before a concert—for even a matter of days, much less months—could seem irresponsible or unwise. Here we see the duality of risk and expression in play, and the unique dynamic improvisational creativity imposes on them. In order to develop skill and mastery one must practice, yet one must also push beyond the comfort and safety that years of practice engenders in order to experience novel modes of expression. The process of improvising music demands not only skill but also the desire to seek out the challenges that will push toward new discoveries.

Sawyer, in his list of five characteristics of improvisation, makes explicit mention of problem-*finding* rather than problem-*solving*: "An improvisational performance is...a problemfinding process." [25] Sawyer argues that within performative practices artists produce a product through their *process* (as compared to, say, a fine artist who produces a *product* in the form of a painting or sculpture), and the emergent process is not one which attempts to answer a well-specified problem or follow a clearly laid-out path. Rather, the artist creates everything in the moment, including moments of tension, unresolved themes and ideas, and challenges to be answered. In Sawyer's words: "In most creative genres, the creative process is a constant balance between finding a problem and solving that problem, and then finding a new problem during the solving of the last one." [25]

More explicitly, Sawyer draws direct connections between musical improvisation and unpredictability, arguing that the two are inseparable from each other:

> "The most salient characteristic of group improvisation is its unpredictability. The word "improvisation" comes from the Latin root *improvisus*, meaning "unforeseen" or "unexpected"...When a group is improvising together, the unpredictability of each participants' performance also implies that the performance will be *collaborative.* Since each performer cannot know what the other performers will do, each has to listen and respond to the others, resulting in a collaborative, and intersubjectively generated, performance." [26]

Jeff Pressing (a skilled musician and prolific academic credited with developing one of the earliest and most influential psychological models of musical improvisation) similarly speaks to the emergent nature of improvisational processes, stating that, "Highly developed skills have distinctive emergent properties...such as adaptability, efficiency, fluency, flexibility, and expressiveness. These are vital components of improvisatory skill." [27] Pressing draws upon a foundational 1984 text by B. Doerschuk to define the "art of improvisation" as resting on an instructor's ability "not to present models for imitation, but to pose problems intended to provoke personal responses" [28] in order to develop expressive individuality. He further describes the improvisational process as "a succession of small problems, each of which is the production of an appropriate chunk time point, where the constraints on action are actions at earlier time points." [27]

3.2.2 Failure, Error, and Mistakes in Improvisation

In her 2013 text, *Embodying Failure: Music, Performance, Risk and Authenticity*, pianist and choreographer Imogene Newland explores how risk and failure encourage creative music-making experiences, unique for their sense of "liveness" and emotional impact. With a heavy emphasis on the role of the musician's body, Newland points to the crucial role that risk states play in a live performance experience for both the musician involved as well as their audience:

> "I have posited the musician's body at the centre of my analysis as I believe that the potential risk for failure is largely dependent on the physical aspects of music making with particular concern for the ability of the performer to embody imperfection. This risk for failure, I hypothesise, is what separates live music performance from other modes of musical experience. In my opinion, the fallibility of the human condition, which has an essentially corporeal basis, plays a key role in creating the conditions that make live music performance edgy, exciting and above all, unique...it is exactly this desire for the physical embodiment of musical ideas—and the inevitable risk of failure that this desire brings—that ultimately defines our live experience and which continues to breed new, exciting and thought provoking work." [29]

Newland also makes clear that virtuosic musicians are not, by virtue of their skill, exempt from engaging with risk, but rather entrenched in a high-risk scenario in which they rely on their skill to carry them. Implicit in this view is the notion that musicians engaging in live performance—at *any* skill level—must engage with risk and the potential for failure if they are to arrive at or deliver an "enrapturing" performance. The level of risk must be commensurate with the skill level of the practitioner, but risk is nevertheless present in the most engaging of live performances.

It is an important distinction to make, here, that virtuosity exists separately from expression, and that although they may be intertwined it is the relationship between skill and challenge that holds a more important role. A flawless piano performance of *Twinkle, Twinkle, Little Star* will not seem particularly impressive if played by a pianist with 30 years of experience. Light that piano on fire (to take an extreme example, though one that is not without precedent), and that same performance might take on quite a different sense of skill and creativity. While some researchers argue that polished, intimate performances by virtuosos are the truest form of expression (more on this later), virtuosos themselves seem to have different ideas about their own experiences. The nuances of virtuosity and expression—and the problematic definitions which exist as holdovers from traditional disciplines—will be discussed in further detail in Chapter 4; however, at this point we turn back to the role of risk in improvisation.

Trombonist and trumpeter Mike Zwerin focuses the discussion toward the role of error in improvisation not as an undesirable element, but rather as the lifeblood of the improvisational encounter:

> "Somebody who decides to play jazz for a living knows he will struggle for the rest of his life, unless he opts for predictable and smoothing compromise. Honest jazz involves public exploration. It takes guts to make mistakes in public, and mistakes are inherent. If there are no mistakes it's a mistake." [30]

Barrett aptly expands on this idea, stating, "Jazz bands...see errors as inevitable and something to be assimilated and incorporated into the performance...errors become accommodated as part of the musical landscape, seeds for activating and arousing the imagination." [21] Mistakes in improvisation are often encouraged rather than avoided, as they contribute not only to the excitement and "charge" of an environment but also to the creative innovation of the performers.

In his interviews with improvisational theater actors, Sawyer illuminates the notion that mistakes push performers toward innovation, and that ""Mistakes" perform the valued function of interrupting the prearranged ideas and forcing an innovative alternative." [24] Sawyer's statement is purposefully written to underscore the contradictory nature within: *mistake*, presented in quotation marks, is semantically incongruous; if a "mistake" is a failure of intention, can it be intentionally engaged with? If it is an unexpected disruption, can it be purposefully designed into an experience?

Regarding an interview with improvisational actor Pete Gardner, Sawyer recounts:

> "Gardner did not believe that mistakes should be avoided; rather, he fondly remembered shows when "we let the seams of the show show themselves a little bit more." It's more exciting to perform with groups that take chances, because "they stretch me in ways I probably wouldn't naturally go"; and such groups are the ones that are more likely to make a mistake. Groups that are too concerned with being slick, with being well received by the audience, may make less mistakes but the performance will ultimately be less exciting and less creative." [24]

Likewise, musicians are sometimes apt to deliberately "mess up" something that is going well in order to break into new, more interesting territory: "Sometimes you get technically good with the chords, you can start to feel constrained; if you reach that point, it would be freeing, to free your ears to play a note, that normally wouldn't belong there." [24]

Returning to Newland, we can consider a definition of virtousic performance which *emphasizes* rather than tries to polish away the risk of failure: "Virtuosic instrumental music performance is examined as one way in which the risk for failure produced by the performer's physical limitations may lead to a desirable performance atmosphere. In this way, the corporeal embodiment of failure is posited as an integral feature of the live recital context." [29] Virtuosity, it would seem, often relies on the willingness of the virtuoso to recognize and welcome that which may, for the less experienced player, be the most intimidating and anxiety-producing aspects of musical performance.

Of Miles Davis' 1959 recording session for the 4-times platinum record *Kind of Blue*, Barrett recounts a similar confrontation between the potential for failure and a desirable performance atmosphere:

> "When the musicians arrived in the recording studio, they were presented with sketches of songs that were written in unconventional modal forms using scales that were very foreign to western jazz musicians at that time. One song, contained 10 bars instead of the more familiar 8 or 12 bar forms that characterize most standards. Never having seen this music before and largely unfamiliar with the forms, there was no rehearsal. The very first time they performed this music, the tape recorder was running. The result was the album *Kind of Blue*, widely regarded as a landmark jazz recording. When we listen to this album, we are witnessing the musicians approaching these pieces for the first time, themselves discovering new music at the same time that they were inventing it." [21]

These emergent themes—*unfamiliarity* for Coltrane, *obstacle* and *disruption* for Davis, *struggle* for Jarrett—are key elements of improvisational performance that play a major role in creative processes. Though they use unique terminology, each musician is speaking to a kind of unpredictability within the musical setting where the choices they make must occur in real-time and they are forced adapt to future states which are, at least to some degree, unknown. As Sawyer puts it, "Improvising musicians and actors value mistakes because they force a performer out of their precomposed patterns." [24] Practitioners who devote their lives to the pursuit of musical improvisation seem to acknowledge the "downside" of being masters of their craft, and strive to find the higher risk states that will challenge them and push their art forward.

3.2.3 Disfluency

In her 2018 PhD thesis *The Show Must Go Wrong: Towards an understanding of audience perception of error in digital musical instrument performance*, interdisciplinary artist and designer S. Astrid Bin turns her focus toward *disfluency*, or "the experience of processing difficulty", [31] which she explores as one facet of musical expression. In a related work, Bin et al. state that disfluency:

> "Has been shown to result in heightened cognitive processing...it is not a lack of fluency that poses a challenge, but rather too much fluency, as 'easiness' means that we tend not to use all of our mental capacities. Disfluency supplies the friction necessary to prompt the use of fuller cognitive abilities." [32]

This idea is supported by Barrett, speaking from his years of experience as a jazz pianist: "Too much reliance on learned patterns (habitual or automatic thinking) tends to limit the risk-taking necessary for creative improvisation; on the other hand too much regulation and control restrict the interplay of musical ideas." [21] Bin goes further in her argument, arguing that improvisation and disfluency exist in a reciprocal relationship:

> "Dealing with an unstable disfluent quantity can be considered a type of improvisation. This separates disfluency from a constraint around which a performer can develop a style that can be practised. Performers can perform this and other behaviours in ways that are risky in order to challenge themselves and enter into a risk state, but constraint is by no means an automatic indicator of the presence of risk. The risk that arises from disfluency, then, is not a design quality or physical element, but a continuous state. In a risk state, a performer will be ascertaining the limitation and may be performing this appropriation in real time." [33]

We will return to Bin's investigations into disfluency, risk, and musical performance in Chapter 4, specifically as it relates to evaluation methodologies in CMPs and the diversification of instrument forms.

3.2.4 Conclusion

Risk takes many forms and spans multiple genres and time periods. Looking at traditional or historical examples of performance arts in general, we can observe several categories of risk that remain more or less unchanged throughout time: the risks to the corporeal body of the performer is a constant element (disregarding, of course, completely robotic performances) of the performance experience, and any physical properties of tools used in the service of a performance are vulnerable to material risk. Mental and emotional risks are critical elements of any activity undertaken by a sentient actor, as are the communicative, social, and spiritual stakes of putting oneself in the spotlight for personal and public judgment.

What changes over time are not these generalizable categories of risk but rather the complexities and nuances introduced by shifting cultural settings and the availability and implementation of novel technologies and tools to realize performance goals. The introduction of the electric guitar would eventually lead to the identification of feedback and distortion (originally considered undesirable consequences of improper use) as valuable expressive musical elements. The humble turntable evolved from playback device to musical instrument. Sound speakers would find extended use in their musical role through strategic and unconventional placement beneath snare drums or next to other resonating surfaces.

What we have known (or thought we have known) about skill, virtuosity, risk, expression, musicianship—these concepts have all shifted drastically in the last 50 years. What it was to be a virtuosic musician just 20 years ago may no longer apply to many practitioners in contemporary musical spaces. The skill sets required or expected of a musician or composer have fractured into many branches of a deeply-rooted tree, and the challenges, risks, and processes faced by a computer musician diverge quite drastically from traditional modes of musicianship. Simply put, the turn to the digital has upset certain longstanding relationships between risk, expressivity, and performance—and even what it means to perform at all.

3.3 Risk in Computational Music Practices

The value of risk as it relates to expressivity in more traditional forms of improvisational musical performance (jazz, particularly) carries over to our discussion of computational music, with several notable shifts. First, we see a change in the relationship between the musician and their instrument, from a rather direct physical connection to an increasingly distanced one. Second, we can observe an entanglement between the interplay of action-potentials and output, shaped in certain ways by the offloading of actuation and sound-production to the computational components of the instrument or system. Lastly, we can note the nuanced ways in which the procedural, participatory, and encyclopedic qualities of the computer [34] can and do influence the risk states with which we engage.

3.3.1 The Relationship Between Musician and Instrument

In their 2016 paper, *Because there was no user in art: Imagining a technological sublime*, interdisciplinary artist, researcher and composer of electronic music Eleonora Oreggia and mathematician and cognitive scientist Graham White consider the contextual relationship between musician and instrument: the performer will undoubtedly have certain beliefs and expectations about any instrument put before them, and the physical properties of the instrument itself will affect the performance. As they suggest, "The materiality of the musical instrument leaves traces on the performance, and thus the materiality of the instrument is essential to the semantics of the performance in a way in which the materiality of a computer is not essential to the semantics of programs that are executed on it." [35]

Beyond the reciprocal give-and-take between the musician's and instrument's physical and material bodies the authors also point to the importance of engaging with risk in order to express something about the performer's experiences in the physical world:

> "The particularity of the instrument is important when the state of a musical instrument changes suddenly and discontinuously. In some cases, the discontinuity of such state changes, rather than being an accident afflicting a performance, a departure from the ideal, can be an essential, intended part of the performance: indeed, the performance can be intended to exhibit just such discontinuous state changes, and thus to convey something important about the way life is exposed to the contingencies and the chaos of the physical world." [35]

Oreggia and White tread into less convincing territory when extending those beliefs and expectations to be wholly instrument-specific. As *de re* beliefs ("context or object dependent" [36]) they not only discount elements of disfluency, experimentation, and risk inherent to more improvisational styles of music, but also do themselves the disservice of discrediting what they had previously hailed as all-important: context. While it is certainly true that a violinist and her audience will have beliefs and expectations about a performance based on their knowledge of the exact materials of the instrument, no one could have expected Nam June Paik's slow-motion violin smashing by the kind of wood the instrument was made out of, or Keith Jarrett's unprecedented playing style at the seat of what appeared to be a functioning piano. The materiality of an instrument does indeed leave traces on the performance (and, I would argue, the performer as well), but those qualities are not always quantifiable, qualifiable, or even known, much less inextricably tied to specific objects.

Newland discusses the nature of embodiment in musical performances, linking it to a sense of authenticity and emphasizing the role of physical failure in the performative experience:

> "The musician's personal authenticity and how this relates to notions of failure in music performance with a special focus on how the musician uses their body to communicate expressively in performance. This discussion offers a further dimension to understanding how the risk for failure contributes to musical experience and how such a conception may be used as a stimuli for new creative work." [29]

She further touches on the core positioning of many musicians who hesitate to embrace levels of technology that might distance themselves physically from the instruments they use: “One of the criticisms of computer music performance has been the noticeable reduction of visible physical gestures in the operation of technological devices that would otherwise be present in instrumental performance. The pressing of a button or manipulation of a computer mouse is a much less visually perceptible movement within the context of a conventional audience/performer spatial relationship than is the lifting of the pianist’s arms away from the piano keyboard after a concluding fortissimo chord.” [29]

Within CMP communities extending, augmenting, and even creating instruments from scratch using digital technology is an ever-growing and diverse objective, with many individuals arguing for more or less technology on the stage. The rise in purely digital interfaces (the laptop in particular) is sometimes seen as an indication of a growing problem in the field: watching a laptop orchestra is a distinctly different experience than watching a classical orchestra, and for many the digital approach leaves much to be desired precisely because of the lack of physicality between musician and instrument. As explained by composer/performer Pauline Oliveros:

> “The body is an instrument of choice for directly making music with voice, hands, feet, and body resonance. This has not essentially changed. However, the distancing of the body in making music began with the first discovered technology for making musical sound as an extension of the body, such as blowing air through a hollow bird bone as a simple flute or whistle...Through the millennia, the distancing of the body by instrumentation has increased exponentially until, with the inventions of recording technology and radio broadcasting, music could be completely disembodied.” [37]

As a composer and performer who readily used technology on the stage, Oliveros expressed a desire for the presence of the physicality of her body, stating that it was ”yearning to participate in dealing with the more than eighty-five performance parameters in the interface in an integral way.” [37] Ethnomusicologist/artist Tomie Hahn, composer/musician Dan Trueman, and composer-/improviser Curtis Bahn echo this desire in their assertion that in order to maintain and extend musical tradition in a newly technological practice the body must be reintegrated into performance, with a more balanced scale and idiosyncratic requirements for interfaces which are more gestural and musical. [38] They also posit that within the field of new music (a discipline which produces an army of novel instruments each year), sound is meaningful because it is inherently about the body, an embodiment of what we see and experience.

This more phenomenological approach to understanding musical expression involves a belief that performance instruments should be idiosyncratic and personal, and serve to "reinforce individual approaches to performance" and "extend our voice and bodies into a new context of interactive performance possibilities." [38] Musician and researcher Marcelo Wanderley goes so far as to suggest: "The ultimate goal is to design new DMIs (Digital Musical Instruments) capable of obtaining similar levels of control subtlety as those available in acoustic instruments, but at the same time extrapolating the capabilities of existing instruments. In short, we need to devise ways to interact with computers in a musical context." [39] The implication, here, is that the physicality of traditional instruments informed (or at least contributed to) the nuances of interactions possible between musician and instrument, which in turn shaped the expressive palate.

In comparison with traditional acoustic methods, engagements with the laptop as a performance tool involves diminished tacit qualities (see Polanyi's *tacit knowledge*, an ongoing feedback loop between ideas and their coming into being [40]). Bahn et al. are not the only individuals to lament over the lack of haptics and physicality within the NIME paradigm; Wanderley and Orio provide an example of a typical feedback system using DMIs: "The performer's gestures are both a part of the choreography and the input for the system; the system's audio output is heard both by the audience and by the performer, who can use it to extract information on the system's status." [39] This particular feedback involves little in the ways of tangible or haptic forms, though of course one *can* press a key rhythmically or swipe across a track pad gesturally.

This sentiment extends beyond music; for example, in their paper *A VJ centered ex-*

ploration of expressive interaction, Hook et. al look at practicing "video jockeys" (VJs) in order to identify design parameters and methodologies for live visual performance. Ultimately, their guidelines include a need for tangibility in performance interfaces, so as to give VJs the feeling of grappling with and holding the media content they are manipulating. [41]

3.3.2 The Relationship Between Physical Actuation and Output

According to Berthaut et al., DMIs provide less information about an instrument and its methods of sound production than traditional instruments. They also provide a different experience to audiences, partially due to the different nature of visual information and partially because of the absence of a direct physical connection between performer and instrument. This is particularly problematic because the perceived causality between performers' gestures and musical result is central to a sense of "liveness," [42] and the better an audience understands an instrument and how it is played, the better they are able to appreciate a performance. [43] Therefore, instruments should be designed to make interactions more obvious and transparent. Bahn et al. discuss this in terms of tradition: Traditional chamber ensembles' high-level performance qualities depend on visual readings of each other. This includes not just *effective* gestures, but also *accompanist* gestures, which are equally important aspects of physicality. For them, gesture is a trace of the performer-instrument relationship. [38]

Dance and choreography in particular seem to maintain their physicality even as they adopt digital technology. The expression capable through the physical body is not negated by the fact that computers now allow for virtual bodies and digitally produced media content. We can see evidence of this in early performances utilizing computers on the stage; as the computer began to transition from a way to calculate and generate visual and auditory content in the '80s to a way to manipulate video and audio in real-time in the '90s and beyond, we see an increase in focus on how the body could be used to control different media modalities. Mark Coniglio's 1989 sensing system, *MidiDancer*, represents one of these early attempts to use the computer as physical computing device that could combine the body with visual and aural material. Steve Dixon explains:

> "Just as a violin responds to the gestures of its player and transforms them into sound, MidiDancer amplifies movements of the performer and translates them into another medium. But they acknowledge that the analogy breaks down "when one considers that we look to the dancer's body for meaning, a burden we do not typically place on a violinist's fingers." They identify the challenge to conceive performances that utilize sensor-activated media effectively but do not compromise the traditional role of the choreographer dancer." [1]

With a focus on gesture as a common source for articulating both aural and visual output, researcher and performer Atau Tanaka emphasizes a similar sense of physical musicality in reference to his own participation in the group Sensors_Sonics_Sights (S_S_S):

> "No one member generates both sound and image, there is no automatic visualization of sound, there is no network communications connecting the three subsystems. Instead, all communication takes place in non-technological channels, through eye contact, and gestural coordination amongst performers." [44]

The gesture of the performer who is crafting a relationship over time tells us something about what they are expressing, and this gestural way of navigating technologically-enhanced performances is an important element of both the performer's and audience's experience of a piece.

What this is all building toward is the (controversial) notion that tangible interfaces are needed for musical expression because, unlike laptops, they overtly demonstrate causality, correspondence, and intentionality to collaborators and audience. In some areas there is a very distinguishable line between the human and computer elements of a process, but in many that line is becoming less clear, particularly as technology becomes richer in capability and complexity and cheaper in price and resource demand. As we have seen argued by researchers involved in digital and traditional forms of craftwork, physical tools enable us to think-through-making, extend ourselves physically through a medium, and carry out idiosyncratic actions as informed by tacit knowledge. In many ways we remain able to construct rich, full experiences with purely digital instruments; however, it does not necessarily emerge naturally or reflect an organic relationship. As multimedia artist David Rokeby states, “At the computer screen, we receive many thousands of pixels at least 60 times a second from our monitors, while sending a few bytes of mouse position or keyboard activity back to the system...The “bandwidth” of *real experience* [emphasis added] is almost unimaginable.” [45]

Digital instruments on the far end of the physical-virtual spectrum have no physical body at all, and as a consequence the elements of sound generation and production normally tangible to the performer are transduced into intangible computational calculations. In order to develop and define a causal relationship between a performer’s actions and the sonic output, mapping techniques step into the role of actuator. Researcher and practitioner of music technology Thor Magnusson makes an apt observation regarding the role of mapping in DMIs:

> “Mapping is perhaps the most integral feature of new digital musical instruments...The sound and mapping engines serve as the core of the digital musical instrument; they are its “real body.”” [46]

How performers relate their body to a musical process that is, for all intents and purposes, disembodied becomes increasingly difficult to query—as do techniques for designing and building novel DMIs. Computational technology not only eliminates the need for a physical instrument in many cases, but fundamentally changes what the “body” of an instrument *is*. If what we know tacitly about our experiences in the world—that the air displaced by rustling leaves or rippling water, the clapping of the hands, the plucking of a string results in what we understand as “sound”—is rendered less relevant in DMIs, we must reconfigure our understanding of what “playing an instrument” means entirely.

3.3.3 The Relationship Between Computation and Risk

Improvisation is a function of navigating endlessly changing situations in which unwanted outcomes must be mitigated, directions must be chosen, and a desired outcome must be weighed against changing probabilities. This process takes place in a feedback loop between people and materials over time, a loop which depends on unpredictability and malleability on both sides—the potter and the clay, the performer and the audience, the user and the computer. Both parties depend on each other in order to move forward together in a process, whether it be in the worlds of theatre, art, craft, or design, and the unpredictability on both sides of that feedback loop carry with them elements of risk, uncertainty, and the possibility for error and failure. As we add digital technology to these processes, the way we improvise is affected: our methods of making become more procedural, and the kinds of errors that are possible change.

In his paper on mapping techniques in DMIs, *The limitations of mapping as a structural descriptive in electronic instruments*, composer and interaction designer Joel Chadabe notes the complicated nature of predictable and unpredictable electronic instruments:

> "A deterministic instrument is defined by the complete predictability of its output relative to a performer's controls...an indeterministic instrument outputs a substantial amount of unpredictable information relative to a performer's controls...The primary benefits of an interactive instrument are, first, that the performer is called upon to think and act like a creative person with intelligence, imagination, and musical expressivity...and, second, that the level of musical skill required to 'play' the instrument is flexible. Interactive instruments embody all of the nuance, power, and potential of deterministic instruments, but the way they function allows for anyone, from the most skilled and musically talented performers to the most unskilled members of the large public, to participate in a musical process." [47]

The brain's associative powers make improvisation and unpredictability natural for human beings [48], but computers function differently. The procedural (generating behavior based on rules [34]), deterministic nature of computation (which carries over to digital tools) produces errors that fall outside of organic human behavior, rendering fundamentally different improvisational experiences and capabilities for human creators and performers. The limitations of digital and human systems, and the ways in which decisions are made over time within them, are different; what is produced by each system is the result of distinct processes.

The presence of the digital on the stage presents a unique opportunity to analyze creative improvisation. On the one hand, modern computers can carry out incredibly complex tasks nearly instantaneously. On the other, it presents the performer, designer, or creator with something to translate. Digital technology is procedural: there is always mapping and translation within human-computer interfacing. When discussing human-computer interaction the word "interaction" itself can be quite contentious—there is often an acceptance of a computer's *reaction* as interaction when, in reality, it is simply a designed *response*. Computers are powerful responders, but one could argue that their responses inherently lack the richness and complexity of human interaction.

For video game designer and researcher Brenda Laurel, both agents in a meaningful interaction must not only realize what is on the other side of the exchange, but also understand that *the other element realizes the same about you*. [49] She references Herbert Clark and Susan Brennan, who expand on the notion that human interactions are "not just linearized turn-taking" and are, in fact, much more complex:

> "To succeed, [two people] have to coordinate both the content and process of what they are doing...they cannot even begin to coordinate on content without assuming a vast amount of shared information or common ground—that is, mutual knowledge, mutual beliefs, and mutual assumptions. And to coordinate on process, they need to update, or revise, their common ground moment by moment. All collective actions are built on common ground and its accumulation." [50]

Laurel implies that in a proper interaction there must be the same possibility for creation and improvisation on both sides of the HCI dash, which can be extrapolated to the argument that computers should theoretically be capable of the same mistakes, errors, and unpredictabilities as their human counterparts. If we accept that risk and error are part of a creative system which is facilitated or driven in part by improvisation, we must consider what kinds of error and risk are afforded by digital systems in order to consider possible modes of improvisation with the technology itself. In computing, an error generally falls into one of two categories: those of *logic* and *syntax*. When computing "correctly," great efforts are made to safeguard against these errors and interactivity is achieved through prediction and analysis: analyze what the human is saying/emoting/directing, predict what will/should come next. [51]

There is a wide margin between what a digital system endeavors to do in order to mitigate risk—predict, calculate, assess—and what a human will do: improvise. Though that improvisation may also involve prediction, calculation, and assessment (what are 12-bar blues charts for, if not that?), when it comes to the unknown a computer attempts to *interpret* an event, and a human *moves through* it. Having iteration at your disposal reduces risk, and digital production techniques are inherently iterative. The computer undoes or restarts; the crafter shifts aim. The computer makes *errors* that can be diagnosed; a human makes *mistakes* that require reflection to understand.

Improvisation does not endeavor only to predict. It thrives in the uncertain and benefits from risk and potential for error. When using physical interfaces there is no digital iteration or computational procedure, there is only process—a process of a thousand small decisions constantly informed by what is happening in real-time. The creator is able to say something about themselves in those small moments, and to put distance between their body and the physical extension of themself is to introduce the potential for dampened expressive capabilities. Though computers seem to grow more human every day, the brain's associative powers simply put us on a different improvisational register. We do not necessarily *need* physical interfaces to express ourselves—many people do this successfully every day with a simple point-and-click laptop interface. However, we should be cognizant of what we lose when we use increasing amounts of digital technology in real-time creative work: opportunities to engage in a process with materials, show something of ourselves, and extend our bodies even further into the world.

3.4 Risk and the Brain

3.4.1 Psychology, Cognitive Science, and Behavioral Science

The fields of psychology, behavioral science, and cognitive science have much to say about what happens, neurologically, when we process risk, unpredictability, and failure. These topics are well beyond the scope of this work; however, a brief discussion of recent research into the neural activity of improvisatory musicians is relevant to the discourse regarding the possible role of risk in expressivity.

Of particular relevance is the work conducted by cognitive neuroscientist Roger Beaty, who draws connections between the activities of the brain when engaged in musical improvisation and Jeff Pressing's theories of improvisation. Beaty's work is unique in that it is not only interested in better understanding the brain's activation when improvising, but also the notion that improvisation may not "rely on the musician's ability to control the creative process, [but] rather on his or her ability to "let go" of control and allow spontaneous processes to unfold." [52] His research (and others', see [53][54] for examples) identifies a surprising *deactivation* in the dorsolateral prefrontal cortex (DLPFC) of the brain, which is responsible for higher-level executive control, planning, and memory. What these findings imply is that, when improvising, musicians may actually experience a suspension or inhibition of conscious decision-making and planning processes, and access "default mode regions...which may allow the improviser to suspend conscious monitoring and enter a "flow-like" state." [52]

The reduction of executive control when engaged in musical improvisation is an important finding, and one which resonates with recent research into creativity and cognition. In Amer et al.'s 2016 article *Cognitive Control as a Double-Edged Sword*, the authors explain that many situations that call for the generation of highly creative ideas actually benefit from a reduction of cognitive control:

> "With respect to problem solving, reduced cognitive control has been found to promote the application of creative solutions and facilitate the use of sim-

ple strategies when complex ones are less optimal...control can hinder performance on open-ended tasks that benefit more from spontaneous, uninhibited thought...engagement of cognitive control may impede creativity by focusing attention on a limited number of non-optimal strategies. Lending support to this hypothesis, studies have demonstrated that creative thinking and musical improvisation are associated with decreased activity in control regions." [55]

The role of uncertainty and spontaneity in open-ended creative tasks has been studied in many contexts, including the classroom. In their 2016 paper *Wild and free: Unpredictability and spaciousness as predictors of creative performance*, cognitive and behavioral scientists van Rompay and Jol conducted a study among high-school students in a creative drawing task and found that exposure to natural imagery that was unpredictable and spacious "boosted actual creativity." [56] When presented with imagery ranging from spacious and unpredictable to non-spacious and predictable (and also urban imagery) the researchers found that "the condition containing visualizations both high on unpredictability and high on spaciousness outperforms all other conditions." Further, the students self-reported significantly higher levels of perceived creativity when exposed to unpredictable, spacious imagery versus the non-spacious, predictable imagery. In summarizing their findings van Rompay and Jol conclude, "Unpredictability is particularly relevant to creativity as it stirs the imagination and arouses curiosity. After all, things that are unpredictable cannot be anticipated based on the old, and hence require imaginative thinking." [56]

This is only a tiny scratch on the surface of deeply complex cognitive, behavioral, and psychological elements of the human condition. However, we can see at least a small sample of the scientific research that is contributing meaningful findings to discourses surrounding the positive role that risk can play in creative experiences.

3.4.2 Flow States

Uncertainty, ambiguity, situational choice-making—all of these factors can be understood as elements of risk within improvised performance. Much has been written about the "emergent" nature of improvisation; because the direction of the performance can not be entirely predicted, the moment-to-moment actions of performers are both reactionary *and* constructive, constrained *and* free. This balance of inward and outward activity can produce what many refer to as a "flow state," in which the performer feels a sense of unity, harmony, and even transcendence during a performance. Coined by psychologist Mihaly Csikszentmihalyi, *flow states* represent an almost mystical sense of mind, body, and environment functioning in effortless harmony:

> "It is what the sailor holding a tight course feels when the wind whips through her hair, when the boat lunges through the waves like a colt—sails, hull, wind, and sea humming a harmony that vibrates in the sailor's veins. It is what a painter feels when the colors on the canvas begin to set up a magnetic tension with each other, and a new thing, a living form, takes shape in front of the astonished creator." [57]

One can look to Csikszentmihalyi's work on flow—a state of being in which an individual feels transported to a different realm of time and/or space and their actions and awareness become a singular entity—for some insight into risk states and expressivity. Csikszentmihalyi argues that a person's level of skill must be well suited to a challenge in order to enter into states of flow, with imbalances leading to either boredom (when skill outpaces challenge) or anxiety (when the challenge is too great for skill level).

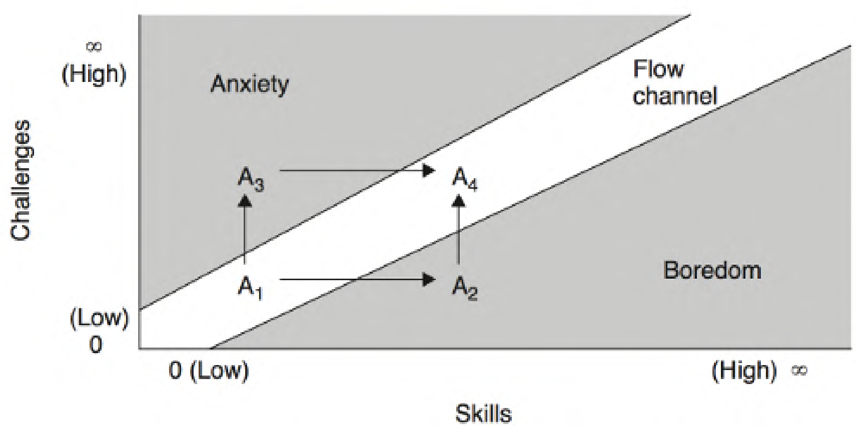


Figure 3.7: Csikszentmihalyi's diagram of flow at the intersections between skill, challenge, boredom, and anxiety [57]

Csikszentmihalyi argues that "it is this dynamic feature [between anxiety/boredom and challenges/skills] that explains why flow activities lead to growth and discovery. One cannot enjoy doing the same thing at the same level for long. We grow either bored or frustrated; and then the desire to enjoy ourselves again pushes us to stretch our skills, or to discover new opportunities for using them.” [57]

Though flow states occur across a multitude of activities it is most often discussed in relation to creativity. Perhaps due to the inherent risk and uncertainty involved in their particular practices, improvisers in music and theater seem to be particularly attuned to the phenomenon. Sawyer (who, notably, studied under Csikszentmihalyi) draws direct correlations between higher risk states and flow: “The most skilled performers prefer to perform the riskiest genres of [improvisation], as predicted by Csikszentmihalyi’s theory of flow; their high degree of skill requires a correspondingly high degree of challenge to attain a flow state.” [24]

It is unsurprising that many researchers and academics in the music field have applied the concept of flow to the musical experience. Musicologists Luc Nijs, Micheline Lesaffre, and Marc Leman, for example, investigate flow as a byproduct of physical and material risk states within musical performances:

> “The embodied experience of participating in the musical environment in a direct and engaged way is based on the direct perception of the musical environment and on a skill-based coping with the challenges (affordances and constraints) that arise from the complex interaction within this musical environment. It becomes an optimal embodied experience (flow) when the musician is completely immersed in the created musical reality (presence) and enjoys himself through the playfulness of the performance.” [58]

For musicians within CMPs, achieving flow states as described by the authors above quickly becomes problematic, especially for those using highly-computational DMIs. Nijs et al. define a flow condition that hinges on transparency and non-mediation—something that is complicated within the black box. As they put it, flow “can only occur when the relationship between musician and musical instrument is characterized by the transparency of the medium.” [58]

3.4.3 Conclusion

With a general overview of the importance and presence of risk in different performative activities throughout history we can move on to a discussion of how risk might be interpreted in computer music practices. In the chapter that follows we will first examine how risk might be categorized and defined as elements of creative performances in general, and then continue to an examination of how we might define and evaluate risk as unique to CMPs in particular.

CHAPTER 4
DEFINING RISK AND EXPRESSION WITHIN CMPS

4.1 Understanding Categories of Risk

To understand risk one might begin with a more generalized discussion how it manifests in performance—that is, what shape(s) does risk take, and how might we categorize these different forms? A cursory speculative exercise produces a list of broad groupings spanning a multitude of qualities: bodily, mental, emotional, communicative, material, social, and spiritual; we can consider the practical instantiations of each risk category in order to work toward a more detailed taxonomy of performative risk in creative practices. While this framework can assist in defining the "costs" involved in each of these concepts, we can also find insights into the productive, beneficial aspects through case studies of existing work that purposefully engages higher risk states in each category.

4.1.1 Bodily Risk

Broadly speaking, bodily risk is channeled through the health and physical safety of the performer or audience, wherein the body can be injured or can produce errors of a physical nature. At the extreme, bodily risk can result in serious physical harm or even death. The practices of fire dancing, sword swallowing, and tightrope walking offer tragic examples of this (e.g. the performing family "The Flying Wallendas," whose members found themselves falling to their deaths, fatally electrocuted, and paralyzed during performances). For practitioners who engage in musical activities further removed from these kinds of daredevil stunts, more common instances of bodily risk include cutting the fingers on instrument strings, bruising areas of the body, muscle cramping, carpal tunnel syndrome, and fatigue.

Figure 4.1: Converge drummer Ben Koller's hands post-performance [59], Violinist Nicola Benedetti's instrument bruising [60], Violinist Frank Almond's hands after a Shostakovich performance [61]

Bodily risk can also take the form of uncontrollable biophysical symptoms such as lapses in muscle memory (i.e. intended/prescribed movements) or physical miscalculations due to distraction or other user error (e.g. pressing the wrong button or turning the wrong knob). In these cases the body does not (or is not able to) carry out intended actions, executes them improperly, or activates uncontrollably. Common examples include muscle twitching, nervous shaking, tripping or stumbling, "freezing up," and other such physical manifestations that vary in their degree of controllability.

Bodily Risk Case Study: Yōsuke Yamashita's Burning Piano (1973):

Figure 4.2: Still from Yamashita's *Burning Piano* [62]

In 1973 jazz pianist Yōsuke Yamashita took part in a documentary film made by Japanese graphic artist Kiyoshi Awazu titled *Burning Piano*. [62] The work placed Yamashita in front of a piano that was destined to be discarded but was instead set aflame as Yamashita improvised music on it. Dressed in fireproof gear from head to toe, Yamashita was determined to play the instrument until it was burned to the point that it would no longer sound.

The process took only 10 minutes. Yamashita would later say:

> "I did not think I was risking my life, but I was almost suffocating from the smoke that was continuously getting into my eyes and nose. I had decided to keep on playing until the piano stopped making sounds, so though I did not mean it, but it ended up having a life-or-death battle between the piano and myself." [63]

Not only was Yamashita in harm's way from the flames and smoke, but as the fire engulfed the piano, its strings were increasingly at risk of snapping (potentially whipping toward his face and body), its body collapsing (onto him)—either of which could have led to serious harm. The physical danger to Yamashita's body was the "risk-cost" of a performance that benefited from a re-situation of the role of performer and instrument, wherein a normally manipulable quality became a shifting, mercurial element whose behavior could not be predicted and whose affordances changed over time.

4.1.2 Mental Risk

During the course of a performance the mind can act (or not act) in ways which hinder or betray the intentions or actions of the practitioner. These risks can manifest in more emotionally-driven ways (e.g. a "racing" mind, mental blocks, confusion, intrusive/invasive thoughts) or by way of cognitive mistakes (e.g. mis-reading a score or other instructions, mis-remembering the order of a sequence of events, or generally "spacing out").

Mental Risk Case Study: Failing, Tom Johnson, double bass (1975):

Tom Johnson's work *Failing: A Very Difficult Piece For String Bass* is a staple among upright bassists, partially due to its distinctive approach to instrumental performance standards. The work includes both bass and spoken parts for the performer and plays with expectations and conventions in musical practices. Professor of double bass and jazz performance Russell White describes this playful dynamic in his program notes for the piece:

> "[*Failing...*] requires the bassist to recite a spoken text while playing a printed part. Both the text and the music to be played are challenging, made all the more difficult by the use of compositional techniques such as unnecessary clef changes, octave displacement and extreme tessitura. The pitch resources are limited and often repetitive, though not quite a twelve-tone row...The text makes clear that "failing," while inevitable, is only validated by a tenacious dedication to success. The piece has been a staple of double bassists for over 30 years. Its humor strikes a chord with all who have strove to succeed while fearing the worst." [64]

Marrying technical challenges with a re-conceptualization of the goals of a performance has made Johnson's piece very popular among skilled bassists, and the work has been recorded on several albums. In the liner notes for Tom Johnson's release of the album *An Hour for Piano*, Kenneth Goldsmith describes the curious nature of the piece:

> "A solo bass player is given such complicated playing instructions that failure is inevitable and, as such, becomes a goal in the piece. Strange, I thought, I never considered failing to be a goal of anything." [65]

Similarly, in the liner notes for a recording of *Failing...* on the album *Plucking*, Samuel Friezen emphasizes the value of embracing failure:

> "*Failing...*, for example, features its own difficulty (already in the subtitle) and the relationship between virtuoso performance and the risk of making mistakes, implicitly inviting the listener to think about conditions of virtuosic music-making, something that we all too easily take for granted. After all, how weird is a musical culture that assumes the power of a performance to lie in the possibility that it might go wrong?" [66]

Johnson's work frequently makes use of subversive approaches to pedagogical norms and standards; Friezen references another of Johnson's works, *Doublings for Double Bass*, in further notes. This piece, again, exploits notions of failures, errors, and mistakes:

> "The cycle is titled that way because every phrase of every piece is double the length of the previous phrase. Each formula directs the player to generate the next phase from the previous one, cumulatively adding one level of structure at each pass. Eventually, the performer – who is instructed to perform the piece from memory – will lose his or her way, at which point the piece finds its natural end." [66]

Mental risk, as described in *Failing...*, encourages the confrontation of mistake-making in musical performances as a way to re-examine cultural norms and expectations. It turns the idea of "failure" on its head, re-positioning the performer's goals and redefining what a successful performance might look like. Rather than viewing extraordinary challenges as roadblocks to creative fulfillment, musicians must let go of the pressures of striving for perfection and embrace their own fallibility with a sense of humor and playfulness. Through this exercise the performer is charged with expressing themself in ways that deviate from "correct" practices, applying their skills in ways which prioritize the creative process over the production of an outcome that is defined and guided by conventional metrics.

4.1.3 Emotional Risk

Emotional risk involves high stakes that are experienced internally, such as embarrassment (whether over a mistake, sense of vulnerability, or even the topic of a performance itself), fear or frustration (of misinterpretations or misunderstandings between performers or the performer and audience), or struggle (with misrepresentations of intentional experiences or objectives). A performer may be impacted negatively by existing emotions, produce negative emotions as a result of their actions, or face emotional consequences that hinder their performance. A performance may suffer if the performer experiences a traumatic event, a piece may arouse negative associations or feelings, or a performer may become frustrated, angry, or otherwise upset with their own performance.

Emotional Risk Case Study: Nirvana, São Paulo Concert (1993):

In the most extreme cases emotional risk can build to a level that is unmanageable—this is something that has been observed with some frequency in pop music, often described in the press as celebrity "meltdowns." For one example we can turn to a 1993 Nirvana concert in São Paulo, where frontman Kurt Cobain—reported to have been so nervous to perform that he mixed pills and alcohol before the show—effectively quit performing a mere 30 minutes into the show. As the rest of the band attempted to continue playing Cobain paced back and forth across the stage, threw his guitar to the ground (where it came unplugged) and eventually smashed the instrument entirely.

This alone was not unexpected: Cobain had become well-known for his destruction of instruments and equipment on stage. However, as the band struggled to maintain some semblance of musical coherence over the next 40 minutes they were unable to wrangle Cobain back into the fold. Bassist Krist Novoselic eventually became so distraught that he threw his bass at Cobain and left the stage. Nirvana's guitar technician at the time, Earnie Bailey, describes having to coax Novoselic to rejoin the performance:

> "Krist threw his bass at Kurt and walked off at one point, and it took a while to get him back out to finish the show. Kurt was kind of a mess, and I don't think Krist could handle the idea of trying to roll through another song. When we finally got him to take another shot at it, he marched out and picked up the bass that had been tossed very hard about 30 feet across the stage, and without tuning it or swapping it out for a tuned one, he kicks right off into the next song. You can imagine how that sounded." [67]

Novoselic would later describe deciding to walk offstage as the beginning of a "mental breakdown" brought on by the complicated history of the band. [68] The group dynamics at play in this case study reflect the emotional toll that producing and performing music can take; Cobain would later give partial insight into this, stating that, "The band started to really fail me emotionally." [69] While there are extreme factors at play in this particular case (intense substance abuse, recurrent suicidal ideation, and undesired pressures of fame for a start) it makes clear the emotional risks one takes in musical endeavors.

4.1.4 Communicative Risk

Communicative risk in performance echos that which we experience in our everyday lives. A performer may not effectively communicate their intended message through a work, or two or more performers may experience a breakdown or failure of communication between each other. There is always a risk of misrepresenting intention when communicating with others; a creative practitioner may design and/or build an artifact, compose a work, or perform a piece with the intention of conveying or embodying a particular message (be it emotional, political, narrative, or otherwise) and find failure in its reception or interpretation.

Because communication within the musical performance space is so often non-verbal (and not necessarily intended to be perceived by an audience), a lingering glance between members or a head nodded in response to the rhythm or flow of a musical passage is easily missed or mistakenly misinterpreted with little time for recovery. Connected supportive or constituent elements of performance may also experience communication errors: channels/pathways/carriers of information, transduction elements, or processing technologies may fail in function. For example, a digital signal processing unit may malfunction, introducing unwanted noise into a signal chain, or a computer producing or manipulating content may freeze. Timing or communicative messages between devices (say, UDP communication between computer applications or wireless communication between computers) may experience interference or otherwise fail.

Communicative Risk Case Study: The Sign of Silence (2012):

All musical collaborations demand that a musician be attuned to group dynamics at some level. To start and stop a song together, cue others to take solos, or convey pleasure or dissatisfaction with the music being produced, verbal and nonverbal communication are central to the collaborative process. Jazz, as a relatively loose and unstructured form of music that is particularly social, requires a high level of non-verbal communication to maintain cohesion among musicians. There is much research regarding musical communication (see [70][71][25] for a start), but less that is focused on *mis*communication, where the effects of unpredictability and failure can be seen. In one such paper, *The sign of silence: Negotiating musical identities in an improvising ensemble*, psychologists and researchers Graeme Wilson and Raymond MacDonald elucidate the complexities of musical miscommunications in jazz improvisations, dissecting a statement made by one of the study's participants:

> **Interviewer:** How did you pick up on—or how were you aware of whether or not [the other musicians] were with you?

> **I06:** If they stopped playing would that be a signal? Okay let's just check, let's get everyone on board here again, it might be deliberate, intentionally not playing for the sake of the music, or there might be something wrong, so that's obviously a sign.[1] [72]

Wilson and MacDonald go on to deconstruct the participant's statement, highlighting some of its latent implications: a collaborator's silence can be interpreted multiple ways, understood differently by multiple members of the ensemble, and convey meaningful communication *or* be an unintentional product of a process gone wrong. As they summarize: "This account of group improvisation implies that silence from a player during group improvisation must be divined by other players in terms of its intentionality, and its musical or communicative function." [72]

4.1.5 Material Risk

The material, physical elements or tools of a creative practice may behave unexpectedly, fail, or break. For example, a guitar string may snap, levels of humidity and/or temperature may warp an instrument, a potter's clay may dry out, a button press may not register, and so on.

Material and physical risk are tightly coupled. As the body is (at least in part) a physical entity, it would be impossible to divorce the material properties of human actions from the physical process of music-making. Similarly, the material risk inherent in instruments made of wood, metal, glass, or other materials is inextricably tied to the hands of the person or entity using them. It is possible to experience physical risk in low material risk states—Steve Reich's *Clapping Music* (1972) is a good example of this—and vice versa, as seen in self-contained musical systems such as William Basinski's *Disintegration Loops* (2002). In the former, the material and physical elements of performance are one and the same; the piece takes form through the interplay between time and rhythmic drift and complexity. In the latter, the piece is guided entirely by material properties which, as they degrade over time, contribute to a shifting composition that ends only when the materials are exhausted.

[1] Minor edits for clarity

The distinction between physical and material risk lies in the property of *agency*: physical risk is experienced through the body, while material risk is embodied in the systems of sound production.

Material Risk Case Study: The Köln Concert (1975):

Pianist Keith Jarrett was scheduled to play a solo improvisational concert at the Opera House in Cologne on January 24, 1975, to be recorded by ECM Records. The show was sold out, with more than 1,400 people in attendance. Jarrett had requested a specific piano (a Bösendorfer 290 Imperial) for the performance, but due to a mix-up the wrong piano was installed on the stage. The piano given to Jarrett was old, out of tune, and broken in places. Not only did mechanics have to tune the instrument for hours at the last minute, but the pedals did not work properly and the high and low strings produced a horrible tone. In essence, Jarrett's instrument was going to fail him materially throughout the entire performance—should he choose to go on. He did.

Listeners reported experiencing a groundbreaking show, with Jarrett employing unusual and mesmerizing techniques: "The substandard instrument forced Jarrett away from the tinny high notes and into the middle register. His left hand produced rumbling, repetitive bass riffs as a way of conveying up the piano's lack of resonance. Both of these elements gave the performance an almost trance-like quality." [73] The limitations of the instrument forced Jarrett to problem-solve in creative ways, and through that process innovate stylistically and creatively. As Jarrett recalls:

> "What happened with this piano was that I was forced to play in what was — at the time — a new way. Somehow I felt I had to bring out whatever qualities this instrument had. And that was it. My sense was, "I have to do this. I'm doing it. I don't care what the f*** the piano sounds like. I'm doing it." And I did." [74]

Jarrett embraced the uncertainty and potential for failure—and the assured material failure in front of him—and ended up producing the best-selling solo jazz album in history (more than 3.5 million copies sold).

4.1.6 Social Risk

Social risk is connected to the communities involved in a performance (small- and large-scale), which effect a musician's status or relationships. Creative acts might produce perceived and/or actual changes in the practitioner's position within a community, their social station, or impact their reputation. Poor performance or output, incompatibility among collaborators, misunderstandings, arguments, political statements, and controversial content can all contribute to social risk states; many of the most well-known musicians and composers of the 20th century have, to some extent, found themselves at odds with other members of the community due to the confrontational nature of their work.

Social Risk Case Study: John Cage:

Today, John Cage is widely considered to be one of the most prolific and influential composers of the 20th century, and so it can be strange to read the reviews of his work written at the time. Many of the works we now consider to have laid formative groundwork for experimental music to develop were, in fact, widely dismissed by the community that was hearing and writing about it at the time.

Cage's infamous silent composition, *4'33* (1952), caused considerable animosity and anger among crowd-goers at its 1952 premiere, with one audience member exclaiming, "Good people of Woodstock, let's run these people out of town!" [75] Paul Henry Lang, music critic for the New York Herald Tribune, penned an article in 1956 in which he urged the so-called "true patriots of music" to destroy the "infidels" [76] such as Cage, who he considered to be imposters and charlatans threatening the institution of "real" music. Of Cage's piece *Radio Music* (1956) Lang would state that the utilization of machines was an "utterly objectionable" affront to respectable composers everywhere, [76] while the music editor of the Tribune, Jay Harrison, would designate the work of Cage, Stockhausen, Feldman, Boulez, and others as "a vicious aural version of the Chinese water torture." [77]

Though it does not appear to be the case that Cage ever strove to make "popular" music so much as he was continually striving to expand upon convention, he nevertheless must have been affected by the many scathing reviews of his work written by his contemporaries. As historical musicologist Suzanne Robinson states:

> "Whereas in his first years in New York he dreamed that attention from the formidable New York press corps would lead to fame and fortune, only a few years later he was dismayed at critics' persistent misinterpretation of his intentions. Subsequently, through his studies of Zen and a revision of his attitude to expressivity he cultivated an indifference to the press. By the early 1960s, he could inform Tomkins that he had adopted Gertrude Stein's notion "that all vigorous art was irritating, and that when it ceased to be irritating and became pleasing it was no longer useful."[78]" [79]

4.1.7 Spiritual Risk

Spiritual risk involves the search for and attainment of flow, transcendence, or other metaphysical states. More obvious examples of spiritual musical practices can be seen in historical religious traditions: meditative chanting, choral music, hymns and spirituals, singing mantras, cantillation, and so on. Music has long been considered a way to touch the divine, to experience some kind of spiritual truth or universal constant. Meditation through music (or music through meditation) can, for some, grant access to a "transcendent, sacred place where [musicians] experience the ineffable in music." [80]

Meditation has also been studied as it relates to expression in performative acts. In a study of graduate students engaged in improvisational acting, Linda Sanders found that after a short meditation session participants reported, "feelings of more presence in rehearsals and performance, a more available emotional freedom, and even cohesion as a group." [81] Researcher and scholar Ed Sarath, who created a Jazz and Contemplative Studies course at the University of Michigan, argues that meditation and mindfulness contribute directly to expressivity and creativity among improvising musicians: "With higher consciousness comes higher frequency of event perception. At this point spontaneity, inventiveness, and interactivity—key facets of improvisatory creative expression and impact—increase." [82]

As far as what is at stake in such a pursuit, we can turn to classical guitarist Aaron Haas, who summarizes it as such: “When technical mastery is absent, the result is a disorganized presentation of the musical material, but when the ineffable fails to shine through, there is an equally grave (if not more grave) mistake of forgetting the purpose of the music.” [83]

Spiritual Risk Case Study: Creative Arts Orchestra:

Not only does Sarath argue that meditative practices can positively impact creative musical expression, he also points to its value in interrupting habitual activities that musicians fall back on when performing. Established in 1992, the *Creative Arts Orchestra* is designed to apply meditative practices to group improvisations. Each performance and rehearsal begins with a period of group meditation and is concluded with an extended period of silence. Haas summarizes the objective of such a musical ensemble:

> “The goal of this orchestra is to free students of their habitual ways of improvising and patterns of playing and join an authentic discourse rooted in the present moment. This relates to the studies previously referenced on avoiding mental traps by relying less on previously learned knowledge and by using divergent thinking to arrive at the most adaptive solution...This kind of group improvisation activity, framed by meditation, helps students better understand their habitual behavior, in order to create in the moment, based on what is actually happening around them, rather than relying on previously learned patterns to improvise.” [83]

Spiritual risk can be seen in any pursuit of divinity or transcendence through music, but it is also an emergent property of creating music “in the moment,” or in “flow states.” Such a state is both a goal and challenge simultaneously—to experience it one must let go of the struggle for attainment. There is an inescapable element of risk when striving toward spiritual ends, as one must stay in the moment even as it is fleeting. If one can engage in meditative musical creation, however, certain barriers to creative expressivity seem to be lifted, and new doors opened.

4.1.8 Conclusion

It is worth noting two things at this point:

1. Categories of risk are a spectrum, and that spectrum is fluid
2. There is plenty of overlap between different kinds of risk: Communication errors may occur due to physical bodies, mental failures might occur in part due to heightened emotional risk states, etc.

While it should be acknowledged that many types of risk can be present in a multitude of creative practices at varying levels, the positioning of CMPs as a practice which merges traditional acoustic practices with contemporary computational technology creates a unique space for investigating how material and physical risk states play out in musical performances. Not only are we presented with a community that is designing and using musical instruments which do not necessarily depend on material conditions, we also see the physical hand of the musician distanced from that material engagement. Computational technology re-situates the interaction between the body and the instrument and thus shifts the ways in which physical and material risk present in performance practices. How these risk states are understood and evaluated may well be an important factor in the current and future expressive capabilities of instruments, interfaces, and the performers' experiences.

4.2 Defining Risk in CMPs

This work posits that heightened risk states provide greater opportunities for musicians to engage in and perceive expressivity in their work. Risk, like expression, is a difficult term to pin down, as it can be objective and subjective, quantitative and qualitative, and highly variable. Further complicating matters is the fact that "risk" is both a noun *and* a verb and must be considered as such. As a noun, risk here represents a class of performative elements which are at "stake" when a creative act is being carried out: monetary risk for the crafter working with fragile materials, social risk for the comedian tackling controversial issues, bodily risk for the artist handing a loaded gun to the audience.

As a verb, risk can mean the potential for harm, danger, or undesirable outcomes for any number of systems. Again, to consider every possible kind of risk would be impossible, so here risk is simply defined as a state of *unpredictability* with the *potential for failure*. When musicians perform in situations in which there is an ongoing condition of unpredictability and the potential for failure, they engage in higher levels of in situ problem-solving, which are direct instantiations of idiosyncratic, creative choice-making. An improvising musician is required to make decisions based on a changing context, and the more challenging the context, the more creative the problem-solving must be (to a point). As Austrian artist Gerfried Stocker iterates in the theme statement for the 2018 Ars Electronica Festival (appropriately themed "Error - The Art of Imperfection"): "Optimization leaves no leeway for the unanticipated, and thus no latitude to recognize and rectify what actually are undesirable developments or to come up with better ideas with which to set forth on alternate courses." [84]

Because risk is so complex an issue, the line connecting it to expressivity naturally runs through many related aspects of performance: skill, virtuosity, liveness, creativity, and much more. As Newland states:

> "If we attend a performance knowing that there is no risk that something might go wrong, I suggest that our overall experience will be diminished. The knowledge that this risk is present effects our perception of the performance by creating an 'edge' to the atmosphere that makes a failure-free presentation all the more impressive. My premise here is that the risk for failure is what contributes to an enrapturing performance and helps to maintain an air of spontaneity in performances that are pre-rehearsed. This quality of performance is dependent upon the ability of the performer to ride the wave of risk and draw from the energy that risk induces, the risk that things will fall apart and ultimately fail." [29]

Newland's assertion that "the 'mark' of imperfection is, for some, perceived as a desirable quality in helping to differentiate individualised approaches to comparable acts, especially when the act may be seen to benefit from a stylised interpretive response" [29]) butts up against issues of "style," and how style is different from "expression."

Interdisciplinary researchers and music practitioners Michael Gurevich, Paul Stapleton, and Peter Bennett make a point of distinguishing "style" and "expression;" the former being elements that are unique to a performer and performance, and the latter more aligned with what we attach to the emotional content experienced and conveyed by a musician to an audience. As they state, style is "a product of both a performer and the system with which they interact [that] leads to the notion of personal style, which we can define as a pattern of stylistic variations that may be uniquely attributable to a particular performer-system interaction." [85] If *style* is the resulting product at the end of a personal path from point A to point B, it can be assumed as an intrinsic component of expression as in situ problem solving and idiosyncratic responses to unpredictability.

The authors make explicit mention of the value of risk in the development of style, stating that, "The concept of risk was identified as a valuable element...An interaction can be structured to allow for stylistic variations that increase the risk of failure, which was observed to be an effective means of communicating style." [86] Though it is important to take note of the details of terminology here (*style* versus *expression*), for the purposes of this thesis we can respectfully recognize a distinction without a difference. That is to say: our working definition of expression is less concerned with inclusionary or exclusionary criteria (emotional and beyond), but rather with how risk creates opportunities for what a performing musician might experience as expressivity in their creative process.

It should also be noted that there is likely a point at which this becomes prohibitive, where a risk state is so high it becomes a distraction that outweighs the challenge. As Keith Sawyer explains:

> "Improvisation's unpredictability makes it a risky way to attain flow; it doesn't always happen, even in a group of talented, well-trained performers. Many improvising actors talk about both the high they get from a good improvisation, and the terror they feel when a performance is not going well. The unpredictability of group creativity can be frightening because failure is public, unlike creative genres like writing or painting. If a painter fails, he or she can paint over the canvas or perhaps even throw it away...Up to a certain point, this fear can contribute to the potential for a flow experience; but once it crosses a certain threshold, the actor moves from the flow zone into the anxiety zone." [24]

One complicating factor in the discussion of risk in CMPs is the strong presence of design practices. Where classical musicians rely on the experienced luthier to construct their instrument, the DMI musician often steps into that role themselves. Much of the discourse within the CMP community is focused on interaction design, instrument/interface prototyping, fabrication techniques, and the use of custom and bespoke musical apparatuses. This complicates notions of defining and evaluating aspects of risk considerably, as each instrument is unique and often both short-lived *and* used by one individual rather than many. In their design, fabrication, and use, the instruments often used in CMPs (DMIs, GUIs, laptops, etc.) are unique in their departure from more physical, analog instantiations of risk. However, there is existing evidence that such a condition is recognized—and remedied—through idiosyncratic design decisions among certain practitioners:

> "A predictable response from the instrument does not seem to be a condition that NIME musicians necessarily look for in their practice. Unpredictabilities are sometimes purposely programmed in NIMEs because they keep the instrument interesting and help improvisations, which tend to become predictable if nothing surprising happened." [22]

In a paper about designing electronic instruments and controllers, Joel Chadabe similarly recognizes the value of unpredictable states as a part of the design process:

> "In the functioning of a slightly indeterministic instrument, a relatively small amount of unpredictable information can simulate a performer's talented assistants, automatically supplying creative details while the macro-music remains completely under the performer's control. Depending upon the amount of unpredictable detail and the way it is triggered, such an instrument may become a powerful performance enhancement for a professional." [47]

The same attitudes held by the jazz musicians discussed in Chapter 3 can be observed in performers within CMPs. For example, of the Trio Brachiale (an ensemble that utilizes a wide variety of analog and digital technology in performance), member Alberto De Campo states, "I enjoy being surprised by the difference between my imagined expectation and what really happens." [22]

It may be helpful at this point to look at a number of case studies that exemplify what has been covered thus far. The instruments and interfaces discussed below each take a different approach to incorporating risk in the design and use of DMIs. As we will see, risk states are purposefully designed into both highly-physical and highly-computational DMIs in different ways and to different ends.

4.2.1 Risk in Highly Physical DMIs

Many practitioners in CMPs choose to design instruments and interfaces which have highly physical modes of interaction. These interfaces rely on physical and material properties not only for user control, but as an integral part of the sound generation process. While these instruments can (and often do) feature knobs, sliders, and buttons, they also rely on traditional modes of acoustic actuation—plucking, bowing, striking, and so on.

4.2.1.1 Keppi (S. Astrid Bin)

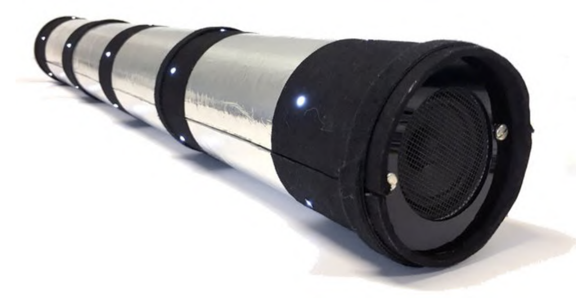


Figure 4.3: Bin's *Keppi* Instrument [33]

In her research into disfluency and creativity, S. Astrid Bin designed *Keppi*, an instrument that instantiates, to varying degrees, high-risk qualities of disfluency. A roughly 2.5-foot cylindrical tube containing speakers, a Bela microcontroller, and sensors, the *Keppi* is played through the tapping and physical manipulation of several electrodes; in addition, several rows of LED lights on the outside of the instrument convey real time information to the musician/performer during the course of a performance. In its three variations the *Keppi* behaves either predictably ("counting down" slowly via the LED indicators), unpredictably (counting down quickly), or in a control state (no countdown at all). Though geared toward evaluating the effect of performers' skills on an audience's sense of enjoyment in situations involving disfluency, the comments gathered by musicians and performers who used more disfluent versions of the *Keppi* were revealing in that they credited such qualities with positive creative experiences. In a related piece of work, Bin, Bryan-Kinns, and McPherson posit that disfluent qualities allowed performers to “positively engage with challenges that require them to leverage their existing skill.” [32]

Bin argues that the presence of risk states—particularly the possibility for error—allows for personal style to emerge through the visible application of skill. She references Gurevich’s discussion of personal style in her writing, but also goes beyond in suggesting that risk may be related directly to demonstrations of skill: “Risking error in order for the control and effort to become apparent may be key.” [33] Through her work Bin presents outcomes that, “Not only provide further insight into the audience experience of error, but also suggest that there exists a useful level of disfluency that challenges performers over time, and that audiences are able to perceive and appreciate performer skill as a result.” [33] Though she focuses on the perception of skill and expressivity on the part of the audience, such a discussion would not be possible without an associated inquiry into the experiences of the performers addressing them. For Bin’s participants, “Tools allow continuous innovations in ways they can be used and what they can be used for, unlimited by specific task. They lend themselves to the exploration, innovation and progress that comes from doing things the way they’re not meant to be done, by committing errors and observing the outcome.” [33].

4.2.1.2 *SoundLathe (Owl Project)*

Figure 4.4: Owl Project's *SoundLathe* instrument [87]

The *SoundLathe* instrument, developed by the Owl Project collective (Simon Blackmore, Antony Hall, and Steve Symons), harnesses audio data gathered from the use of a traditional wood lathe by means of eight sensors. The data gathered is used computationally to drive audio synthesis, turning highly physical material engagements into a musical composition. [87]

In their description of the instrument, the creators pay special attention to the cultural context of CMPs and offering a response to the digital trends they observe. In art historian and theorist Mat Gregory's description of the *SoundLathe*, this culture (as described by musician/scholar David Toop) is referenced:

> "Many debates about contemporary performance in the world of electronic and improvised music begin and end with the laptop computer: live, there is nothing interesting to watch; the relationship between action and sound is hidden from the audience; if the musician died on stage, or fell asleep, the computer would simply go on playing. [88] Sound Lathe provides a bold, dynamic and distinctly material response to this scenario, presenting the audience with not only a real, physical, sculptural object, but also a clearly visible and observable process of production - offsetting the intangibility of digitally produced/performed sound. Sound Lathe explores the relationship between the crafting of physical objects and the shaping of sound." [87]

As a designed instrument the *SoundLathe* marries traditional craft and manufacturing processes with computational music-making, and serves as a commentary on the importance of material and physical engagement in CMPs. Though their work exists solidly in the computer music genre, it actively rails against the immateriality and invisibility of digital music-making practices, embracing the “slightly faulty and incomplete” elements of performance that they see lacking in the community.

4.2.2 Risk in hybrid DMIs

Between highly-physical and highly-digital instruments are physio-digital hybrids: within these systems the majority of sound production or generation is handled by computational elements; however, the actuation of such processes requires a physical touch that is impacted by the materials of the interface. Unlike a keyboard and mouse, the ways in which the physical body interacts with the materials of the interface changes the product of the process. For example, the instrument may afford interactions which shift as it is opened, rewired, rotated, or chained together with other objects. Unlike highly physical DMIs, the sound produced by hybrid DMIs does not necessarily draw from its physical materials. However, the visible process of interaction remains an important element of performance and provides an observable link between physical actions and the production of sound.

4.2.2.1 D-Box (Zappi & McPherson)

Figure 4.5: Zappi and McPherson’s *D-Box* instrument [89]

The *D-Box* is an instrument designed by Victor Zappi and Andrew McPherson, created specifically to engage with exploration, unpredictability, and subversion in musical contexts. Zappi and McPherson speak to the community of musicians using computational technology and DMIs in their practices, pointing both to the novelty of new instruments as well as the ”black box” nature that they often exhibit. Black boxes, as referenced in this context, refer to objects that are designed to be rigid and unknowable, resistant to modification and unpredictability.

As an instrument the *D-Box* is specifically designed to be “open” in its ability to be hacked, circuit-bent, and explored by musicians for the purposes of discovering “novel idiosyncratic musical features.” [90] While “openness” may initially conjure notions of extreme degrees of freedom and design affordances, the *D-Box* is, in reality, highly constrained, affording only one or two degrees of freedom (depending on which build of the instrument is being used).

In fact, the authors make explicit mention of “expressivity” as enabled through DMI design, noting that the conventional line of thought seems to be that more dimensions of control equate to more expressive possibilities. Counter to this belief, they argue that fewer control parameters may in fact lead to increased levels of self-expression, even as performers struggle with the challenge of a highly constrained instrument:

> “Comments from the interviews make clear that participants perceived the device as very constrained. Interaction was defined as “limited”, “frustrating” and artistic production was referred as “a challenge”. Performers’ reactions to these limitations consisted of searching and finding novel and “interesting” solutions to play the instrument...Performers apparently explored unconventional techniques both because of and in spite of the perceived constraints.” [91]

While such limited control may seem to run counter to ideas of expressive possibilities, Zappi and McPherson found that when given a *D-Box* with 2 degrees-of-freedom, musicians, “explored fewer playing techniques than the 1 degree-of-freedom group, who discovered a diverse and unusual set of ways to play the instrument. Moreover, the 1 degree-of-freedom group rated the instrument more highly than the 2 degree-of-freedom group.” [91] In essence, the simpler and more constrained instrument prompted higher levels of creative exploration and musical outcomes, suggesting that musicians will push harder to overcome extreme limitations in service of creating interesting music.

Not only did participants in the *D-Box* study display idiosyncratic and surprising engagements with the instrument (from directly touching circuits with their hands to inserting custom-programmed microcontrollers into the signal chain), they also made creative choices that could not have been predicted or designed for. As designed interactions increased, exploration decreased: "The addition of a second degree of freedom had the counterintuitive effect of reducing the exploration of the instrument's affordances...participants with the 2DoF instrument not only tended to engage more with constraints rather than affordances, but specifically focused on a single, dominant constraint, limiting hidden affordance exploration." [91] The "identity" of the *D-Box* was *created*, rather than predetermined, through its idiosyncratic use in the hands of multiple musicians. Through their study the authors present a commentary on the potential for the "limitless" computing power of the black box to become a barrier to creative expression, and draw a parallel to the findings of Gurevich et al.'s 2010 study [85] involving a DMI with only one button:

> "This two-state device (tone or no tone) represents perhaps the simplest possible electronic musical instrument, yet the performers developed a broad array of playing styles. In addition to rhythmic variations, many performers discovered non-obvious playing techniques such as muting the speaker with the hands or tapping on the box. Despite the simplicity, many performers felt that they had not achieved mastery of the instrument during the study period. Reflecting on the diversity of styles, the authors proposed "that the very fact that the instrument was so constrained helped to make space for this personal element to emerge." [91]

4.2.2.2 *Log1k (Owl Project)*

Figure 4.6: Owl Project's *Log1k* interface [87]

Another of many instruments designed by the Owl Project collective, the cleverly-named *Log1k* combines physical engagement with material properties of an interface with digital audio production technology. Fabricated from a section of logs split in half and filled with electronic components, the *Log1K* was, in the words of the creators, "Originally designed and constructed as a complete alternative to using laptops during live audio performances." [87]

Though it embraces some conventions of highly-computational DMIs (the *Log1K* has sampler and sequencer capabilities and is even hinged length-wise to resemble conventional laptops), one user of the instrument describes it as a path to "liberation from complexity and the infinite choices provided by an audio programming language such as SuperCollider." [46] In the documentation for the project one particular statement is even more explicit in regards to the current state of CMPs:

> "The Log1k...contribute to a wider and more pressing critical dialogue which...confronts the centrality of computers in contemporary electronic music, particularly within a performative context. In such performances, the intangible and almost mysterious production of electronic laptop-generated sound is equally matched by the static, minimal and impenetrable presence of the performer. Here the relationship not only between art and audience comes into question, but also that between art and artist, artist and audience." [87]

The (conceptually) simple addition of a physical component (raw wood, in this case) provides a musician and audience with qualities that are lacking in purely digital systems: constraints that prompt exploration, tangibility in an oft-intangible mode of sound production, and a way to actively engage with the material and physical conditions of being an artist in the act of creation.

4.2.3 Risk in Highly Computational DMIs

To this point we have focused on existing investigations into DMIs that involve significant material properties—black box wrappers, if you will. However, CMPs also feature highly digital performance systems, ones that are not wrapped in additional materials but instead leverage the flexibility and power of a computational system as it exists: the blackest of boxes. Broadly speaking, there are two methods of live music production in fully-digital systems: Digital Signal Processing (DSP) and live-coding. DSP can be used as an umbrella term for any music that is created through the digital generation or manipulation of audio signals via the Graphical User Interface (GUI) of a computer system[2]. Live-coding is a practice wherein audio is generated or manipulated through writing and executing lines of code on a computational system. Live-coding, laptop orchestras, and computer music performances are all considered here to be "fully digital" systems: they utilize no external interfacing beyond the laptop itself and are relatively immune to shifting material conditions.

Though it can, of course, be argued that a computer's material components can overheat, or that the material properties of a sound card will affect musical capabilities, these conditions themselves (at least so far as this author is aware) are not readily manipulable—they live within the black box, and are not a part of the performance system itself. One might also argue that a musician can expressively "play" a laptop, with as much gesturing and physicality as any other instrument. Opinions certainly vary in regard to this claim;

[2]DSP is found across many modalities and does not necessarily require a GUI, but for the purposes of this discussion we will focus on software-based DSP interactions

however, it can also be said that a line of code typed with the most dramatic of flourishes will be executed by the computer in exactly the same way as any other.

The case studies presented in this section are not intended to support an argument that laptop music is not expressive. Music created by *any* means can be expressive. What these case studies offer is a way to understand how risk states can be (and have been) built into non-physical systems for musical performance, and *why* such states can be extremely valuable to the performer's sense of self-expression.

4.2.3.1 Gibber (Roberts)

It is a well-acknowledged paradigm in the CMP community: digital systems offer a sense of aural "limitless-ness" that individual physical instruments do not. Because the technology available to us today can replicate the sounds produced by any acoustic instrument with fairly high fidelity (not to mention create sounds which are physically *impossible* with an acoustic instrument), each digital performance system is limited more by *design* than inherent *constraints.* As Magnusson states:

> "Many musicians, determined to fight the fossilization of music into stylistic boxes, often choose to work with programming environments that allow for more extensive experimentation. However, problems here include the practically infinite expressive scope of the environment, sometimes resulting in a creative paralysis or in the frequent symptom of a musician-turned-engineer." [46]

Many computer musicians develop highly personalized performance systems (often on a piece-to-piece basis), while others customize their coding environments to be as generalizable as possible. Even more do a combination of both, depending on the circumstances of performance and practice. Computational tools such as Cycling '74's *Max*[3] or the open-source programming language *Pure Data*[4] can offer a great deal of creative freedom to musicians, as they can be used in ways that are modular, customizable, adaptable, and above all else, *stable*. However, many platforms for live-coding are "shells" of a sort,

[3] www.cycling74.com
[4] www.http://puredata.info

reading code procedurally and constrained by the libraries and resources packaged within the system itself. Because they are, in many cases, static software programs running in live performance situations, the relative “openness” of live-coding environments presents unique challenges to flexibility: computers can generate nearly endless sonic outputs, but are constrained to the coding language being used within the platform.

While there are several risk states that can impact a performance with a live-coding system (emotional, social, or mental, for example), it can seem foreign to imagine physical and material risk states impacting an instrument whose activities depend on the zeroes and ones at the heart of a digital system. That doesn’t mean, though, that physical and material risk are absent. Charles Roberts, assistant professor of computer science at Worcester Polytechnic Institute, recounts his early experiences as a live-coder who purposefully programmed risk elements into his personal coding environment:

> “In my first live-coding performance, I also fetishised what I thought (at the time) were the virtuoso aspects of live coding. I created small animations for source code that would shake it, blur it, confuse it; why not add to the pressures of a live performance with obfuscation and obstruction? While I was intrigued by the idea of increasing the difficulty of a performance practice that already seemed complex, I was also trying to make code, and the act of coding, more exciting for the audience.” [92]

While Roberts’ first performance ultimately ended with a software crash only minutes into the performance, he elucidates both the unique position of risk as an element of computational performance practices as well as the value of maintaining such elements in less physical musical practices. When live-coding without visual animations he says, “I miss viewing the program as a dynamic, changing entity.” [92] Roberts took the concept of material risk and created a digital metaphor—the lines of text that drive the digital system can themselves be subjected to “physical” malformations. While this is inconsequential to the computer itself, it can place the performer in a riskier performance state.

4.2.3.2 Emacs (Wilk)

Live-coder Joseph Wilk describes his use of Emacs (a text editing platform) to create music through code. Wilk utilizes code not only in laptop performance, but also in the control of musical hardware such as synthesizers and external MIDI controllers; he himself draws distinctions between the notions of computational and physical instruments, separated in part by the disembodied and procedural nature of coding:

> "There is a level of indirection between the code and the effect on the music. You push keys on your computer keyboard and nothing happens. Only when you run the code does the music change. I wanted to add realtime control to my performances while still remaining in code and Emacs. Bringing the performance closer to musical instruments were instant feedback is a core part of the performance experience...Doing crazy things with Emacs starts to open more doors in musical expression." [93]

Wilk describes self-designed plug-ins for coding that implement unpredictable and potentially catastrophic performance qualities (though there is a button that enables an immediate return to the original (safe) code state). One plug-in developed for this purpose seeks out characters within code and replaces lowercase letters with uppercase ones, while another "breaks up" the text, causing increasing levels of jitter that eventually results in the end of a performance. In his description of the system, Wilk expresses an almost nihilistic sentiment, stating, "I've used emacs animations to augment emacs with more feedback for the performer and a chance to destroy the order and structure the programmer has spent the entire performance building." [93]

This acknowledgement that physical properties for computational control are valuable, and that material metaphors to make coding more unpredictable and risky has creative potential, are particularly impactful coming from a musician who is experienced in an array of physical and disembodied modes of computational creativity.

4.2.4 Conclusion

What we are able to ascertain, from these case studies, are several salient points:

1. Practitioners in CMPs design instruments and interfaces that run along a spectrum from entirely digital to highly physical
2. In the case of a highly digital system, some musicians purposefully introduce mechanisms for unpredictability and the potential for failure in their musical processes
3. These mechanisms are sometimes metaphors for physical and material risk states that are not natural to highly computational systems

The limitless nature of the laptop can, in fact, be a hindrance—potentially even prevent musical creativity. As Magnusson states, "[Computational] systems like the [mLog, Phalanger, and ixi lang] are so open and flexible as interfaces that it is only when they have been given rigid mapping to sound engines that they gain their function—and indeed identity—as expressive musical systems." [46]

4.3 Defining Expression in CMPs

4.3.1 Virtuosity, Mastery, and Skill

Attempting to understand expression in musical contexts is difficult—partially because "expression" can have different meanings to different people, and partially because there is no hard-and-fast rule regarding what expression is or is not. We use the word "expression" within music to describe facial movements, physical gestures, variations in timing and dynamics, and many other discrete, observable phenomena. We also tie the idea of expression closely to conveyance of emotion (particularly extreme positive and negative emotions), individualistic interpretations of written scores, valence, affect, engagement, enchantment, skill, and more.

Perhaps the most succinct early example of this discourse can be found in Dobrian and Koppelman's 2006 NIME paper titled *The "E" in NIME: Musical Expression with New Computer Interfaces*. The authors acknowledge attempts to understand expression through quantifiable units (Pöepel's classification system of coded and decoded cues, for example [94]), transparency (Fels et al.'s proposal of expressivity as a result of transparency of mapping for audience and performer, for example [95]), and control. [96] Ultimately, Dobrian and Koppelman propose that, "Sophisticated musical expression requires not only a good control interface but also virtuosic mastery of the instrument it controls."

There is nothing inherently wrong with such a definition of expression; however, Dobrian and Koppelman go on to make two related, highly problematic statements. They first state that, "Virtuosity facilitates expression"—a statement that is difficult to argue against. It is particularly convincing if you consider their definition of musical expression, which features the word "virtuosic" in the characterization itself. Certainly, any musician who has achieved mastery with an instrument is very likely to experience some sense of expressivity, if for no other reason than nearly all virtuosos have been playing music for several decades and therefore have the sheer number of hours invested in their practice to secure expressive states more predictably. However, the authors go on to also claim that a "lack of virtuosity inhibits expression." This claim is highly exclusionary and highlights the privilege embedded in their very definition of expression.

Virtuosity neither bypasses higher levels of risk, nor should we discount the activities of non-virtuosic musicians. At any skill level musicians must match their skills to appropriate challenges within the activity they are engaged in, and as Newland has pointed out it is this evolving dynamic that produces "enrapturing" live performances. In fact, it would be fair to propose that unpredictability becomes *more* important with higher levels of skill and mastery. Novice musicians experience almost impossibly high levels of unpredictability and failure as they work to learn their instrument, but those elements decrease as skill and mastery rise. There is a need to continually raise these stakes in order to maintain and promote new modes of creativity and expression for the practicing musician.

4.3.2 Exploration, Experimentation, Evolution

Dobrian and Koppelman reflect an opinion regarding expression that severs the concept from risk, disfluency, exploration, experimentation, and many other compelling elements of creative performance from the experience of expression. For them, anything less than a well-rehearsed performance by a virtuosic musician falls short of the pinnacle of expression:

> "There is nothing wrong with this experimentation. Indeed, it is vital to the progress of this field. And in fact there is nothing so very wrong with putting this experimentation onstage in a less-than-refined form at demonstrations, workshops, and conferences. But it would be a mistake to pretend that such an onstage experiment is a good representation of the expressive capability of that instrument, or that it can—except in a few fortunate instances—be legitimately compared to a high-caliber professional virtuosic music performance." [96]

This is an extremely narrow view of what expression means to practicing musicians in experimental fields and makes no attempt to obscure the opinion that the way to create more expressive experimental performances is to model new instruments on traditional ones. In fact, they unapologetically suggest that the most efficient way to make more expressive instruments is to simply attach sensors to instruments which are already being played virtuosically by experienced musicians.

It is important to be cognizant of the unique cultural context of CMPs and how the definition of "virtuosity" differs from more traditional musical practices. Historically, musicians have dedicated themselves to the mastery of one instrument over the course of their careers, as evidenced by the eponymous titles with which they identify: violin-ist, pian-ist, basson-ist. Of course, it is not uncommon for a skilled practicing musician to play multiple instruments; the question of, "What do you do?" is in most cases actually a question of, "What is the instrument at the center of your discipline, with which you identify yourself most strongly?" In other words, "What instrument are you best at?" An answer such as, "I play lots of instruments" is met with skepticism at best and annoyance at worst, and experienced musicians generally learn to embrace simplicity over specificity. Computer music practitioners, however, are often afforded a deceptively limited "computer music" or "laptop" for their reply, as attempting to list specific DSP techniques or instrument building methodologies is no easy task. Because it is very much an exploratory practice the tools and technologies of the CMP practitioner often develop and shift over time, even over the course of a single work. As Morreale et al. state, "[NIMEs] are constantly in development and almost in no occasions in a finite state." [22] As for what "virtuosity" means in such a context, they find that, "[This] particular performance practice results in learning trajectories that often do not lead to the development of virtuosity as it is commonly understood in traditional performance." [22] In fact, in their study regarding performer perspectives on their practice they found that, "8 performers believed that virtuosity does not apply to their practice: "It is not clear to me what virtuosity would look like with this instrument" (Tom Mudd). Four respondents simply do not value the development of virtuoso performance in their practice: "It is not the goal of practice with this instrument. To think about virtuosity would be to miss the point of what the instrument has to offer" (Moore)." [22]

Longevity (a crucial component of virtuosity in traditional musical practices) and mastery are not necessarily—or even often—a goal with DMIs in CMPs. Exploration, iteration, and novelty, however, are. Understanding expression through "virtuosity" (at least as Dobrian and Koppelman imagine it), therefore, is in some ways incompatible with the discipline. The research published in the NIME and ICMC communities has (perhaps unintentionally) produced implied standards regarding what "good" DMIs look like, and this has in turn shaped the ways in which we evaluate the instruments themselves. Attempting to understand expression through virtuosity, usability, or the accurate execution of tasks deemed "musical" results in a narrow band of aesthetically-acceptable practices that prioritize the product of a performance rather than the creative process.

Expression needs not be so narrowly defined as a path toward traditional concepts of virtuosity. Gurevich and Treviño point to some of the issues that result from attempting to do so in their 2007 paper *Expression and Its Discontents: Toward an Ecology of Musical Creation*. The authors make explicit mention of the problematic correlations between expression and other qualities found in the dominant models proposed by researchers. This includes mapping ("In proceeding directly to the means of expression, this kind of argument conflates an ambiguously defined expressive content with the means by which it is expressed"), transparency ("The current dominant discourse assumes that increased medium transparency is synonymous with the "improvement" of an interface's musical capabilities"), and coding/decoding ("Implicit in the described model is the ability of the listener to subtract the "score" from the "perceived sounds" in order to arrive at the expressive difference, and that this difference between text and performance is audible"). [97] Gurevich and Treviño deftly point to experimentation and improvisation—practices in which the performer may have no interest in a predetermined emotional objective or intention to convey one particular thing or another to any/all members of an audience—as legitimate cases of expressive musical experiences. Thus, "Contemporary aesthetic possibilities demand a model that addresses musical creation without necessary recourse to a discourse that assumes a determinate expressive content." [97]

Although this thesis does not equate skill to expression, it is worthwhile to consider the distinct differences between what "skill" means in physical and computational contexts. Speaking to the distinct registers to which musical knowledge can be applied, Magnusson states (of digital systems) that:

> "The primary skills demonstrated are not at a level that is directly musical or "instrumental." Rather, we find an expertise involving the knowledge of electronics, computer science, artificial intelligence, and digital audio synthesis. The primary virtuosity is not at the level of the instrument itself or in the relationship between the agent and the object, but rather below the instrument at the strata of hardware and code...Virtuosity of new musical instruments is therefore not to be found at the level of the interface itself where the performer's body interacts with perceived affordances of the physical interface, but at the level of code or hardware of various strata, where the structure of the search space is defined and limitations are set." [46]

The skills that are developed and employed in expressive musical acts are distinctly different in practices involving traditional and digital processes. This is not to say that there is a definitive line clearly cut between acoustic and computational musical practices, as both place the musician in a process of creative expression with musical ends. It merely suggests that what we understand as "skill" and "virtuosity" in one practice can not necessarily be applied to another, and the metrics we use to better understand these processes must account for such differences.

4.3.3 Conclusion

This thesis takes an alternative approach to understanding expressivity, one which is more aligned with Gurevich and Treviño's view of musical creation as an "ecological formulation." Rather than consider the roles of practitioners within CMPs as free-standing and distinct agents (composer versus performer versus listener, etc.) they are recognized and considered as a part of an interconnected network influenced by both internal agency and external influence. As they state, practitioners in CMPs are "part of a system that includes external factors such as genre, historical reception, sonic context and performance scenario. Any number of configurations may exist, each with its own unique makeup of forces and particular ecological balance." [97]

This work does not, then, attempt to understand expression through gesture, emotion, or virtuosity, as Dobrian and Koppelman do. It instead accepts that expression is a *state of being* which emerges for a performer through various facets of the performative experience: the instrument being used, the context of the performance, the venue, the audience's response, the mindset of the performer, and so on. As Gurevich and Treviño suggest, "Expression does not inhere in any specific medium or stage in a chain through which it is passed. The content of music is therefore no longer limited to the text and the expression; rather it becomes a fluid and dynamic outgrowth of the ecology of a given performance. Expression is an optional modality or intention of creation." [97]

Expression here is a variable, reflexive state that can manifest as gesture, emotion, and virtuosity, but can also range from highly visible to completely unascertainable to observers. One does not have to be intimately familiar with an instrument to experience an expressive state, nor is virtuosity a prerequisite for such an experience. In fact, this research aims to provide support for the notion that higher risk states can foster increased perceptions of expression for the performer through the nature of experimentation, unpredictability, and the potential for failure.

With all of this in mind it is reasonable to conclude that caution must be exercised when developing a definition for expression. It would be irresponsible to suggest that expression is one identifiable thing, or that it can be objectively measured. However, it is possible to offer a clarity regarding what expression is considered to be *in this work*, which is done by way of flexible conceptual boundaries. For the purposes of this work, expression is:

1. A *state of being*,
2. experienced by a *human agent*,
3. who is *intentionally engaging* in a *creative musical activity*

The flexibility of these boundaries, though necessary, present some issues of their own. Terms such as "experience" or "intention" are tricky in their own right. Further clarification is provided for reference here; however, it should be noted that the above, simplified terminology will be referenced in subsequent chapters. For the purposes of clarity, each component used to define expression is expanded as follows:

1. A *state of being*: Emotional, mental, and bodily conditions that combine to form a sense of existing-in-time.
2. Experienced by a *human agent*: A conscious human being with an awareness of self and full autonomy.
3. Who is *intentionally engaging*: Making a conscious decision to act, in order to serve a purpose (of any kind).
4. In a *creative musical activity*: Producing sonic material (aural, visual, written, etc.) as a result of an individual's actions (or series of actions).

4.4 Moving Forward: The Value of Risk and Expressivity in CMPs

This research recognizes the multitude of categories of risk: bodily, emotional, communicative, material, social, spiritual, and many more. To consider each of these components would be impossible; this work will focus on what I believe to be most relevant to current issues in experimental musical practices: physical and material risk.

There are endless points of entry into understanding and querying risk and expressivity in performance; however, these two categories are particularly salient when querying the unique position we find ourselves in as computer musicians. Returning to the previously identified qualities of computationally creative practices (that it is procedural, participatory, and encyclopedic), the most relevant areas of inquiry emerge through the shift in physical and material relationships between the musician and their mode of expression. Therefore, the studies designed for this work take a narrow line of inquiry into how engaging with physical and material risk states may play into the levels of expressivity experienced by improvisational musicians. The participants within these studies are active practitioners in the computer music community who engage at varying levels with the conceptualization, construction, and use of novel musical instruments.

If we accept that:

1. Risk is a quality that involves unpredictability and the potential for failure, AND that
2. Risk is an inherent quality of live (and particularly live *improvisational*) performance, AND that
3. Risk is valuable in its potential to create situations that prompt idiosyncratic problem-solving and interaction on the part of a performer, THEN
4. Higher risk-states may increase the level of expressivity experienced by a performer

If we further accept that:

1. Computational technology has the potential effect of distancing the performer's body from the instrument being used, AND that
2. Physical and material risk depend on such a connection, THEN
3. Introducing unpredictable physical and material elements into the practice of computer musicians MAY increase the level of expressivity experienced by a performer

We have seen many case studies of practitioners in CMPs in this chapter who, for all their differences in approach, strive toward the same goal: creative musical expression. Whether their instrument is dependent on material properties or is entirely coded, the value of physical and material risk states are apparent. In Chapter 5 we will take a closer look at how systems such as these have been evaluated within the community and discuss the benefits and shortcomings of multiple methodological approaches.

CHAPTER 5
EVALUATION IN CMPS

5.1 Problems within Existing Approaches

Much of the recent research into expressivity and music has taken to more empirical methods of understanding, harnessing qualitative tools to measure different components of the musical experience. These tools include biophysical evaluation apparatuses (Galvanic Skin Response (GSR) [98], EKG [99], EEG [100], electromyogram (EMG) [44][101], heart rate [102], eye tracking [103][104], gesture recognition, and more). Perhaps unsurprisingly, much of the work in the past two decades has explored activities in more experimental musical practices (particularly those in the NIME and ICMC communities) that merge technology and creativity through the creation and use of musical design objects. It is imperative to acknowledge the appropriateness of such work, but also identify the ways in which it falls short to better understand how the situation might be improved.

5.1.1 Musicians are not Users, and Instruments are not Devices

Because the NIME community has its roots in HCI (and in fact existed first as a workshop at the 2001 ACM Conference on Human Factors in Computing Systems (CHI)) much of the research into evaluating musical systems draws inspiration from HCI research. In her 2001 paper, *A Framework for the Evaluation of Digital Musical Instruments*, Sile O'Modhrain provides us with an excellent review of existing methodologies for evaluation and provides a way to better understand the "competing interests [of] performers, designers, and manufacturers" that influence different ways of understanding a complex and nuanced practice. [105] She begins by illuminating what "evaluation" means to different groups of people: "For most performers, performance on an instrument becomes a means of evaluating how well it functions in the context of live music making, and their measure of success is the response of the audience to their performance.” [105] Performers might be focused on the capabilities of an instrument to convey their intent, while for the designer it might be more important to evaluate the response of the instrument to physical actuation and measure the reliability of use. A manufacturer might have a very different set of priorities involving costs of production, marketability, and branding, and an audience might be more concerned with observable gestures and movements which can convey skill and mastery. Because musical performance—that which involves DMIs, especially—has so many stakeholders (composers, designers, audience, performers, etc.), one may not necessarily be successful in applying “evaluation” techniques as we know them in HCI to musical experiences.

	Possible Evaluation Goals			
Stakeholder	*Enjoyment*	*Playability*	*Robustness*	*Achievement of Design Specifications*
Audience	critique, reflection, questionnaires, observational studies	experiments concerning mental models		
Performer/ Composer	reflective practice, development of repertoire, long-term engagement (longitudinal study?)	quantitative methods for evaluation of user interface, mapping, etc.	quantitative methods for hardware/ software testing	
Designer	observation, questionnaire, Informal feedback	quantitative methods for user interface evaluation		use cases, feedback regarding stakeholder satisfaction
Manufacturer	market surveys, sales	sales, consumer feedback	quantitative methods for hardware/ software testing, consumer feedback	market penetration (performers, consumers), sales, consumer feedback

Figure 5.1: O’Modhrain’s “Stakeholder” Approaches to Evaluation [105]

One of the most influential contributions to the topic of evaluating instruments comes from Nocola Orio and Marcelo Wanderley in their 2002 paper *Evaluation of Input Devices for Musical Expression: Borrowing Tools from HCI*. Their proposed method of evaluation has been adopted by many researchers due to its clear framework and applicability to DMIs, which, unlike traditional acoustic instruments, are often not easily analyzed by mechanical structure or physical actuation. They propose that new musical devices can/should be evaluated in terms of performance with a set of “representative, and simple, tasks” on the note-, score-, and sound processing-level of control. They base much of their methodology on tasks considered to be "common user action[s] in HCI," drawn from HCI pioneer Bill Buxton: "*pursuit tracking*, *target acquisition*, *freehand inking*, *tracing and digitizing*, *constrained linear motion*, and *constrained circular motion*." [39]

While useful in efficiently evaluating instruments and performer outcomes based on smaller isolated tasks, this approach may not be as well-suited to understanding and evaluating the perceptions of a performer. The methodology is appropriate for evaluating interfaces and controllers, which can be very task-oriented in actuation and use, but less appropriate for musical instruments and the evaluation of expressive activities, which are not as clear-cut as "musical tasks." O'Modhrain aptly identifies the strengths and weaknesses of Orio and Wanderley's framework:

> "Although other approaches to evaluating DMIs at the task level exist, that of Wanderley and Orio has gained a firm foothold within the DMI design community. It is important to remember, however, that this framework is intended to evaluate the usability of DMIs...Performers are the only people who can provide feedback on an instrument's functioning in the context for which it was ultimately intended, that of live music making." [105]

In their 2015 paper *HCI Models for Digital Music Instruments: Methodologies for Rigorous Testing of Digital Music Instruments*, Young and Murphy present an review of existing methodologies and draw upon O'Modhrain's "stakeholders" differentiation framework to propose an "optimized" evaluation technique for DMIs. The authors position themselves as evaluators of users using devices, arguing that because "DMIs are often evaluated idiosyncratically...established evaluation methods from other areas are somewhat ignored." [106] The framework proposed for DMI evaluation is concerned with functionality, usability, and the musician's overall "user experience."

Possible Evaluation Goals				
Stakeholder	Enjoyment	Playability	Robustness	Achievement of Design Specifications
Performer / Composer	Reflective practice, development of repertoire, long-term engagement (longitudinal study)	Quantitative methods for evaluation of user interface, mapping, etc.	Quantitative methods for hardware / software testing	
Designer	Observation, questionnaire, informal feedback	Quantitative methods for user interface evaluation		Use cases, feedback regarding stakeholder satisfaction

Figure 5.2: Characteristics of O'Modhrain's "Stakeholders" [106]

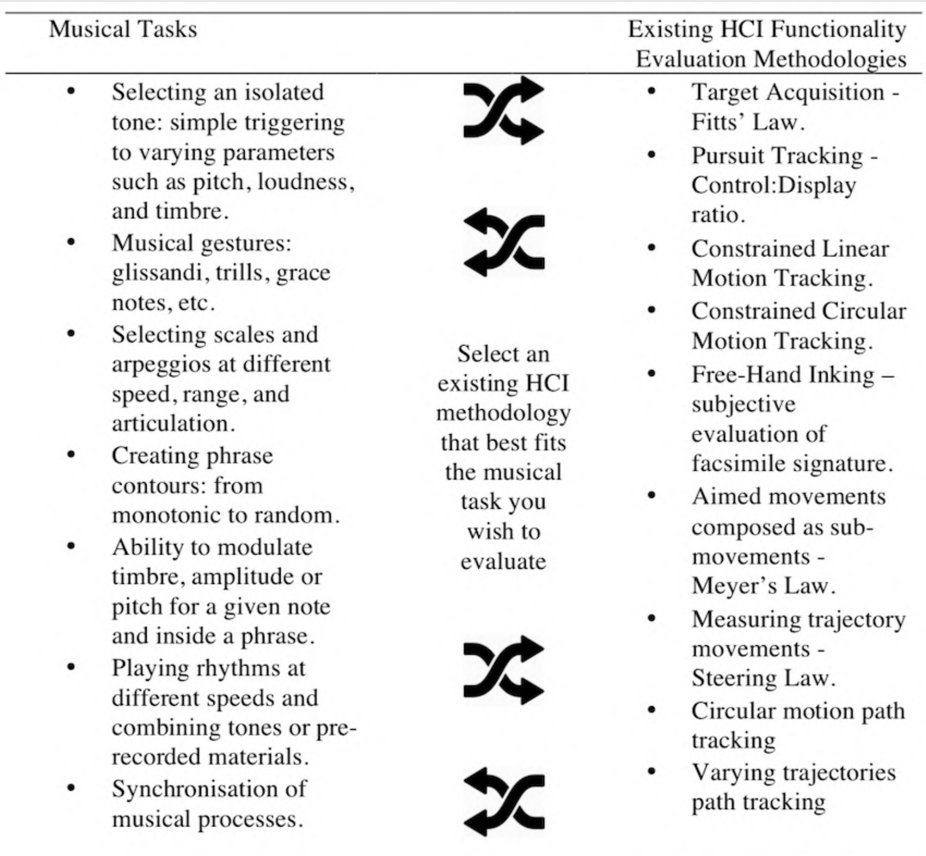


Figure 5.3: Musical tasks evaluated via HCI methodologies [106]

As stated by the authors, HCI can offer tools that "direct interface designers away from generic, single purpose, interface-testing methods." [106] Unfortunately, as noted by Morreale and McPherson, DMIs are often purposefully idiosyncratic, highly personalized, and limited in their long-term use. [107] The authors also argue that when evaluating DMIs the "prototypes need to be functional, where gestures can be captured with precision, and in turn, they need to be responsive in sound generation without any noticeable latency." While this may be a fair requirement for HCI-style user testing, the disciplines of design, performance, and other creative fields provide clear examples of studies in which non-functional, representational, and adversarial artifacts serve as rich loci for understanding user experiences, prompting new design directions and better understandings of cultural and contextual underpinnings within groups of practitioners. A discussion of design practices is beyond the scope of this paper, but *speculative* [108], *adversarial* [109], and *fictional* [110] design techniques are good points of entry.

Ultimately, Young and Murphy argue that, "Functionality, usability, and user experience are evaluated in HCI studies in order to create a comprehensive representation of a device in use." It can be argued, however, that while a device may indeed be adequately evaluated by its measures of functionality, usability, and user experience, those metrics may in fact fall short in evaluating musical instruments (which are not simply devices) and the experiences of musicians (who are not simply users). As stated by the authors themselves, "The appraisal of standard Usability Evaluation Methods (UEMs), such as time-on-task and number-of-errors for instance, cannot be used alone to assess a user's experience," and it is worth considering that although musical instruments can be evaluated by their functionality and usability, these are only two elements of a much larger, more complex system. Though Young and Murphy may have successfully distilled musical instruments to devices in order to target elements of functionality and usability, this methodology is not well-suited to research into the elements of expressivity central to performance paradigms.

5.1.2 Metrics for Understanding the Performer's Experience

Approaches to understanding the qualities of a musical instrument from the perspective of the musician have been undertaken, with some driven by the desire to, "Combine the valuable research outcomes from the computer sciences community and the musician's perspective at a semantic level." [111] In their paper *The Thummer Mapping Project (ThuMP)* Paine et al. used semi-structured interviews with experienced musicians to identify, quantify, and categorize control gestures used by practicing musicians. Their analysis of the text gathered in these interviews (utilizing the Leximancer software system) produced "tone, (tone colour, sound colour (resonance), tone quality), dynamics, volume, expression, duration, vibrato, articulation, attack, release, sustain, pitch and intonation" as categories of control for evaluation. However, the authors note that these categories were so predictable that they seeded doubt among the researchers as to whether or not the held knowledge of the analyst (who happened to be an experienced musician) unduly influenced the results. A second round of analysis was undertaken by an individual skilled in qualitative data analysis (but who had little musical knowledge) using a different software system (NVivo). The results from this second round were slightly different: dynamics, pitch, vibrato, articulation, release, and attack were drawn from the data as control categories.

Participants in the Thummer study were tasked with repeating a "target sound" after experiencing a demonstration of the instrument by an experienced player and completing several assigned exercises. This approach assures a more dependable measure of "successful" playing, but it is based on preconceived notions of success as defined by the researchers themselves, as well as an assumption that the varied backgrounds, training, and experiences of varied musicians do not meaningfully impact the data collected. Further problematizing this notion is the proposition by the authors that experimentation and extended technique (lumped together in the paper under the term "variability") was likely only present due to the "limited training period" the musicians experienced, and would reasonably be less observable in the case of "continued practice." This suggestion is problematic for several reasons:

1. It asserts that variability is undesirable
2. It reaffirms the fact that "success" on a particular instrument is a matter of quantitative metrics that prioritize reproducibility and predictability over surprising and/or unpredictable measures taken by the musician
3. It discounts the fact that extended techniques and experimentation are critical elements of practice not only in early stages of learning, but in later stages of mastery.

Ultimately, Paine et al. contribute discrete control parameters which are embedded historically in "successful" acoustic instruments and that can be extrapolated as design affordances for NIMEs and DMIs, but their measure of success is firmly rooted in "playability" as a set of tasks which can be accurately executed by a player. Because DMIs exist on a spectrum from highly physical to hybrid to disembodied it is possible to carry out user-focused evaluation methods in certain conditions—particularly those in which musical interactions are carried out through button presses or mouse clicks. However, as control parameters become more complex (those involving material properties, such as Bin's *Keppi* or Owl Project's *SoundLathe*, for example), so too must methodologies evolve to account for nuance and idiosyncratic playing styles.

The studies designed for the work presented in this dissertation do not accept or impose musical goals onto players, nor do they assume that certain paths to musical creativity ("tasks") are better or worse than others. What is of interest is an understanding of each participant's experience, regardless of musical output or process.

5.1.3 Expression: Musical, Emotional, Perceptual

Formal evaluations of creative practices are notoriously difficult, but increasingly important in discussions of the integration of new technology into traditional creative practices. It is important to recognize the difference between instrument/interface-facing studies and user-facing studies, which often approach similar topics with different objectives. The

NIME community has a rich history of evaluation of expressivity, much of which attempts to understand the propensity for expression in terms of design affordances and constraints. Jordà and Mealla's 2014 paper *A Methodological Framework for Teaching, Evaluating, and Informing NIME Design with a Focus on Expressiveness and Mapping*, for example, evaluates system and performance expressiveness through 5-point Likert scales regarding *mapping richness* and *synthesis richness*, and evaluates performance expressiveness through scales measuring *musicality*, *expressiveness*, and *virtuosity*. Their evaluation framework was applied in a classroom setting, with a focus on highly restrictive design processes and teaching students to prototype and self-reflect on NIME design. While their results offer important insights into DMI design and the relationship between mapping and expressivity, the outcomes are mostly relevant to the evaluation of DMIs as performance objects rather than how different design decisions effect impact the experience of the performer themself.

As stated previously, HCI offers many entry points into understanding, designing for, and evaluating empirical and quantitative criteria such as task accuracy, device usability, and reproducibility, but is not as well-suited for qualitative measures of user experience and expressivity. These qualities, though, are not unstudied in the NIME community. In their 2005 paper, *On Interface Expressivity: A Player-Based Study*, Professor of Media Cornelius Pöepel attempts to evaluate musical expression through the experiences of musicians who are charged with "making use of their existing technique for the creation of expressive music." In order to evaluate musical expression quantitatively Pöepel turns to the domain of music psychology to draw out certain criteria "known to be relevant" to the construction and transmission of cues that he argues enables the performer to "code" emotional expression and that the audience can "decode" into representations of emotional expression. These cues are: "tempo, sound level, timing, intonation, articulation, timbre, vibrato, tone attacks, tone decays and pauses." [94]

While these may be quantitative elements of a performance which can lend their qualities to musical expression and that may also indicate emotional expression through music, there is a clear one-sidedness to the research: what the audience experiences and what the musician experiences may be vastly different. As Gurevich and Treviño note, "A consequence of this model is a search for standardized encodings of expressive or emotional artifacts within music," [97] which is a problematic assertion. One can not create a definitive list of what emotion and expression look like, and there is no reason to believe that music can be evaluated quantitatively for such metrics. Furthermore, as Stowell et al. point out:

> "Poepel operationalises "expressivity" into a number of categories for stringed-instrument playing, and investigates these numerically using tasks followed by Likert-scale questionnaires. This limits users' responses to predefined categories, although a well-designed questionnaire can yield useful results. Unfortunately Poepel analyses the data using mean and ANOVA, which are inappropriate for Likert-scale (ordinal) data. The questionnaire approach also largely reduces "expressivity" down to "precision" since in this case, the tasks presented concern the reproduction of musical units such as vibrato and dynamical changes." [112]

As Pöepel himself admits, he makes the assumption that, "Playing technique is used to create expressive cues with the aim of coding expressive intention into sound." We see, here, an attempt at evaluating highly physical DMIs (all three instruments in the study are augmented acoustic string instruments) through psychometric measures of the participants' experiences with the different instruments within the study. The data gathered is constrained to comparisons of the specific instruments of the study, and subsequently provides an ordered ranking of usability among the devices. This is certainly valuable information to gather and assess; however, this framework is not able to contribute very much in terms of how participants perceive their own experiences of creative expression.

The research presented in this dissertation is not interested in understanding existing techniques as modes for expression, nor is it directed toward the audience's perception of a musician's performance. There is a good deal of existing research into audience perception of CMP performances (see [113][114][115]), but sparsity regarding how performers themselves engage with risk in performance with DMIs. It also bears mentioning that some performers—in all varieties of practice—simply have no regard for the opinions or experiences of the audience; in fact, many practitioners express active disdain for such concerns. With the acknowledgement that audience evaluations are a fertile and valuable research track, this work strives to understand whether or not higher risk states—with any kind of instrument, traditional or novel—present wider-ranging or deeper opportunities for creative problem-solving and expression on the part of the performer.

5.1.4 Conclusion

The evaluation methods for different performance metrics are drawn from a wide array of disciplines because the communities that are designing, building, and performing is itself diverse. Interaction design and HCI seem particularly appealing to individuals in these communities; such methodologies provide insights that are useful for understanding how design affordances and constraints impact musicians' use of instruments [116], mapping techniques for expressive and gestural performances [117], task-based reproducibility [39], speed, accuracy, and precision [94], usability and functionality [106][118], and perceptions of the performer and audience [119]. However, many of the more nuanced experiential aspects of performance—particularly from the perspective of the performer—remain under-examined.

Oreggia and White clarify poignant differences between science-based disciplines and creative practices:

> "The decisive difference is the attitude towards reproducibility: in science, reproducibility is sought after, whereas, in contrast, variation (either deliberately produced or arising out of random, uncontrollable processes) is an essential part of the creative process." [35]

They make clear that unpredictability, variability, and the unknown can be desirable elements of a creative process. Where many existing evaluations of expression and creativity with DMIs fall short is in an appreciation of the messiness that comes with the territory: the tools being used may lend themselves to evaluations of reproducible or generalizable metrics, but the *how* and *why* of expression as perceived by a performer are not so easily categorized.

5.2 Alternative Evaluations of Musicians and Musical Instruments

5.2.1 Evaluating a Unique Practice

The discourses that emerge from the work referenced above depend primarily on empirical understandings of metrics that are not necessarily representative of the full creative musical experience. As such, there is also work being done which consciously provides a counter-view to these HCI methodologies, pointing out not only the shortcomings of applying strict empirical methodologies within creative/artistic contexts but also making the case for research which is more akin to "thick descriptions" [120] —qualities that perhaps require more phenomenological, subjective methodologies. Stowell, Plumbley, and Bryan-Kinns, for example, conducted a study which applied discourse analysis to the language used by practicing musicians, allowing them to, "Take apart the language used in discourses (e.g. interviews, written works) and elucidate the connections and implications contained within." [112] In an effort to move beyond HCI's tendency to conduct formal evaluations in "short exploratory sessions," Steven Gelineck and Stefania Serafin purposefully carried out a longitudinal study which spanned four weeks—a timescale rarely found in NIME and ICMC. As they explain, "short evaluation sessions (1–2 h long) can definitely be very powerful in understanding many aspects of a new musical tool, but there are issues that longitudinal approaches are better at uncovering...[and] understanding the experience of using the instrument is essential. This is difficult to do using task-based methods." [121]

The quantitative and qualitative research being done in the NIME and ICMC fields seems only minimally concerned with performative edge cases that function in a less predictable, more risk-prone space. The term "edge case" refers to work that does not design out the flaws of an instrument, but rather embraces them. O'Modhrain points to an issue of sterilization that occurs when research purges less clean-cut activities and performance states from studies; she states that performers, “Can adapt to properties of instruments that are non-ideal–the sticky pedal on a piano, for example–so that an impartial assessment of an instrument’s playability is also desirable if a solid design is to be assured.” [105]. Evaluation is no easy task, even with the most straightforward objective. Attempting to understand something as complex as expressivity in a community as varied as CMPs is made even more difficult by the extreme diversity of instrumentation and personal practice; therefore, it is natural that the most extreme cases will present the greatest evaluative challenges.

This work is interested not in creating foolproof safety nets, fully debugged systems, or securing a state of completely reliable reproducibility. What it *is* interested in is recognizing and including fringe activities that actively embrace the potential for failure and the unknown. It is not entirely surprising that researchers are perhaps hesitant to engage with work that is opposed in some ways to “desirable” test conditions—how do you produce generalizable findings for practices that don’t strive toward reproducibility? How should one design a study around the unpredictable?

5.2.2 Evaluating Unique Instruments

Because DMIs are extremely varied and highly personalized they can function at varying levels of transparency and accessibility. One of the guiding philosophies behind evaluations of musicians using DMIs seems to be that of “low floors, high ceilings, and wide walls.” In essence, the most successful interfaces and instruments for musical expression are easy to get started with, offer rich possibilities for long-term development of skill and virtuosity, and offer a diverse range of interactions. This philosophy was first proposed by Seymour Papert [122] and has been taken up by many researchers in computational creativity, particularly those activities which involve coding languages as a creative tool [123][124][125][126]. The value of such architectural descriptors is clear when designing for learning objectives, particularly among children. Initially proposed in response to the "mathphobia" prevalent in so many young learners, low floors allow for approachability, while high ceilings and wide walls increase opportunities for learning and self-expression.

Highly computational DMIs are not so far away from educational coding; both disciplines use textual code to engage with digital systems in productive and creative ways, and so it makes sense that the design principles will align naturally. However, it is not always the case that musicians wish to experience low barriers to entry, or diversity of clear affordances, or even long-term interactions. Further, the risk states that have so far been argued as valuable conditions for provoking expressivity are largely incompatible with such values. As we've seen in the work of Roberts and Wilk, even when using the blackest of boxes there is room for unpredictability and chaos.

It is also worth mentioning that "low floors" play out much more successfully in an educational context wherein the objective of an activity is often simply to exit an experience with more knowledge than you entered with. Musical performances (particularly improvisatory ones) often hinge on the ability of the musician to channel their skills and creativity through an instrument or interface as a process. Even if the musician enters the experience with no knowledge of the specifics of an instrument at all, the skills they have developed over the course of their career will enable them to engage in a musical process. In Chapter 9 we will see this situation play out in a study deployed to musicians from a multitude of backgrounds (even some with a minimal amount of instrumental training) who all approach the same unknown instrument to craft an improvisatory musical performance on the spot.

Because DMIs exist across highly physical, hybrid, and highly computational instruments they can not be considered as tract housing, each with the same blueprint as the next. Further, notions of approachability and complexity are not as clearly defined in creative endeavors as they might be in educational ones. The presumption that a low barrier to entry and high degree of interaction potential are indications of all "good" DMIs must be set aside in favor of a more comprehensive understanding of individual experiences.

5.2.3 Appropriate Methodologies for Evaluating Experiences

Having identified several ways in which existing evaluation techniques are not appropriate to the study of a performer's phenomenological experience, it is important to also reference existing work that approaches this task with more relevant outcomes. In contrast to the work outlined above, the work referenced in the following section will exemplify musician-centered research that provides data that, though less clean and quantifiable, more accurately represents the lived experiences of performers in CMPs.

5.2.3.1 Identities from the Performer's Perspective

As well as identifying the shifting definition of "virtuosity" in digital musical practices, Morreale, McPherson, and Wanderley endeavor to evaluate the "performer's perspective" in their 2018 paper *NIME Identity from the Performer's Perspective*. [22] They conducted an online survey targeted toward the NIME community—in particular, 171 musicians who had performed at the conference in the five years preceding their publication (though a second questionnaire was additionally sent to 45 performers who had not performed during that particular time frame), with a total of 128 respondents. The primary objective of the authors was to engage with questions of the "identities" perceived by performers and what (if any) common characteristics might be present among practitioners in the field. Respondents were prompted with both open-ended and closed questions regarding their experiences, and thematic analysis was applied to the resulting dataset. This methodology allowed the authors to empower the respondents to speak to their own experiences and reflect on themes which emerged from the data.

The value of this qualitative methodology is clear in the authors' first comment on their findings: "By definition, *newness* should have been a logical and obvious factor in the experiences of the practitioners (the "N" in NIME representing "novelty," after all)...Surprisingly, more than half of respondents reported the use of instruments over 5 years old, prompting the conclusion that we may need to reconsider how the community defines "new."" [22] The term "instrument," as it is commonly considered in the NIME community, also came under scrutiny: "The Roli Seaboard was mentioned by 3 performers when asked to list the NIMEs they play but it also appeared in the list of the traditional instruments that one respondent plays, indicating lack of agreement among performers when labelling a musical instrument as a 'NIME'."

Their study also reaffirmed the notion that practitioners in CMPs are, indeed, difficult to categorize in their identities, evoking O'Modhrain's concept of "varied stakeholders." Beyond being performers nearly all of the respondents reported involvement in the instrument-making process, and many considered themselves composers and artists in addition to musicians and performers. The authors conclude that the data provides "evidence to the relative diversity among performers, confirming the feeling that a NIME performer is also somebody that strives to elude definitions and categorisations." In fact, Jordá has coined the term "digital luthier" to address the ubiquity of designer-cum-performer model of NIME practitioners. [127]

One of the elements that make CMPs so unique is this multiplicity of roles and self-identification, which additionally contributes to the conceptual shift in what we can consider "virtuosity" within the practice. Mastery and skill play out not only in the product of a performance but in the iterative design process, compositional techniques used, and technological innovation. As Morreale, McPherson, and Wanderley put it, "The tension in the combined performer-designer role has implications for NIME virtuosity. When the performer is also the designer, virtuosity is not only a matter of extended practice but also of instrument redesign." [22] The authors also found that, "Most performers are confident considering themselves virtuosi with the instrument" when analyzing respondents' thoughts on their own mastery of their instruments, and yet contradictions are also present: "When asked to indicate the number of musicians that can be considered virtuoso with the instrument, 76% (N=60) answered that no virtuosi exist (so far)."

Morreale et al. come to surprising and insightful conclusions in their study of practitioners, in part due to their methodological approach. Enabling participants to use their own language and share their experiences in depth and detail provoked themes that may have been difficult to design a study around, and that are not well-suited to empirical, quantitative methods of evaluation.

5.2.3.2 Understanding the Present, Imagining Futures

In their 2012 paper *A Survey and Thematic Analysis Approach as Input to the Design of Mobile Music GUIs* Tanaka et al. report on findings gathered from an online survey deployed to the NIME community (with 177 respondents). For data gathering the authors utilized user centered design (UCD) methodologies from within HCI practices, which are purposefully geared toward more ethnographic, qualitative methods of understanding user experiences. The dataset was then analyzed using thematic analysis, which, due to its flexibility and appropriateness to exploratory avenues of engagement and inquiry, proved useful in "eliciting a potential narrative that was not prescribed by the design of the survey questions." [128]

These methodologies were particularly useful in understanding user experience in a situation that, again, demonstrates the diversity of practitioners in CMPs and their wide-ranging (and often divergent) experiences with technologies. The responses from participants were not considered to be answers to a particular set of problems but rather a collection of experiential descriptors that "[allow] researchers to identify emergent topics not explicitly stated in survey questions." [128] Because participants were able to answer open-ended textual prompts and questions with their own words, the methodology "gave more room to respondents to refer to their personal experience...thematic analysis was intended to identify emerging themes and enable us to understand respondents concerns, in particular those that we hadn't predicted or prompted by our own questions." [128]

5.2.3.3 Beyond Evaluation

In his 2011 paper *Beyond Evaluation: Linking Practice and Theory in New Musical Interface Design* Andrew Johnston acknowledges the disconnect between evaluation methods and the production of valuable theory in practice-based research (as many consider CMPs to be engaged in), and the gaps in knowledge that exist when alternative methodological lines of inquiry are not considered:

> "[HCI techniques for evaluation are] certainly worthwhile. However, this approach is very much focussed on the devices and their ability to efficiently translate the intentions of the user into parameters for the computer. The experiences of the users who use the devices, being harder to quantify, are comparatively neglected." [129]

Johnston points to the fact that evaluations of practice-based researchers, which are so often assessed in quantitative measures (effectiveness, efficiency, and task-based activities), have more to offer in terms of their experiences as creative practitioners:

> "We need to broaden the scope of what constitutes 'evaluation' in this context, and acknowledge that while ergonomics and efficiency are important, they are not the primary determinants of the quality of a musical interface. This thinking is reflected in the broader field of HCI, where there has been recognition that the task-based approach alone is inadequate, particularly when considering software intended to support creative work." [129]

To actualize this perspective on evaluation Johnston conducted user studies with musicians that involved video-recording the participants while they played virtual instruments, as well as speaking about their experiences (in a "think aloud" approach) and answering interview questions. Through the application of grounded theory methodologies, Johnston was able to prioritize "*generating*, rather than validating, theory" from the data gathered. [129] The findings that he arrived at were not made weaker by the fact that, "Musicians did not always approach the virtual instrument in the same way," but rather allowed this finding (which, in more quantitative contexts might be considered problematic or flawed) to guide the analysis to meaningful insights into categories of "modes of interaction" among participants. While the study did not begin with a goal of understanding modes of interaction, the topic was allowed to emerge from the data naturally. Johnston effectively used qualitative methodologies in order to generate "theory closely tied to the evidence from rich qualitative data." [129] The insights emerged from data which was directly tied to the experiences of the participants.

5.2.4 Qualitative Analysis

In their 2008 paper *Discourse analysis evaluation method for expressive musical interfaces*, Stowell et al. shrewdly point out that, "Using precision-of-reproduction as a basis for evaluation...becomes problematic for musical systems which are not purely deterministic. "Randomness" would seem to be the antithesis of precision, and therefore undesirable according to some perspectives, yet there are many musical systems in which stochastic or chaotic elements are deliberately introduced." [112] Stowell, Robertson, Bryan-Kinns, and Plumbley explain that:

> "A formal evaluation is one presented in rigourous fashion, which presents a structured route from data collection to results (e.g. by specifying analysis techniques). It therefore establishes the degree of generality and repeatability of its results. Formal evaluations, whether quantitative or qualitative, are important because they provide a basis for generalising the outcomes of user tests, and therefore allow researchers to build on one another's work." [112]

In order to responsibly explore notions of risk in performance (and potentially extract this element as an element of design) research studies must consider that musical composition and performance are not strictly task-based experiences, and the "user" in these cases are engaged in highly subjective internal processes.

Stowell et al.'s work tackled some of the issues inherent in these qualitative and quantitative evaluation techniques for live music–making practices involving human–computer interactions in their 2009 paper *Evaluation of live human-computer music-making: Quantitative and qualitative approaches.* As the authors point out, there have been many evaluations of musical performances in this realm, but they fall short in a number of ways. Some require competing mental resources (talking while performing) and some attempt to use observation of performer behavior, which forces us to accept observable indicators of "success" which may or may not exist. [130]

The authors apply a quantitative method of evaluation inspired by the Turning Test, but of more relevance to this dissertation is their qualitative method based on discourse analysis: "Discourse Analysis (DA) is an analytic tradition that provides a structured way to analyse the construction and reification of social structures in discourse...Discourse Analysis's strength comes from using a structured method which can take apart the language used in discourses (e.g. interviews, written works) and elucidate the connections and implications contained within, while remaining faithful to the content of the original text." [112] Though this process does not produce results which are easily abstract able or generalizable (e.g. statistics), it does engage in a structured approach to understanding the nuanced connections and context which might be shared among varied practitioners.

Discourse analysis shares many characteristics with other analytic methodologies for understanding phenomenological experiences such as grounded theory, conversation analysis, and interpretative phenomenological analysis. Most notably, it searches for and identifies "themes" across datasets; by drawing attention to patterns of meaning that appear and reappear, these methodologies give insight into the values, priorities, and experiences of participants. In Chapter 8 details will be presented regarding the specific methodology employed in this research, thematic analysis, which was chosen for its flexibility and appropriateness to understanding the internal and external experiences of musicians.

5.2.5 Conclusion

It is clear that there is room (perhaps a *need*) for evaluation methods that run the gamut of empirical and experiential perspectives, particularly within a field that so fluidly moves between artistic and research spaces. Understanding mechanical actuation methods, accuracy of technique, and mapping strategies are cleaner quantitative questions (though there is plenty of room for qualitative data as well). However, understanding the experiences and perceptions of a performer when engaging in their practice is a much more nuanced—and certainly more qualitative—topic, one that problematizes much of the research being carried out.

The following chapter lays out the research questions that are central to this work, and makes clear the methodological approach and its appropriateness.

CHAPTER 6

OVERVIEW OF STUDIES

6.1 Study Rationale

The purpose of the studies detailed below is to query the role of physical and material risk in two musical contexts. The purpose of this is twofold:

1. Understand the perceptions and experiences of practitioners in the computer music community when using musical instruments that embody high- and low-risk states
2. Query the perceptions and experiences of computer music practitioners using computational instruments through the application of appropriate metaphors for physical and material risk.

6.1.1 Boundary Objects

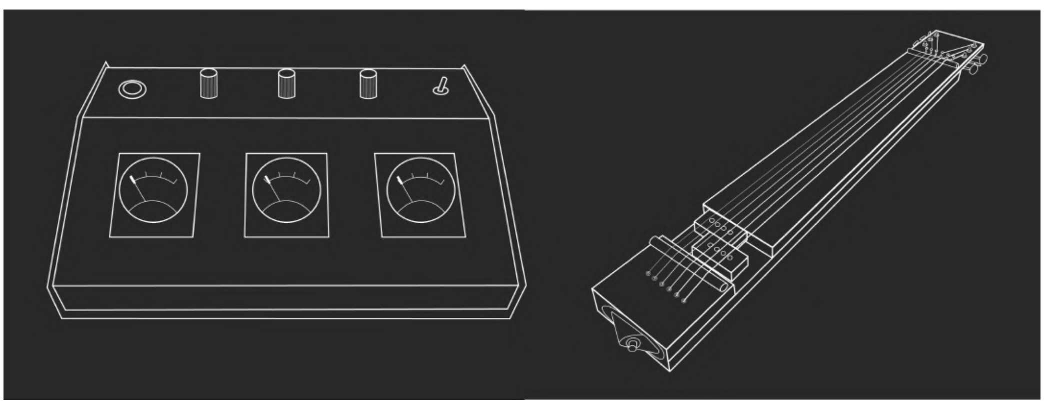


Figure 6.1: Boundary Objects: Instrument/Interface Design

Boundary objects are artifacts developed to facilitate complex conversations with diverse groups of people. They are sometimes described as "bridges and anchors"—flexible enough to be interpretable by individuals while maintaining a common frame of reference for research. [131] Two boundary objects were created for this research: the *Torpere*, which engages physical risk, and *null/void*, which embodies material risk. Each instrument draws from our definition of risk and conveys those qualities in different ways. The *Torpere* is physically connected to the body while the *null/void* interface imposes a metaphor for material risk onto the resources of a computer instrument.

6.1.2 Torpere

The *Torpere* study was positioned on one extreme end of the DMI/CMP spectrum: the use of an experimental, novel instrument by practitioners in the computer music community that is an embodiment of high and low physical/material risk states. This first case study allows us to work toward an understanding of the role that physical and material risk might play in musical practices involving novel instruments. The *Torpere*, though not digital or computational in nature, manifests a direct instantiation of higher and lower risk states and provides relevant data points regarding the appropriateness and value of incorporating physical and material elements of risk into instruments that take the form of more detached, computational interfaces. In the interest of serving the computer music community, the study was deployed to an appropriate participant group consisting of musicians in the Music Technology program at Georgia Tech. All of the participants involved had experience in not only in musical improvisation, but also in the use of novel instruments and interfaces—often self-constructed—in their computational musical practices. Aside from these shared experiences the participants represented many backgrounds and interests, including composers, engineers, and classical and experimental musicians. The ways in which each participant utilized technology was highly personal, from DAWs (digital audio workstations) and analog synthesizers to DMI construction and robotics.

The study took the form of in-depth conversations regarding not only the creative processes of the musicians generally, but also the impact that introducing high levels of physical and material unpredictability into the instrument being used had on the improvisational experiences. Contrasted with identical experiences on a low-risk instrument, this produced insights that spoke not only to the role of risk in a multitude of musical practices but also provided a valuable baseline for understanding how risk of an extreme physical and material nature can impact the experience of practitioners engaged in the computer music community.

By querying these musicians—experienced practitioners in computational performance practices—on their experiences with a low-risk and high-risk version of a novel musical instrument, insights were produced regarding the role of risk in expressive musical improvisation and the value that incorporating risk might have in novel musical instruments of any kind (particularly those that are digital rather than analog). The study was designed to first build knowledge about each participant's approach to improvisation and creative expression, and then analyze their experiences with low- and high-risk instruments in order to gain insight into the role that risk can play in expressive musical engagements.

6.1.3 null/void

null/void engaged with risk and expression at the other extreme of the spectrum: purely digital interfaces for musical expression. One challenge in this study was figuring out a way to apply constraints and limitations on what is a seemingly limitless system. In order to apply the concepts of physical and material risk onto a practice which is inherently non-physical and immaterial, an interface was developed to function as a referential system acting directly on conceptual computational resources.

Musical activities of any kind share some universal properties: frequency content, amplitude, and arrangement in time, for a start. It is possible to quantify certain qualities of those properties, such as number notes, changes in pitch, time duration, loudness fluctuations, spectral content, tempo, rhythmic pattern, and so on. The *null/void* interface was designed to focus on just three properties of the most fundamental elements of music: change in pitch, change in amplitude, and passage of time. In using the interface it is possible to imagine these qualities as physical resources, limited in quantity and observable to performers.

This "digital resource constrainer" was distributed to four practicing computer musicians who were actively engaged in live-coding and/or laptop music performance. As with the *Torpere* study, an informal interview was conducted to gain an in-depth understanding of each participant's personal approach to risk and creative expressivity in their practice. Unlike the *Torpere* study, the participants were encouraged to use the *null/void* system as they wished over the course of several weeks. The *null/void* interfaces were deployed as *cultural probes* to serve two purposes:

1. Extend the range of the study from the limited number of laptop musicians in the Atlanta area to a much wider pool of participants
2. Generate richer data regarding the impact of the system on practices which, due to their highly personalized nature, involve digital systems that can not be adequately translated to a lab setting

The resulting data from the *null/void* study provided an opportunity to compare and contrast notions of risk and expression across a wide spectrum of DMIs from as diverse a population as possible.

This research is intended to provide preliminary data regarding the implications of finite physical and material resources on a practice which is entirely digital. With the *null/void* system, laptop musicians were be prompted to engage with low- and high-risk states through metaphorical resource limitations. In the low-risk state, the use of pitch and dynamic content (as well as the duration allotted to each performance) "ran out" over time, eventually rendering the performer with exhausted material reservoirs. In the high-risk state, resource caches acted unpredictably: at times the performer experienced a subtle or extreme purge or injection of resources, which forced creative problem-solving and resource management.

6.1.4 Conclusion

The hypothesis being investigated in this study posits that *new musical instruments that respond more unpredictably and that carry a higher potential for failure create increased opportunities for in situ problem-solving and idiosyncratic behavior on the part of the* *musician.* Because fully digital systems lack the material and physical properties inherent to more traditional instruments (and more approachable NIMEs), the first study engages with questions of high-risk states through the physical and material properties of a highly constrained physical instrument. The second engages with these same issues through the application of a material metaphor onto intangible computational resources. Through the process of thematic analysis, themes from across these two datasets allow insight into how physical and material risk function in CMPs, and what value higher levels of risk might have for computer musicians.

6.2 Instrument and Interface Design

6.2.1 Torpere

In 63 A.D. Roman court physician Scribonius Largus directed patients with leg pain to stand on a rocky sea shore with electrical fish underfoot until the pain subsided—or to place one of the fish directly on the head as needed to alleviate headaches. These black torpedo (from the Latin *torpere*) fish propagated the use of electrical signals to stimulate bodily muscles as therapy, a practice that lasts to this day.

The *Torpere* is an instrument designed to facilitate explorations into the role of physical and material risk states in creative and expressive musical practices. A transcutaneous electrical nerve stimulation (TENS) unit connected to the instrument's strings produces an unpredictable tactile experience that prompts the musician to apply their skills in new ways, reconsider their relationship to an instrument, and push past their boundaries of comfort. Touching the instrument with a body part or metallic instrument bridges connections across different strings, which means that each point of contact influences the flow of the electrical currents and results in surprising physical and sonic effects for the player.

It was important to design an instrument for the *Torpere* study that was simultaneously recognizable and familiar enough to be approachable for musicians with varied backgrounds, but also present a level of disfluency and novelty. The instrument needed to support a certain level of skill-transfer from multiple instruments because the study did not target practitioners who were specifically skilled in one particular instrument or another. Someone familiar or practiced with a guitar or bass would see their skills transfer fairly directly, but a pianist, percussionist, and violinist would also have many points of entry to playing the instrument. Even a non-practicing musician (such as myself) would be capable of approaching the instrument and making some sound without an overly imposing sense of intimidation. Of the highest importance was an ability to support musical improvisation for any individual.

While the instrument was designed to be approachable and playable without much (if any) musical training, it was also important to present scalable challenges. This was accomplished partially through the addition of the TENS unit, but also in the lack of frets on the instrument body, the wide array of tools that could be used, and the hand-made quality of the build itself. Because the study was not interested in evaluations—qualitative or quantitative—of the music/sound produced by the musician, there was no implicit or explicit judgment regarding any sense of composition for the player. Instead, the instrument functioned as a boundary object that touched on ideas of risk and unpredictability and how those factors influence a performer's experience. The instrument was flexible enough to meet the skill level of any musician while also challenging them to explore, push further creatively, and innovate.

6.2.1.1 Development

Several approaches and form factors were considered in early brainstorming sessions regarding how to design a physically and materially "risky" instrument. Among these ideas were a razor-wire violin, glass drums, self-detuning instruments, and a "shrapnel" keyboard. However, when considering how to support the objectives outlined in the previous section, the notion of augmenting a familiar instrument with an unfamiliar physical sensation came to forefront as a way to balance approachability and unpredictability through design.

The guitar is one of the most ubiquitous instruments available today, not only through its prevalence in pop music but also by means of its geographic and historical reach. Plucked string instruments such as the lute, banjo, sitar, pipa, dulcimer, and many more exist across time and cultures immemorial, making a guitar-like instrument an object likely to appeal to individuals from a wide range of cultural and experiential backgrounds. Augmenting the instrument to behave unpredictably was a simple matter of exploiting the natural materials with a variable stimuli—in this case, applying an electrical charge to the metal strings. This was tested through the use of a TENS unit, with one electrode connected to a musician's hand and the other to the strings of the guitar.

Figure 6.2: TENS tests: standard electric guitar (left); conductive materials (right)

To support a variable-state instrument certain design affordances had to be considered and implemented that rendered constructing a bespoke instrument more practical than customizing an existing one. Taking inspiration from homemade cigar box guitars and lap steels, initial prototyping was done with a "DIY" 2x4 lap steel kit. This allowed for the identification of potential issues and subsequent iterations on the design.

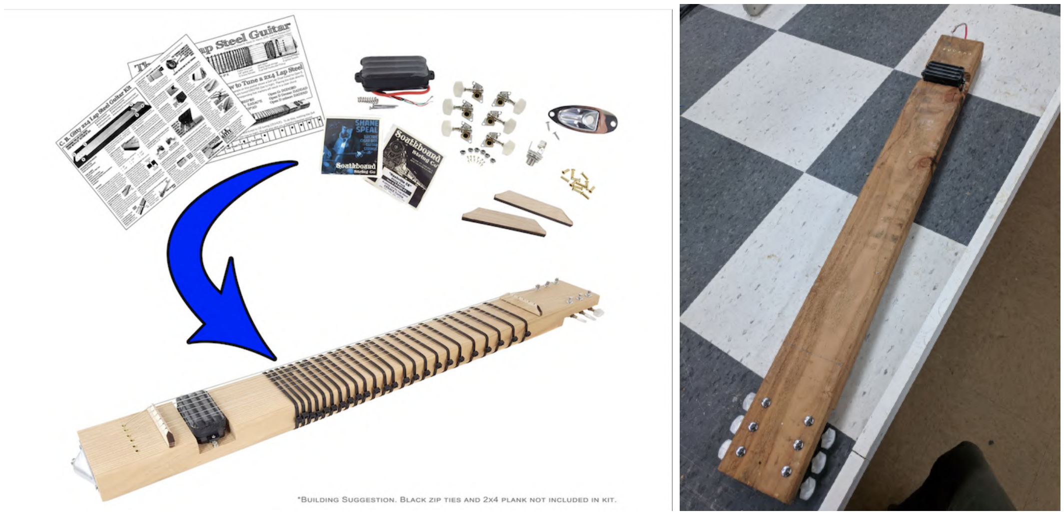


Figure 6.3: DIY Lap Steel Kit (left), photo from www.cbgitty.com; Torpere V1 (right)

Because the form factor of a guitar-like instrument is so familiar and accessible it was important to create opportunities for players to explore ways of playing that extend beyond plucking and picking. The tools developed for this purpose ranged from minor novelties such as guitar slides and finger picks to more abstract tools such as a modified violin bow, clay-cutting wire, drum snares, and steel chopsticks.

Figure 6.4: Torpere Playing Implements

Each implement was made to be conductive, and in some cases major modifications were made. For example, to make the entirety of a violin bow conductive, not only did the stick have to be wrapped in metal (copper, in this case), but the hair of the bow itself needed to somehow conduct the electricity between the strings of the guitar, the stick of the bow, and the player's hands. In order to accomplish this two bows were produced: one low-risk, and one high-risk. In the low-risk version 32-gauge nickel wire was threaded through the hair of the bow and wrapped around holes drilled in the tip and the frog in order to maintain conductivity throughout the entirety of the implement. In the high-risk version this wire was replaced with electroplated diamond wire, which is traditionally used as a saw blade in gem-cutting trades. Not only does this wire conduct electricity, but it also has abrasive properties which, when used on the strings of the guitar, actually has a damaging effect on the materials of the instrument.

Figure 6.5: Nickel wire wrapped bow stick (left); Nickel wire bow hair (right)

6.2.1.2 Physical Connections

During prototyping stages the *Torpere* was designed as one large "circuit" that would be connected by the musician touching the metal string of the instrument. To support this, one lead from the TENS unit was connected to the guitar strings, and the other lead was connected to the player by means of an electrode attached to their hand. It was observed, through casual use and informal testing with individuals in close proximity, that attaching an electrode to the user's body lent a clinical feel to the use of the instrument. Further, being connected to the TENS unit at all times resulted in a feeling of being unable to disconnect from the electrical stimulus, which could produce higher levels of fear and anxiety for participants. Therefore, the decision was made to connect both positive and negative leads from the TENS unit to individual strings on the *Torpere* so that one could experience the electrical signal through touching the strings while having the freedom to remove their hands and immediately suspend the sensation at any point in time.

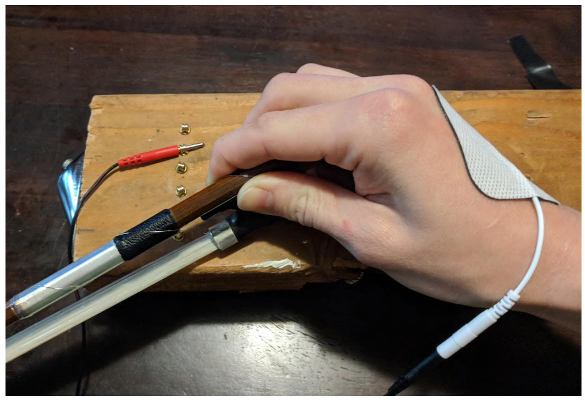


Figure 6.6: Testing TENS connectivity through bow

This reconfiguration also had the benefit of creating more opportunities for exploration and unpredictable responses, as touching different strings connected the "circuits" in multiple ways. It also supported a greater diversity in terms of implements that could be used to play the *Torpere*: the connection between the hands and the strings could theoretically be made by playing the instrument with a copper bow or steel drumsticks, but became tenuous based on the placement of the electrode on the player's body. By confining the TENS unit to the instrument entirely any connection experienced through a metallic object could be more reliably made.

6.2.1.3 Unpredictable Unpredictability

One of the more surprising findings gained through the prototyping process was an unexpected level of unpredictability based on playing style. Though it was designed to be unpredictable by virtue of the electrical signal and varying ways to bridge connections between strings, what was not foreseen was a variable response from the instrument when moving along the length of the strings. When playing with a metal slide, for example, it appeared that a "charge" could be built up as the player ran it up and down the length of the strings; this would then discharge at unpredictable times in a kind of electrical "burst." This sensation was reminiscent of the surprising *zap* one experiences when touching a metal door handle after walking across carpet, and the natural reaction for players was to pull their hands away as quickly as possible. While unpredictability and surprising outcomes were desirable, this extreme byproduct of use seemed to move beyond challenge and into an anxiety-producing sphere.

We also found that the instrument "felt" different for each individual playing it, with levels of comfort ranging quite a bit. This also seemed to be based in part on environmental factors that shifted day-to-day. Depending on the humidity and temperature of the room, as well as how dry or wet a participant's skin was, the perceived strength of the TENS signal varied. This issue would make user testing susceptible to a variety of issues, including difficulty in establishing a baseline for each musician and ensuring that the relative strength of the stimulus remained as consistent as possible across the sample group.

Both issues (the electricity "build up" and variable skin conductance) were addressed through the use of conductive gel. By applying a quarter-sized amount of the gel onto the hands, the added layer of moisture reduced skin resistance and allowed for easier and more stable conductivity with the TENS unit.

6.2.1.4 Materials and Fabrication

Finally, in order to make the instrument as self-contained and consistent as possible for multiple users the connection of the TENS probes were changed from alligator clips to integrated string connection. Guitar strings with steel-plated ball ends were chosen, allowing for the metal probe ends to be inserted directly into the wound string in a plug-and-socket configuration.

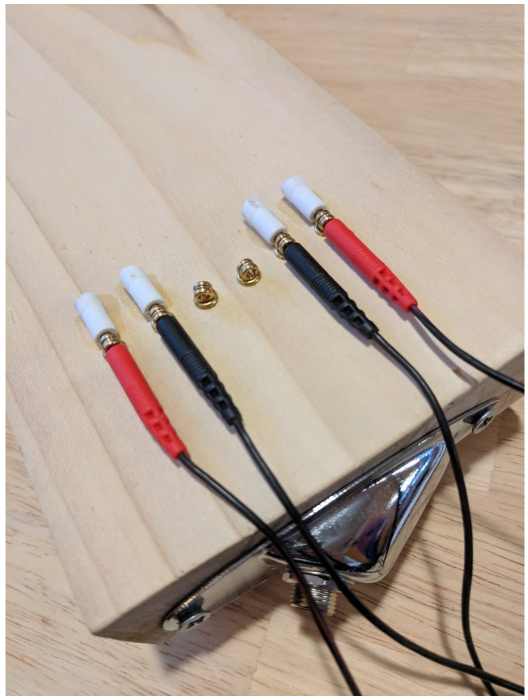


Figure 6.7: TENS connections and metal ball ends

Poplar wood was chosen for the final instrument due to its availability, cost, and workability. The final version was made wider and longer than the first to support greater control over string tuning and improved double pickups.

Because it was significantly wider than the 2x4 iteration it was not possible to use the DIY kit's pre-fabricated wooden saddle and nut. Bone was considered as a possible alternative; unfortunately the standard sizing available for this purpose was not wide enough. Therefore, version 2 initially featured steel threaded rods for the nut and saddle, inspired by the practices seen in the homemade lap steel tradition. This material is a good candidate for such a purpose due to its customization in terms of length as well as the natural ability to secure horizontal placement of the strings which rest in the rod threads. What had not been anticipated was the obvious issue in connecting the instrument strings together with a metal object; the electrical stimulation afforded to players is only possible when bridging the positive and negative TENS leads (via the metal strings) with the body. Ultimately, oak dowels were used as the final bridge and nut.

Figure 6.8: Oak nut

Metal string ferrules were inserted and attached to the tip and frog of the bow to increase the ease of rewiring, tightening, and loosening the metal strings and diamond wire. The wires were wrapped and soldered to a small metal bolt at one end and threaded through the ferrule in the bow tip. At the frog-end the wires continued through the second ferrule and were wrapped several times around a wing nut, which was then tightened to keep the wires in place while still allowing for later adjustment.

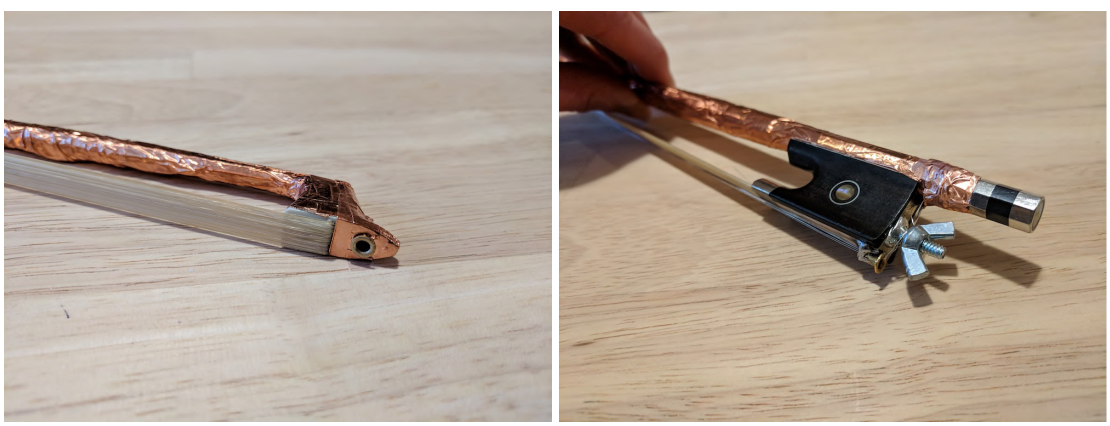


Figure 6.9: Bow ferrules and wing nut

6.2.1.5 *Torpere: Final Design*

Figure 6.10: Final Torpere design

6.2.2 null/void Design

null/void is a boundary object designed to apply a metaphor for materiality onto a digital performance practice. Much like the text shaking, blurring, and deconstructing of Roberts' Gibber or Wilk's Emacs animations, *null/void* imagines a world in which unlimited digital capabilities are reliant upon finite resources that can be exhausted through use. The objective of *null/void*, then, is to represent these depleting resources as materially as possible during the course of a live laptop performance.

Though there are many musicians who do solo sets when performing with computers, practitioners who specialize in this particular facet of CMPs often perform in groups, from laptop orchestras to electroacoustic ensembles. It was important to create a system that flexible enough to be used by a single performer, and also support input from two or more laptop performers if necessary. By presenting performer(s) with an instrument that visually conveys a sense of resource depletion—and effectively "shuts off" their access to resources when the tank is empty—it was possible that laptop musicians might feel compelled to reconsider their approach to composition and performance and pursue different creative paths based on the resources available to them.

Beyond the metaphor of the system the *null/void* interface offered a second, higher-risk modality. In its high-risk state, the "resource banks" available to performers were randomized and unpredictable. Over the course of a performance, musicians were randomly "gifted" additional time, pitches, or dynamics–or found portions of these banks suddenly depleted. Exploring performers' reactions to and experiences with such a system illustrated the ways in which the lack of physical and material risk in computational creativity (and the possible unpredictability of the resources available over time) impacts the performer's experience.

6.2.2.1 Design Inspiration: Sonoscale

Figure 6.11: Sonoscale design artifact

The *null/void* artifact took conceptual inspiration from work done by live-coders and computer musicians such as Wilk and Roberts, as well as from personal prototyping experiments undertaken in the Digital Media program at Georgia Tech—in particular a design exercise called *Sonoscale*. *Sonoscale* was an artifact designed in response to a prompt presented in a Design of Networked Media course; students participating in the class were asked to consider a particular set of mediated interactions as a network and query the nature of these networked actions and the impact of media within such systems through a designed artifact. *Sonoscale* was a speculative design [108] exercise that attempted to reconsider the limitless nature of computer music performance as a limited, measurable activity. By physically representing assets shared between performers, the project aimed to explore the impact of imposing constraints on resources in a digital practice. Through the project, practitioners in the field of computer music were interviewed and prompted to reconsider how they made decisions, collaborated, and composed in real time while simultaneously making this process more transparent for an audience.

The project considered computer music performances as networks comprised of nodes that represent individual actors, and edges which embody the flow of activity between connected elements. When comparing such a network of nodes and edges in traditional and computer music practices we can see several notable differences.

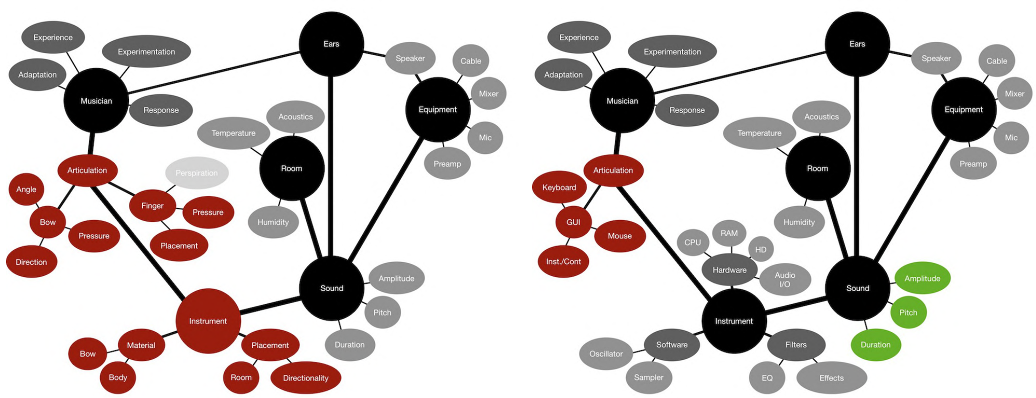


Figure 6.12: Networked nodes and edges: traditional (left); computer music (right)

In a traditional performance one might consider the musician, their instrument, the sound system, and the audience's ears as major nodes. Between the musician and the instrument is the articulating edge: the musician actuates her instrument with fingers, bow, lips, or other means, and that activity sets the materials of the instrument vibrating, resonating, and otherwise shaping the sound which is produced. Between the instrument and the sound system is a transduction of acoustic energy which results in amplification and other coloring of the sound. Finally, between the sound system and the audience's ears is the room with unique acoustics, atmosphere, and physical characteristics. There are many other factors at play (and many other ways in which these nodes and edges overlap and connect), but we can consider this as a basic foundational network representation in order to pose more important questions.

When we consider the evolving field of computer music, in comparison, we are often faced with a partially or fully non-physical system that is mostly constrained by the wishes and desires of whoever designed the software and hardware. The network changes: the articulating edge connecting the musician and instrument nodes is reduced to interactions with a GUI. No longer do material properties of the instrument determine sonic output (unless, of course, you push your computer to the point of overheating). The *Sonoscale* artifact raises questions about possible future scenarios:

1. How might a physical representation of shared resources impact the norms and standards of a specific group of people?
2. What if computer musicians were increasingly constrained in the options over time?
3. What if digital music actually relied on physical resources?

Sonoscale attempted to broach these questions to the CMP community and encourage practitioners to consider how different constraining measures might affect the way they approach computer music and shift the network dynamics of computer music in interesting and productive ways.

In terms of design, the hourglass-inspired system continually measured the activity levels of musicians and depleted resources accordingly. Some of the appeal of this artifact was in the metaphor; an hourglass evokes certain qualities: running out of time, being timed, collaborative and competitive experiences (such as in gaming), and precious (at least aesthetically) materials. There was an added benefit of being modular; the material contents within could be assigned to any matter of musical parameter: time, amplitude, duration, timbre, and so on. An Arduino microcontroller was connected to a simple servo motor separating the top and bottom halves of the hourglass, which was filled with sand. The microcontroller evaluated the RMS levels of any audio passing through, calculating not the *amount* of change, but rather the *rate* of change. In this configuration, a musician could play many notes at one volume without depleting resources, but dynamic changes were more expensive. Higher rates of change caused the servo motor to rotate the "door" separating the top and bottom halves of the hourglass open, allowing more sand to pass through. Less change caused the door to close, stopping the flow.

Three practicing computer musicians were invited to have informal conversations regarding their creative process with the hope of soliciting feedback about how the *Sonoscale* might prompt them to reconsider, re-imagine, or reevaluate their standings. Ultimately the goal of the interviews was to assess whether or not the designed artifact raised the intended questions:

1. Would the artifact change the behavior of the musicians?
2. Would the artifact prompt musicians to reconsider their use of musical actions?
3. Would the imposition of constraints lead to novel creative activity?

The participants were shown a short video of the artifact and the basic workings of the system were explained. They were presented with the following questions:

1. What are your initial thoughts regarding this design artifact?
2. Do you imagine that having such an artifact in front of you would impact a performance? If so, how?
3. If you were performing with another computer musician, and the activity of both of you caused the hourglass to run out faster, do you think that you would feel differently about the performance? If so, how?

One observation shared between all of the musicians was that the object itself was aesthetically interesting, and would make a positive contribution to the stage–at least in a visual capacity (one participant expressed the desire to have a large-scale, human-sized version on the stage). As they discussed the possibilities of using such a system more, the conversation turned to alternative ways in which artifacts could be used to impose constraints on digital resources. This resulted in an impromptu brainstorming session of sorts in which the following ideas and observations emerged:

1. It could be interesting to have multiple *Sonoscales* on the stage at once, either assigned to each collaborator, or else attributed to different musical parameters, so that pitch, dynamics, duration, and whatever else you assigned could "run out" independently.

2. Audience participation could play an interesting role if individuals were somehow able to add or remove resources from the performer's artifacts.

3. Using the *Sonoscale* as a timer could prove very appealing. If performers were required to get through so much material before the sand ran out, it would be an interesting challenge to calculate a performance.

4. The speed of the sand could be mapped not only to musical parameters, but also used as a kind of conducting system, changing the speed over time as a way to impose structure or form onto a piece through changing resource costs.

Alongside the positive elements described by the musicians were several shortcomings. Of particular note was the observation that, despite the material properties of the device, the *Sonoscale* did not actually do anything that a digital artifact could not do. Along these same lines were comments that the correlation between the artifact and sound was not entirely obvious (certainly not for the audience, unless they were informed of the system beforehand), and that aside from the physicality of the object itself, there was no real haptic connection for the musicians. One mixed reaction concerned the emotional risk involved with using something like the *Sonoscale*–namely that it would cause the performer to be much more self-conscious and aware of their own actions (especially if they were sharing the resources with other collaborators). This could be a desirable element or a hindrance, depending on the situation and feelings of the performers. Lastly, the issue of agency emerged, with one participant expressing the desire for a more of interactive relationship with the artifact: "It would be cool if there was a kind of feedback loop that you could enter into with it, and also the process could be reversed." This observation in turn led to interesting discussions of possibly sonifying the falling sand and making that sound into an additional element of the performance that the performers could utilize and respond to.

While the artifact itself was not necessarily a resounding success, the propagation of ideas beyond the initial conversation and the discussions of constraints, cost, structure, and self-awareness provided support for the position that these are questions that are worth being asked. One interviewee stated that the *Sonoscale*, "Provides constraints to an otherwise constraint-less activity" and expressed an interest in exploring the idea further. It is with this feedback in mind that the *null/void* project took form.

6.2.2.2 Design Inspiration: Tube Amps and Voltmeters

Beyond the conceptual inspiration of the *Sonoscale*, *null/void* takes design considerations from several other sources, particularly analog audio equipment. Much of the iconic gear from the '60s and '70s featured vacuum tube amps, analog voltmeters, and diecast aluminum form factors, often in strong pastel tones; these characteristics would be immediately recognizable to most musicians who use audio equipment. Many musicians and enthusiasts today build their own "clones" of this kind of vintage gear, or make bespoke equipment of their own with analog parts, but there are also many existing digital media projects that utilize retro components in novel ways.

One of the most common uses for vintage tube components is to re-purpose them as digitally-controlled light sources, such as vacuum tube lamp and cold cathode displays ("Nixie tubes") below. These design objects combine old technology with modern microcontrollers to create retro-futuristic display objects. Analog voltmeters–another identifiable feature of vintage audio equipment–have also been repurposed in novel design projects such as clocks and weather displays.

Figure 6.13: Left to right: Voltmeter clock [132], Voltmeter weather display [133], Nixie clocks [134]

These projects provide compelling evidence for the aesthetic and theoretical appeal of combining electric and electronic elements in hybrid analog-digital design objects. The "warmth" and materiality inherent to physical components seems to provide a counterpoint to the comparatively "cold," invisible nature of computational technology. Utilizing analog technology subsequently became an important part of constructing and conveying the material/physical metaphor with the *null/void* system.

6.2.2.3 Footprint and Computational Hardware

Because the object was intended to evoke feelings of live performance it was designed to look "at home" alongside other audio equipment such as effects units, stomp boxes, and amps. Plugging in to an auxiliary audio unit as a part of a signal chain is a relatively natural part of musical performance practices, and musicians may find it intuitive to look to such a piece of hardware for information regarding their signal. The analog nature of the visible components of the *null/void* box were chosen to reinforce the notion of finite, material resources, and marry the concepts of audio technology and physical limitations in one unified form.

In prototyping stages, *null/void* was constructed to feature three analog voltmeters controlled by Arduino microcontrollers and housed inside an aluminum diecast stomp box. The box was intended to eventually offer XLR or TRS input points into one side of the housing, and audio output connections on the opposite end. The goal was for computer musicians to be able to set the duration of their performance and the resource "banks" for pitch and dynamics before the start of a performance and simply plug their interfaces into the side of the stomp box. When the resource banks depleted the audio output chain would be broken, ending the performance.

Through this first version of the interface it was quickly apparent that space would be an issue. In addition, continued testing with the voltmeters and early attempts to code audio analysis onto the microcontrollers made it clear that the Arduino platform would not be suitable for audio input and output. Ultimately a Raspberry Pi 4 was chosen for this task, not only for its computational power but also the ability to support the USB audio interface that was chosen for the project (Behringer U-Control UCA202). The Arduinos found a dedicated use in controlling the voltmeters, with just one microcontroller per interface.

Figure 6.14: null/void interface V1, V2

A Hammond Manufacturing 30-degree sloped aluminum console was selected as an enclosure, and holes were drilled for the installation of buttons, knobs, meters, power supply, and audio input/output.

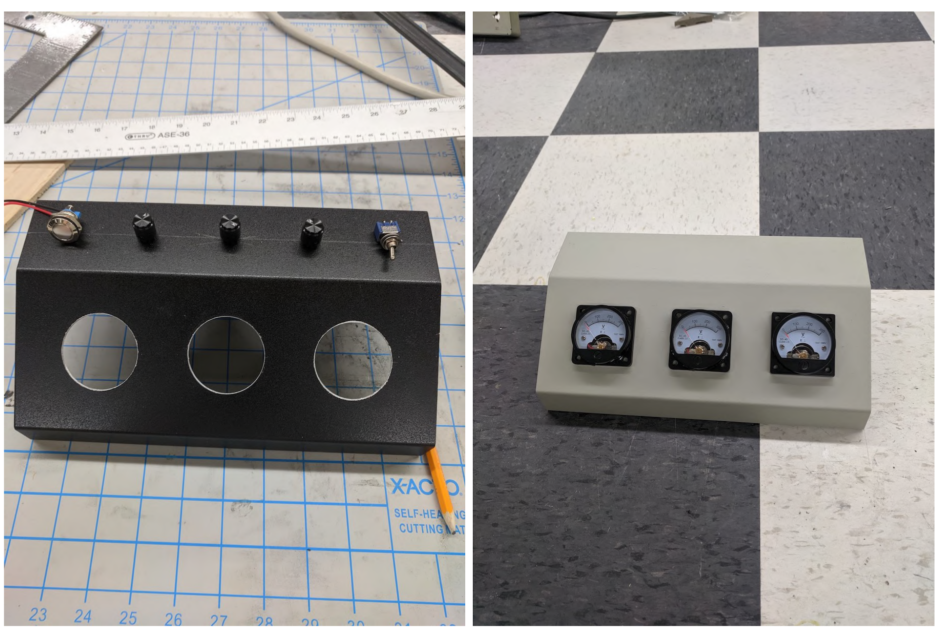


Figure 6.15: null/void console fabrication

In total, each interface contained the following hardware:

1. Raspberry Pi 4 Computer
2. Arduino Nano Microcontroller
3. Audio Interface
4. 3 Analog Voltmeters
5. USB Power Supply
6. 3 Potentiometers with Machined Metal Knobs
7. 1 Toggle Switch
8. 1 16mm Momentary Press-Button

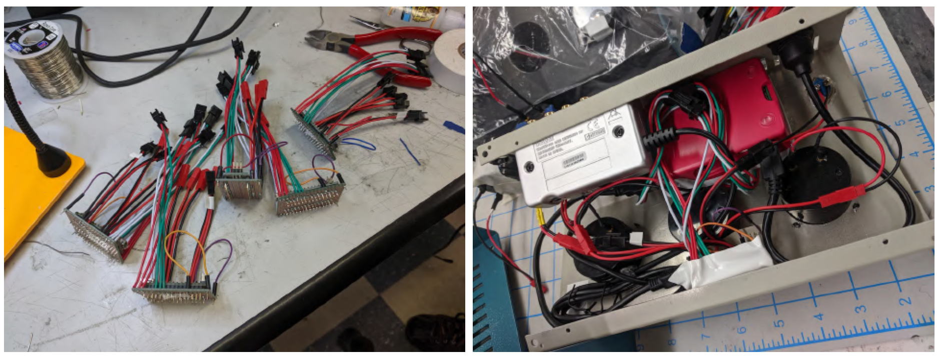


Figure 6.16: null/void circuitry and internal hardware

The addition of meter labels, stamped identification codes, gaskets, and rubber feet rounded out the *null/void's* final form.

6.2.2.4 null/void: Final Design

Figure 6.17: Completed null/void Interfaces

CHAPTER 7
RESEARCH METHODOLOGY

7.1 Torpere Research Methodology

7.1.1 Overview

The hypothesis investigated in this study posits that *new musical instruments that respond more unpredictably and that carry a higher potential for failure create increased opportunities for in situ problem-solving and idiosyncratic behavior on the part of the musician.* These conditions ultimately foster a higher perceived level of expression on the part of the performer, who will not only be prompted to adapt to continually changing conditions but also pushed to engage in activities that reached beyond trained/practiced behavior. By comparing the experiences of a musician when using a very stable, predictable instrument versus an unpredictable one, this work attempts to better understand the role of unpredictability and risk in the creative and expressive choices that musicians made during musical improvisations.

7.1.2 Study Design

1. **Recruitment:** Recruitment of participants began in the School of Music at Georgia Tech and specifically targeted individuals who were known to be engaged in research at the intersection of music and technology. Several potential participants were identified through shared courses in the music department as well as attendance at the New Interfaces for Musical Expression (NIME) conference. A total of seven participants took part in the study. In terms of demographics, all seven participants identified as male; the average age was 26 (median = 25), and the average years' musical experience was 19 (median = 15).

2. **Information Session:** Before testing, participants were given a brief overview of the instrument and the TENS system that would be attached in the high-risk version of the testing. Participants were be provided with a brief overview of the musical instrument they would be using–this description did not suggest methods for playing

or handling the object, but rather familiarized musicians with the concept of TENS devices and general material differences between the two instrument versions in order to allow each participant to make an informed decision regarding proceeding with the testing. They were then provided with the required image releases and consent form to sign.

3. **Waivers and Releases:** Participants were required to sign the following releases and waivers:

   (a) Consent Form.

   (b) Single Image Release Form.

4. **Pre–Testing Questionnaire:** A pre-test discussion was carried out with each participant in order to establish a baseline understanding of the mental models which were already in place for each musician. Because the research questions being explored in this study are qualitative and highly subjective, participants were asked several questions regarding their experiences as improvising musicians (see Appendix C). These questions were designed to probe what performers considered to be experiential cues signifying higher or lower levels of creative expressivity during a performance. This data provides insight into how performers evaluate their own experiences, interpret the complexities of creative processes during musical activities, and navigate the uncertainty of improvisatory situations.

5. **User Testing Overview:** The user study itself was carried out in two stages, each with an associated review period immediately following the testing.

   (a) **Low–Risk (LR) Test Conditions:** First, in LR testing, performers were presented with the *Torpere* instrument in its low-risk state [each participant began with the *Torpere* tuned to B, F#, B, D#, F#, B. They were encouraged to make any tuning changes they wished at any time]. "Low-risk" here refers to the relative stability and predictability of the object; modeled after a slide guitar, the LR *Torpere* could be strummed, picked, bowed, or played with a metal slide. Aesthetically, the *Torpere* is recognizable as a derivative of a lap guitar and it does not contain any materials, electronics, or peripherals which would be unfamiliar to even a novice musician. Performers were given roughly 5-10 minutes to familiarize themselves with the instrument and its modes of actuation and sound production, and given the opportunity to ask questions about the instrument. They were then given 5-10 minutes to compose and perform a short improvisatory performance, which was videotaped.

      i. Immediately following their performance, participants were asked to watch the video of their improvisation and reflect on and describe their experience. This discussion was also videotaped. The discussion was loosely guided by the researcher, but each participant was encouraged to speak frankly and openly about their subjective experience. If appropriate, the tester could draw from the pre-interview data gathered before the testing as a prompt for further discussion.

(b) **High–Risk (HR) Test Conditions:** After the LR testing, performers continued with the high-risk version of the instrument. In HR testing, performers were presented with the *Torpere* instrument in its high-risk state. The TENS unit was connected to the strings of the instrument, conducting current that could be transferred to the user when the strings were bridged by the fingers or any metal object (specialized copper-wrapped bow, metal guitar pick, drum snares, metal slides, etc.). Before this testing condition commenced the instrument was first calibrated for each participant; participants were directed to apply conductive gel to their hands and given further direction to apply more as needed throughout the course of the HR testing. The TENS unit was then installed on the instrument in the OFF position, and each musician was asked to place their hands across the strings. The TENS unit was then be powered on at its lowest setting (1) and participants were asked to report the point at which they felt the device's electrical sensation. The power setting was subsequently stepped up (2, 3, 4, etc.) until the participant reported that they could feel a mild to moderate level of current. If the participant reported any discomfort the setting was reduced. In order to assure the lowest possible risk of shock or pain to the participant the TENS unit was be set at at the lowest level at which performers reported feeling the current. Performers were again given roughly 5-10 minutes to familiarize themselves with the instrument and ask any questions they had. They were then allowed 5-10 minutes to compose and perform a short improvisatory performance, which was videotaped.

   i. Immediately following their performance, participants were again asked to watch the video of their improvisation and reflect on and describe their experience. This discussion was also videotaped.

7.1.3 Video Elicitation

> "If a phenomenological study is based on the assumption that involved participants best understand their own lived experiences, then the participants should identify and explain significant interactions."
>
> *Bonnie Raingruber* [135]

Participants in the *Torpere* Study were asked to improvise for 5-10 minutes with each version of the instrument, followed by a immediate video reviews. During the video reflection portion of the study each musician was asked to describe their thoughts, feelings, and creative process as they viewed their performance. Though each participant was encouraged to start and stop the recording at any time and guide the conversation as they felt appropriate, at times they were prompted to explain what was going on in a certain moment, describe their creative decisions, and be gently guided back toward the relevant research topics if needed.

Video review, as a methodology, is a relatively recent development in research techniques, and is referred to by many names. In their 2012 paper *Video Elicitation Interviews: A Qualitative Research Method for Investigating Physician-Patient Interactions* Henry and Fetters conducted a literature review of existing techniques and acknowledge that, "Identifying the studies was difficult, because no standard terminology exists for this method. Terms used include Integrated Methodology for Preserving and Analyzing Clinical Transactions (IMPACT), stimulated recall, and video re-view...video elicitation, stimulated recall, and interpersonal recall." [136] In my own research I additionally came across the terms "video-stimulated-interviewing" [137] and "video-cued reflection" [135]. Despite the numerous terms by which it goes, a general definition is agreed upon:

> "Video-stimulated recall (VSR) is a method whereby researchers show research participants a video of their own behavior to prompt and enhance their recall and interpretation after the event." [138] The benefits of such a method-

> ology are outlined by Fetters and Henry: “Data from published video elicitation interview studies suggest that interview participants have 3 distinguishable kinds of experiences. First, participants typically recall the thoughts, beliefs, and emotions they experienced during the interaction. Second, participants frequently re-experience or relive the interaction while watching themselves on video and may even display physiologic or emotional changes in response to the events in the video recording. Finally, participants often reflect on their thoughts and actions or those of their interaction partner.” [136]

Video Elicitation Methodologies (VEMs) have a strong foothold in the fields of Education (particularly educational training), Psychology, and Medicine, perhaps due to the clear and distinguishable roles between two parties engaging in an activity with a shared goal [137]. Medical education, which increasingly relies on the acknowledgement the complexities of patient-doctor relationships (“bedside manners”); training in the field of psychology are both highly dependent on the interpersonal dynamics between “professional” and “patient;” and educators are similarly related to their students as “experts” teaching “novices.”

In this way, VEM can act as an equalizer that levels a playing field, where researchers and participants are able to both step back from and re-engage with a shared experience and, through remediation, reflect on what has happened without real-time situational distractions. Professor of Education Keith Barton explains that images, “Can function as a third party in interviews, as researchers and informants work together to explore and understand their content...Not only can such tasks make interviews more comfortable, they also can equalize the interpretive process by giving participants greater voice.” Further, he states that VEM can, “Facilitate [personal] conversations by displacing the focus of interviews onto external stimuli and, in some cases, changing the power balance between researchers and participants.” [139] As medical researchers Paskins et al. detail, “VSR appeared to have added value in patient interviews, empowering patients to express what was important to them and to divulge more emotional or reflective responses to the consultation.” [138]

7.1.3.1 Appropriateness and Applications

VEMs are relatively new to the research "scene," and understandably so, considering the need for technology which is not only commercially available, but also able to accurately, dependably, and conveniently be implemented into interpersonal human exchanges. In recent years, however, technology has met pace with need and is increasingly incorporated not only as a valid components of varied research methodologies, but also as a valuable tool for professional practice in multiple fields.

Due to the intense and highly focused nature of musical production it would not be effective to ask participants of the *Torpere* study to describe their experiences during a performance. Barton elucidates this issue across many fields, including educational training: "In many naturalistic settings, participants cannot be asked to verbalize their thinking at the same time that they are involved in ongoing activities...As a result, researchers have attempted to gain insight into cognitive processes by asking participants to recall their thinking at a later time, frequently while they watch video recordings of lessons or lesson segments." [139]

In his paper *'So, as you can see...': some reflections on the utility of video methodologies in the study of embodied practice*, Paul Simpson details this exact sentiment in his experiences as a researcher tasked with reflecting on his own experiences during a musical performance: "With a significant part of my attention focused on performing, and not necessarily being able to take notes at the time of the occurrence, there was no way I could keep a note of the duration of certain occurrences or how they related to each other, or even the specific details of what people said/did." [140] Though he argues that no VEM can capture or recreate the embodied experiences of a performer, he also points out that, "The video facilitated my reflection on the relations that occurred and what complex–singular relations contributed to their coming about, or was useful in the illustration and examination of my auto-ethnographic experiences. There is a significant distinction to be made here between the video facilitating the reflection on and examination of these contingent affective relations as a further form of documentation, but not as necessarily constituting the actual presentation of these affects." [140]

There are those who believe, however, that VEMs may be capable of more than simply prompting reflections on affective experiences. Mental health specialist Bonnie Raingruber argues that:

> "Video-cued narrative reflection provides moment-by-moment access to tacit experience. The immediate nature of the videotape captures emotional nuances, embodied perceptions, spatial influences, relational understandings, situational factors, and temporal manifestations. By watching videotaped interactions, participants are able to re-collect, reexperience, and interpret their life world. Video-cued narrative reflection allows participants to be simultaneously engaged and reflective while describing significant understandings." [135]

Simpson further describes the affordances of VEMs, which can allow "participants and researchers alike bring into focus aspects of practice that have previously been blurred or out of shot...the researcher can begin to explore how people use space and their bodies, how people interact with space, understand where and how they look, and ultimately gain a far more nuanced idea of how participants derive meanings through movement." [140] Though the *Torpere* study was mainly concerned with how the participants described and differentiated their experiences with each instrument—and whether or not their experiences of creativity and expression were impacted by the heightened risk state—capturing the spatial and temporal relationships of each musician became important markers for discussion and reflection. For example, during their high-risk video reflection Participant 3 can be seen shifting from bowing and plucking the instrument to placing many objects on the its strings, dropping metal tools on it from varying heights, and generally reducing direct bodily connection over time (see Figure 7.1).

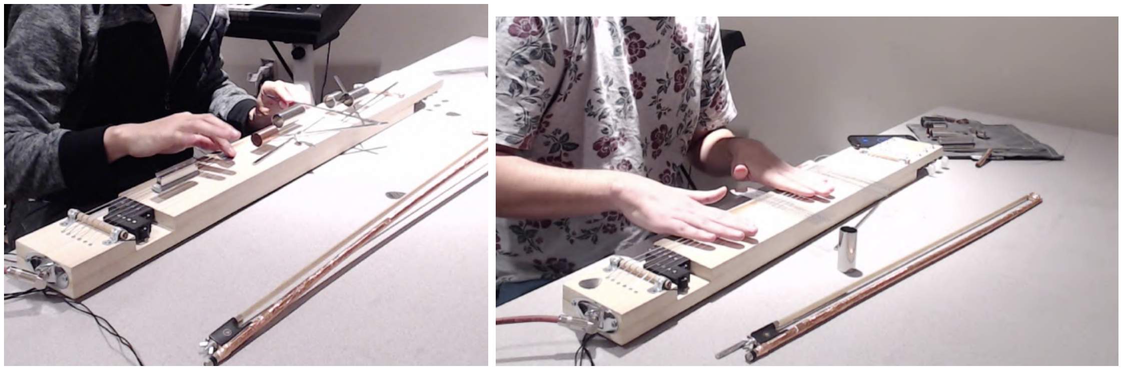


Figure 7.1: P3 reducing physical connection to the instrument, compared with P5's full physical engagement

By addressing this shift and prompting P3 to consider why this might have happened it was revealed that the sensations they felt gradually but steadily formed a sense of fear in their mind, which they began paying more and more attention to and actively trying to attenuate by retreating as far from the instrument as possible while still creating music.

The physical and material risk embedded in the high-risk version of the *Torpere* depends intrinsically on the bodily engagements of the practitioner; the perceptual experience is shaped by the corporeal. Raingruber emphasizes this point in her statement that, "Somatic understandings and perceptual experiences may be the most fundamental measure of how we experience the world...Experience is best described not with words but by embodied responses, practices, sensory perceptions, and tones or climates of feeling." [135] The immediacy and sometimes overpowering nature of the somatic experience can be seen clearly in the experiences of nearly all participants in the *Torpere* study. Participant 1, for example, experienced a buildup and subsequent release (burst) of electricity when playing the high-risk version of the *Torpere* and stated, "After that big shock I kind of just, like, moved away from stretching the strings too much, I think." When asked to elaborate what impact this had on their creative process, P1 elaborates:

> **Interviewer:** So how much—I don't know if "fear" is the right word, but, like, tentativeness because of the electricity were you feeling throughout this?
>
> **P1:** Oh yeah. Less right after the shock, actually. Because it—it moved from subconscious to conscious over the course of the rest of the improv session.

In addition to the aforementioned issue of limited mental bandwidth when simultaneously performing and describing an experience, VEM introduces a bit of space between more jarring physical experiences and the in situ response of the participant, which might be involuntary or subconscious. Participants in such a "reactionary" state may be unable to access the words needed to describe what they are experiencing. VEM allows for the researcher to both "bring experiences back to life and...develop a renewed contact and deeper familiarity with the original experience...[it] allows one to back up and look again" while also "[putting] participants back into their experiences [and] allowing them sufficient distance to re-collect their thoughts and feelings." [135] This is, of course, all in addition to the well-known fallibility of human memory: "A person's memory and insight into his or her own mental processes are notoriously imperfect and inaccurate. Video elicitation interviews can facilitate more accurate recall of specific events that participants are likely to forget or mis-remember during standard interviews. Participants often notice new or unexpected aspects of the interaction during video elicitation interviews." [136]

Because the *Torpere* study is interested in understanding the subjective experiences of practiced musical improvisers it was important to acknowledge and respect not only the expertise of the study participants, but emphasize the validity of their personal experiences and feelings. As Barton explains, "Participants may know a great deal about a topic and have a great deal to say, but special tasks are sometimes necessary to bring their ideas to the surface, as well as to encourage them to articulate those ideas in deeper and more complex ways. Elicitation techniques accomplish this by making the research process more transparent, comfortable, and authentic." [139] Loosely guided video reflections allowed each musician to control the pacing of discussion and address their personal experiences as important, relevant, and worthy of study.

Barton describes this empowerment for participants, who "literally become experts who lead researchers through content rather than receptacle of information, extracted by researchers, analyzed and assembled elsewhere. With many tasks, participants can control the exchange of information, introduce ideas and concepts they consider relevant and significant, and participate meaningfully in the research process. Giving participants greater control can also yield data that more authentically reflect their conceptual categories." [139] Raingruber similarly describes participants' increased agency through VEMs: "In traditional interviews, the researcher must craft the question and ask it in a way that encourages reflection. Video-cued methods acknowledge the ability of a participant to know, to understand, and to reflect on his or her own experience." [135]

7.1.3.2 Caveats and Cautions

Any and all research that monitors and evaluates human behavior shares the same age-old concern that, by watching someone or something, we may inadvertently change or influence behavior. Video is, of course, no exception to this: "One theoretical concern with using video recorded consultations for research is the notion that video recording alters "natural" behavior...The existing literature suggests little or no effect of video recording on GP behavior; however, there is a lack of empirical evidence supporting this assertion (and no studies to our knowledge have investigated the effect on patient behavior) and little prospect of furthering this evidence base in the absence of randomized studies with covert recording." [138] One needs not participate in a study to appreciate this concern—who has not felt the pressure of a lens pointed at them? Despite these seemingly generalizable experiences, Henry and Fetters found that, "52 researchers investigating camera-related behaviors in different clinical settings have found scant evidence to suggest that video recording changes participant behavior." [136]

Others disagree, arguing that not only does VEM result in negative feelings on the part of those being recorded, but that these realities are not reported *because* of the recording process: "Despite the method being broadly acceptable, participants did describe various responses to either the video or VSR including anxiety, distress, feeling self-conscious, and bored...To our knowledge, the finding that patients may find viewing their consultation distressing or even boring has not been previously reported. It is possible that some of these expressed emotions hindered participants from opening up in the postconsultation interviews, although it proved difficult to provide any empirical evidence to confirm or refute this hypothesis." [138]

7.1.3.3 The Fact Versus the Feeling

The single most difficult issue to overcome during the *Torpere* study was eliciting information from participants about *what* they felt during their improvisations, as opposed to *why* they felt that way. van Braak et al. describe in detail the distinction between two modes of elicitation afforded by VEM: *recall*, which "Gains insight into cognitive processes underlying and taking place during actual behaviour," and *reflective*, which "Produce[s] an interpretation of a phenomenon (behaviour, practice) as the participant understands it." [137] The goal of the *Torpere* study was to gather reflective data: insights into the subjective experiences of participants. What happened, in reality, was a strong tendency among participants to recall the *how* and *why* of a decision or action.

It is tempting to attribute this in part to the natural inclinations of participants: many had backgrounds in engineering or computer science, and may have been less comfortable—or at least less familiar—with describing ambiguous thoughts and feelings instead of clearly defined, observable phenomenon. However, part of the problem might have been introduced by the elicitation method itself. As Simpson identifies, "While in video we can see the minute detail of bodily movements and non-verbal communication, alongside verbal communication and other sounds, it arguably provides little in the way of a sense of the felt aspects in and of these movements." [140]

7.1.4 Qualifications and Characterizations of this Research

To summarize, this research is:

1. **Performer-oriented:** The perception of the musician is the highest concern. The role of the audience is of no relevance in this particular case, and any notions of "coding" emotion through musical cues or evaluating the quality or success of the musical

output is disregarded. Motor precision, technical skill, and other indicators of musicianship are likewise irrelevant—the use of experienced musicians is important for the sole reason that individuals with a wealth of experience creating and performing music are better able to self-evaluate and self–reflect on subjective measures of perceived expressivity in relation to years of experience in the field.

(a) Guided by O'Modhrain's Performance-Based model of evaluation:

i. Identification that, "Ultimately the best evaluation of a performance is one's own impression of how compelling it was to participate in or to attend...Performance should be considered as the ultimate evaluation of any instrument design, and digital instruments are no exception. Performers are the only people who can provide feedback on an instrument's functioning in the context for which it was ultimately intended, that of live music making."

2. **Instrument-Independent:** Unconcerned with the application of existing techniques and/or knowledge which the musician brings to the table. While the instrument may emulate certain standards (stringed, guitar-like, electronic/acoustic (as opposed to digital)), various methods of actuation are available to the performer (bowing, striking, strumming, picking, sliding), and there is no expectation of emulation in the research context.

   (a) Designed to explore principles of expressivity and risk which will develop into potential design guidelines

3. **Qualitative:** Focused on the subjective experiences of the performer during a creative act. Task reproducibility, musical accuracy, and/or any other quantitative measures of "successful" musicianship or instrument functionality is of no value.

   (a) Inspired by Stowell et al.'s approach to discourse analysis, "An analytic tradition that provides a structured way to analyse the construction and reification of social structures in discourse...In live musical interaction the performer has privileged access to both the intention and the act, and their experience of the interaction is a key part of what determines its expressivity."

4. **Phenomenological:** The relationship between musician and instrument is paramount to the research, not as a user-device relationship, but rather as a phenomenological experience more akin to crafter and tool, through which a creative practitioner navigates an experience to produce creative content unbound by quantitative metrics (accuracy, reproducibility, actuation technique, etc.).

   (a) Accounts for mental models as defined by O'Modhrain: "An internal representation of an experienced reality. It is built on-the-fly, from knowledge of prior experience, information acquired via perception, and problem-solving strategies. Such a model contains minimal information, is unstable, and is subject to change. Its purpose is to guide decision-making in novel situations and to provide feedback on such decisions."

7.2 null/void Research Methodology

7.2.1 Overview

As with the *Torpere* study, recruitment for *null/void* participants began in the School of Music at Georgia Tech, specifically targeting individuals experienced with musical improvisation and computational technology. In addition, a call was released on social media requesting that interested computer music practitioners communicate interest in potentially participating. Roughly 10 musicians responded; however, those residing abroad were ineligible to participate in the study due to IRB policies. A total of four participants took part in the study: The average age was 33 years old (median = 35), and the average years' musical experience was 26 (median = 28).

7.2.1.1 Cultural Probes

While the *Torpere* study was structured around in-person interviews, the *null/void* study was deployed quite differently. It was crucial, with the *Torpere*, to collect rich data sets regarding how practitioners physically interacted with the design objects and engage in reflective discourse as promptly as possible after each improvisatory performance. Not only did the observer collect information regarding how each participant engaged with the materials of the instrument, but also paid close attention to how each individual considered their own performances—something made possible through VEMs. This was a successful approach due to several factors:

1. **Standardization:** Each participant was provided with identical tool sets with which to craft an improvisation
2. **Duration:** The data gathering process could be conducted over one 2-hour long session with each participant
3. **Demographic:** The study aimed for a wide sample of practitioners from many different backgrounds: engineering, classical music, improvisation, and so on. Each participant was familiar with different physical and digital tools for music production

4. **Scope:** The point of interest in the study was limited to the experiences of the performer when using two related systems (A/B comparison). Both versions of the instrument were novel to participants, with one functioning at a higher risk state than the other. Novelty was a baseline factor for the entirety of the experience, with the highest risk state engaged through physical and material unpredictability and potential for failure

null/void required a different approach due to the difference in each of these areas:

1. **Standardization:** Computer musicians do not often perform with standardized systems; each performer has a coding environment of their own, often drastically different from other practitioners. Attempting to create a new environment for multiple practitioners to use would very likely be creatively stifling to someone used to their own coding software

2. **Duration:** Deploying a novel coding environment to multiple computer musicians would require prohibitively long training sessions. It was more appropriate to give participants a *null/void* system to use within their own practice over a longer period of time and collect data throughout

3. **Demographic:** This study aimed for a relatively narrow scope in terms of practitioners: those who use laptops alone as their instrument. Additionally, the community of active laptop musicians is less localized than computer music practitioners in general, and gathering a suitable number of participants locally would present its own set of challenges

4. **Scope:** The point of interest in this study is not an A/B comparison, per se, but rather the application of a modular tool which can be inserted into any kind of live coding situation. Because many computer musicians use different platforms for different performances, offering a generalizable tool for use in a practice which may employ varied combinations of digital tools was better suited to gathering rich data for the study

Researchers and designers Gaver, Dunne, and Pacenti have developed a unique methodology for experimental design practices geared toward understanding the experiences of small communities, one which is deployed through "cultural probes." Cultural probes (CPs) are most often packages of materials sent to participants with the intention of stimulating the imagination and gathering insights into the lives and experiences of individuals and communities. Logistically, this approach is an effective way to combat distances, both geographic and cultural.

In previous chapters we have seen an argument for the inclusion of edge cases and fringe activities within CMPs rather than looking primarily at the most prevalent practices of the community. CPs function in this spirit of inclusion and experimentation, as it, “Allows us–even requires us–to be speculative in our designs, as trying to extend the boundaries of current technologies demands that we explore functions, experiences, and cultural placements quite outside the norm.” [141]. It also serves the function of, “[Shaking] the preconceptions” about a particular culture. [142]

The methodology embraces what the authors describe as, “Traditions of artist-designers rather than the more typical science- and engineering-based approaches” and draw inspiration from many artistic movements including Situationism, Dadaism, and Surrealism. In addition, the practice of deploying CPs is largely situated within a design context that is interested in understanding the value of new technologies within a specific community with unique cultural identities. Most importantly, like thematic analysis CPs place participants in an “expert” role rather than “subject” of a research inquiry.

As has been made clear, the research conducted in the *Torpere* and *null/void* studies explicitly embraces the subjectivity of practitioners’ experiences rather than attempting to objectively measure such phenomena. CPs allow for a, “Mingling [of] observable facts with emotional reactions.” [142] In a project such as *null/void*, where theoretical and conceptual questions were being posed (often with a speculative future in mind) CPs offered the possibility of collecting data to support “conceptual interests, technological possibilities, imaginary scenarios and ideas for how to implement them.” [142].

Cultural probes were an appropriate methodology for data gathering in the *null/void* study because they offer the following qualities that resonate with the spirit of inquiry:

1. **Deployment:** CPs can be sent to multiple practitioners regardless of their geographical location and used by participants regardless of their personal performance setup
2. **Empowerment:** CPs allow for each subject to speak about their experiences candidly, and does not encourage a power differential that is present in other formal research methodologies. The “status quo” of existing research objectives and priorities are encouraged to fall away, opening the door to those within the community that may feel marginalized or excluded from the discourse

3. **Subjectivity:** CPs encourage participants to share their experiences in their own words, and places value on subjective experiences

4. **Unpredictability:** Because CPs prioritize the phenomenological aspects of a performer's experience and does not presume authority on the part of the researcher, it offers a level of flexibility in terms of the data that is gathered—like thematic analysis, CPs allow for unexpected and surprising themes to emerge from the data. While more rigid methods may unintentionally impose limits on the possible data gathered, CPs remain open to any and all points of relevance.

7.2.1.2 Cultural Probe Materials

Beyond the *null/void* interface itself a range of materials were included in the packages sent to participants, including a whiteboard, markers, magnets, journals, action and reflection prompts, and access to an online repository for uploading image and audio documentation.

7.2.1.3 Designing Interview Questions

The interview questions for the *null/void* study were developed from the *Torpere* questionnaires. Similar questions regarding musicians' approaches to musical improvisation, dealing with mistakes and errors, and expressing themselves through their instruments appeared in both studies, with slight adjustments for physical or computational contexts. Some questions were added to the *null/void* interview guide to prompt discussions regarding unique features of computational musical systems; for example, "Why did you begin using computational technology in your practice?" and, "Do you think that computational technology offers something that traditional/analog instruments don't?"

Because there was no formal video reflection in the *null/void* study (though it was facilitated with one participant), post-study questions were fairly direct. Generally, participants were asked about their different experiences with the low- and high-risk *null/void* modes, whether or not the interface caused them to feel differently about their musical process, and what role the interface played in their perceptions of creativity and musical expression.

7.2.1.4 Action and Reflection Prompts

One component of the *null/void* cultural probe package was a set of action and reflection prompts. Intended to offer optional sources of guidance to participants, these prompts take inspiration from both design practices and experimental music; in particular Peter Schmidt and Brian Eno's 1975 *Oblique Strategies* card deck served as guidance in the development of prompts that would engage *null/void* participants in self-reflection and musical activities. The cards contained the following prompts:

Reflection:

- How much do you worry about failure? What kinds of failure do you worry about?
- How do you think about the limitations of your instrument?
- What do you do when something goes wrong?
- How do you create music that reflects your own voice?
- How do you feel when you don't know what's about to happen?

Action:

- Set your resource bank values to the following: TIME = MAXIMUM, AMPLITUDE = MINIMUM, PITCH = MINIMUM. Improvise until one of your resource banks run out.
- Set your resource bank values to the following: TIME = MINIMUM, AMPLITUDE = MAXIMUM, PITCH = MAXIMUM. Improvise until one of your resource banks run out.
- Improvise a piece with 5 sections.
- Improvise a piece around a single note or phrase.
- Use extreme silence and noise.

CHAPTER 8

ANALYSIS

8.1 Thematic Analysis

Thematic analysis was applied to the qualitative data from both the *Torpere* and *null/void* studies. The process was undertaken solely by myself as the primary investigator. This was done for two reasons: first, as the interviewer who engaged with each participant in a one-on-one capacity, I was uniquely equipped with an understanding of the latent meanings behind the textual data of the study. Having observed the emotional and nonverbal behaviors of each participant over the course of many hours, the nuances of their comparative descriptions between low- and high-risk engagements were apparent in a much more meaningful way than might be observed by a third party who was privy only to the abstracted transcription data.

Second, my ability to relate the content of the interviews to the real-time improvisational performances that they describe was crucial for understanding the sentiments that were expressed through participant reflections. Because thematic analysis not only accepts the viewpoint of the analyst as inherent to the exercise, but as a *valuable* element of the process, the bias involved in these studies is acknowledged, accepted, and presented with as much transparency as possible.

8.1.1 Torpere

The interview and video reflection sessions were transcribed for the seven *Torpere* participants. Roughly five hours were transcribed, with the average duration for each portion of the study being:

Participant	P1	P2	P3	P4	P5	P6	P7
Pre-Testing Interview	12.00	13.00	21.49	15.50	7.50	26.30	19.06
Low-Risk Improvisation	10.00	7.18	10.40	7.50	8.18	8.52	8.23
High-Risk Improvisation	10.15	7.28	11.30	7.15	10.50	7.08	14.00
Low-Risk Reflection	10.49	8.31	16.23	8.10	8.46	14.58	14.14
High-Risk Reflection	12.15	10.36	14.36	11.35	10.25	23.19	30.13

8.1.1.1 Rough Coding

Initial patterns across the data sets were identified using a complete coding approach. In contrast to selective coding, which identifies specific instances of narrow criteria, complete coding identifies, “Anything and everything of interest or relevance” to the research question. [143] Because this research is interested not only in understanding the role of risk in expressive activities, but also how computer musicians experience the many facets of physical, computational, and improvisational engagements, it was crucial to consider the entirety of their experiences as valid and valuable insights into those qualities of their process. Therefore, each statement from participants was considered relevant if it expressed an opinion, feeling, or thought regarding the following:

1. Personal approaches to musical creativity, including modes of exploration, performance, improvisation, and composition
2. Physical and/or computational interactions, including discussions of instrument and interface constraints and affordances
3. Definitions and considerations of elements of unpredictability, risk, and/or failure in the creative process

Each statement made by participants within the transcripts was analyzed for relevance to these criteria. If identified as relevant a statement was given rough codes summarizing the opinion, belief, or thought expressed by the participant. A total of 1141 of these initial codes were produced across *Torpere* participant statements: 387 from the pre-testing interview portions, 335 from low-risk reflections, and 419 from high-risk reflections. These initial codes were largely semantic and maintained the explicit language used by each participant. For example, P1's statement, "So this is actually the right amount of unfamiliar to play with for it to be fun" was coded as "The "right amount" of unfamiliarity is a fun/positive element." P3's statement, "At this stage, I think I was more frustrated than, like, really free to do anything. Still trying to control the pitches" was coded as "Attempting to impose control can lead to frustration."

Participant	P1	P2	P3	P4	P5	P6	P7	Total
Pre-Testing Interview	85	44	71	58	34	84	11	387
Low Risk Improvisation	54	39	50	45	25	102	20	335
High Risk Improvisation	76	50	55	55	54	86	43	419
Total	215	133	176	158	113	272	74	1141

Statements were coded with as many codes as necessary to represent the emotions, opinions, and beliefs conveyed by participants; for example P6's statement, "I was unusually invested the first time, more so than I've been with anything in a while. Because it was unfamiliar, but it was tonal and I knew that I could change things and that I was drawing on existing musical knowledge" was coded as "Balance of unfamiliar and known framework results in high investment," and "Familiarity allows for the application of existing skills and knowledge." Because codes also took context into consideration—in this case, because P6 was speaking positively about the low-risk version of the instrument in comparison to the high-risk instrument—the statement was additionally coded as "Unfamiliarity and unpredictability must be contained within a familiar framework to be positive."

8.1.1.2 Topics and Individual Collation

After coding, participants' codes were collated using a combination of semantic and latent approaches, where the semantic language used was largely maintained while also identifying potential conceptual and theoretical frameworks across their individual coding corpus.

The 1141 rough codes were reduced to 697 across the seven participants. The codes were compared across the entire data set and broadly grouped into *topics* in order to work toward the identification of candidate *themes*. Initial topics that emerged from this process include the following:

Participant	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**Total Per Topic**
Unpredictability	37	15	20	20	47	9	31	179
Constraint/Affordance	0	6	1	512	6	20	6	51
Error/Failure/Wrong	5	13	6	13	3	22	4	66
Goals/Objectives	11	8	12	4	3	22	4	64
Physical/Computation	1	0	0	0	0	2	1	4
Thinking/Cognition	2	0	0	1	0	3	0	6
Creativity/Process	5	0	1	2	4	10	1	23
Schema/Paradigm	23	13	13	4	3	12	3	71
Control	19	4	6	4	6	14	1	54
Performance	17	1	3	0	5	3	4	33
Composition	1	0	1	2	4	15	2	25
Improvisation	3	0	0	3	4	6	3	16
Exploration	17	1	0	9	4	8	2	41
Total	137	65	77	90	89	173	66	697

8.1.1.3 Cross-Collation and Candidate Themes

Through each step of this process codes were considered relevant and valuable. However, only by examining the overlaps and divergences among *and across* the seven members of the study could meaningful themes allowed to emerge. The 697 codes within the 13 topics were analyzed both in terms of the context in which they occurred as well as the context of the other six participants' codes, which allowed for further refinement of the coding framework.

Some topics were subsumed into a larger unifying group; for example Composition, Exploration, Performance, and Improvisation each involved discussions of what makes different musical activities unique based on process and context. As such, these categories were combined to form Topic 7: Creative Modes. The categories Physical and Computational Systems, Thinking and Cognition, and Creativity and Process were each concerned with the role of the body, mind, and tools for production are used in creative activities; therefore they were combined into the larger Topic 4: Creativity. In total, eight topics were identified that reflect the most meaningful elements of participant experiences as relate to risk in musical engagements, containing 241 cross-collated codes:

Topic	**Total Per Topic**
Unpredictability	26
Constraint/Affordance	14
Error/Failure/Wrong	33
Goals/Objectives	24
Schema/Paradigm	22
Creativity	54
Control	20
Modes	48
Total Codes	241

Themes and subthemes were developed as necessary to maintain relevant distinctions between these larger coding clusters. Though participants consistently contributed to discussions regarding the fundamental topics, individual beliefs, opinions, and thoughts were highly personal and often contradictory. Given the diversity of perspectives, many candidate themes that developed into formal themes encapsulate a diverse range of idiosyncratic sentiments regarding a singular phenomena. For example, Topic 5. Schema and Paradigm includes three themes: 5.1 Schema and Paradigm are Required, 5.2 Schema and Paradigm Scaffold Creativity, and 5.3 Schema and Paradigm are Limitations. Each theme represents multiple codes as collated among and across participants. For example, within Theme 5.3 the code "Paradigms and objectives can be rigid and restrictive, limiting creativity and exploration" broadly represents the feelings expressed by multiple participants at varied times, with some examples including:

> **P1:** Touching the pickups and going through the feedback could have been a thing to explore. But as far as sort of normal playing on the strings, I was like "Oh I know what this does."

> **P2:** When I try to play with the bow actually, it's hard to–it's not like violin where you have a curved bow, it's all flat. So, I think the only string in this case I can use is, like these two...I try my best to figure out, to change the instrument, but it doesn't work.

> **P3:** I think I was more frustrated than, like, really free to do anything. Still trying to control the pitches. I'm trying to do the harmonics thing...I'm still in the mode of trying to make some stable pitch and sound with this harmonic thing, this sliding thing, like a guitar paradigm.

> **P6:** I don't have frets so I can't play this comfortably... I tried pushing down the string hard enough where I could actually play notes without having to do this, and it hurt my fingers so much that I stopped.

In Topic 2. Constraints and Affordances, we can see two themes: 2.1 Constraints and Affordances are Productive, and 2.2 Constraints and Affordances are Barriers. These themes represent the ways participants reflected on their experience with the *Torpere*, but also encompass the perspectives they expressed in discussions about their practice. Both of these themes have three subthemes that detail the particular commonalities that emerged across participant data—for example, if Participant 1 and Participant 5 reflected that their improvisation was driven by a desire to discover the *Torpere's* sonic capabilities, and Participant 7 described an interest in understanding the physical affordances of the instrument, those codes would both be represented in Subtheme 2.1.1 Constraints and Affordances Drive Exploration. That subtheme sits within Theme 2.1 Constraints and Affordances are Productive, which itself lies beneath the broad Topic 2. Constraints and Affordances.

8.1.2 Torpere Thematic Codebook

The final thematic codebook can be seen below, where the relationships between topics, themes, subthemes, and codes can be observed. A full codebook that include individual codes can be found in Appendix A.

Topic	Theme	Subtheme
1. Risk: Unpredictability	1.1 Unpredictability is Valuable	1.1.1 Unpredictability Pushes Beyond Familiar
		1.1.2 Unpredictability is New/Revealing
		1.1.3 Unpredictability is Human
	1.2 Unpredictability is Negative	1.2.1 Unpredictability Kills Creativity
		1.2.2 Unpredictability Kills Performance
		1.2.3 Unpredictability is Uncontrollable
2. Constraints and Affordances	2.1 Constraints & Affordances are Productive	2.1.1 C&A Drive Exploration
		2.2.2 C&A Are Uniquely Interesting
		2.2.3 C&A and Emergence
	2.2 Constraints and Affordances are Barriers	2.2.1 C&A are Impositions
		2.2.2 C&A Lead to Abandonment
		2.2.3 C&A Conflict with Skill
3. Failure, Error, and Wrong	3.1 FEW are Negative	3.1.1 FEW are Objective
		3.1.2 FEW is Incompatibility/Conflict
		FEW Ruin Everything
	3.2 FEW Are Valuable	3.2.1 FEW Prompts Creativity
		3.2.2 FEW are Human
		3.2.3 Failing at Failing
4. Creativity	4.1 Creativity and Cognition	4.1.1 Plans and Methods
		4.1.2 Setting Creativity Free
	4.2 Creativity is Physical	
	4.3 Computational Creativity	
	4.4 Creative Tools	

Topic	Theme	Subtheme
5. Schema and Paradigm	5.1 S&P are Required	
	5.2 S&P Scaffold Creativity	
	5.3 S&P are Limitations	
6. Goals and Objectives	6.1 Goals and Objectives are Inherent	6.1.1 G&O Define Creative Processes
		6.1.2 G&O are Judgeable
		6.1.3 G&O are Fluid
	6.2 Creativity is Free from Goals and Objectives	6.2.1 Lack of O&G is Good
		6.2.2 O&G Cause Problems
7. Modes	7.1 Exploration	7.1.1 Bounded Exploration
		7.1.2 Exploration as a Process
		7.1.3 Exploration as Unbound
	7.2 Performance	7.2.1 Performance, Bound
		7.2.2 Performance Objectives
	7.3 Composition	7.3.1 Composition, Bounded
		7.3.2 The Composition of Composition
8. Control	8.1 Control is a Requirement	8.1.1 Control is Skill and Knowledge Made Visible
		8.1.2 Control is Required for Creative Expression
		8.1.3 Control or Bust
	8.2 Control is a Constraint	8.2.1 Control Hinders Creativity

The significance of this codebook is twofold:

1. It allowed, through the process of development and refinement, for salient themes to emerge based on the experiences and perspectives of practicing computer musicians
2. It presents a network of the values, beliefs, and needs of computer musicians through which we can begin to understand the possible criteria for expressive musical engagements and the role that risk might play in those activities

8.1.3 null/void

Roughly 2 hours and 48 minutes of interviews with the four *null/void* participants were transcribed, with the duration of each being:

Participant	**P1**	**P2**	**P3**	**P4**
Duration	1.15.08	38.20	26.00	27.55

8.1.3.1 Rough Coding

The same process used for the *Torpere* data was applied to the *null/void* transcripts. First, complete coding was used to produce rough codes across the dataset. Participant statements were analyzed for relevance using the same criteria as the previous study, with one addition:

1. Personal approaches to musical creativity, including modes of exploration, performance, improvisation, and composition
2. Physical and/or computational interactions, including discussions of instrument and interface constraints and affordances
3. Definitions and considerations of elements of unpredictability, risk, and/or failure in the creative process
4. **Statements regarding the conceptualization of materials and resources in computational musical systems**

Because the *null/void* study was introducing an object to musicians with the explicit purpose of representing pitch, amplitude, and time, it was important to make accommodations for that particular topic. While a statement such as "I was thinking about my materials" might not necessarily be of tantamount importance within the *Torpere* data, it would be extremely relevant to the *null/void* research; therefore it was valuable to keep this additional factor in mind.

Participant statements were analyzed for relevance in terms of these criteria. If identified as relevant a rough codes was given to summarize the statement. A total of 818 initial codes were produced through this process.

Participant	**P1**	**P2**	**P3**	**P4**	**Total**
Rough Coding	358	159	181	120	818

8.1.3.2 Topics and Individual Collation

These rough codes were collated among each individual using a combination of semantic and latent approaches, where the semantic language used was largely maintained while also identifying potential conceptual and theoretical frameworks across their individual coding corpus.

The original 818 rough codes were reduced to 462 using this process. By comparing the codes across the entire data set they were broadly grouped into the following 14 topics:

Participant	P1	P2	P3	P4	Total Per Topic
Improvisation	12	0	8	3	23
Performance	2	7	6	2	17
Exploration/Experimentation	3	2	2	1	8
Design	4	6	2	5	17
Schema/Paradigm	19	16	1	8	44
Computation/Acoustics	21	4	0	4	29
Limitations/Constraints	0	9	8	0	17
Failure	20	14	3	4	41
Expression	7	7	8	1	23
Agency/Otherness	8	6	7	12	33
Unpredictability	11	16	10	6	43
Metaphor	24	3	5	5	37
Resources	23	1	30	8	62
HCI	10	13	29	16	68
Total Per Participant	141	102	92	65	462

8.1.3.3 Cross-Collation and Candidate Themes

As with the *Torpere* data, candidate themes were analyzed for similarities and divergences. The contents of some candidate themes were divided and absorbed into and among others, and some consolidated entirely. For example, Improvisation, Performance, and Exploration/Experimentation were combined under Topic 1: Creative Modes. Elements of Unpredictability, Expression, and Computation/Acoustic were divided and recombined into two topics: 2. The Effects of Unpredictability, and 5. Defining Risk: Computational Unpredictability. These two topics represent the sentiments of the three original groupings, but do further work in highlighting the latent connections of unpredictability, randomness, design, and expressivity in computational music. Similarly, the majority of codes within the topics of Design, Limitations/Constraints, and Schema/Paradigm were combined within Topic 3. Paradigm and Schema (with some finding a place in Topics 5. Computational Unpredictability and 6. Making a Metaphor Real. Below are the final seven *null/void* theme categories:

Topic	**Total Per Topic**
Creative Modes	29
Effects of Unpredictability	17
Paradigm/Schema	18
Computational Failure	21
Computational Unpredictability	30
Making a Metaphor Real	13
Effects of Metaphorical Risk	50
Total Codes	178

8.1.4 null/void Thematic Codebook

The final thematic codebook can be seen below, where the relationships between topics, themes, subthemes, and codes can be observed. A full codebook that include individual codes can be found in Appendix B.

Topic	Theme	Subtheme
1. Creative Modes	1.1 Exploration	
	1.2 Performance	1.2.1 Performance is...
		1.2.2 Performance Does...
	1.3 Improvisation	1.3.1 Improvisation in Performance
		1.3.2 Improvisation as Exploration
2. The Effects of Unpredictability	2.1 Unpredictability is Valuable	2.1.1 Expression as Response
		2.2.2 Unpredictability as a Prompt
	2.2 Unpredictability is Negative	
3. Schema and Paradigm	3.1 Expectations and Assumptions	
	3.2. Successful Schema and Paradigm	
	3.3 Unsuccessful Schema and Paradigm	
4. Computational Failure	4.1 Computational Failure is Different	4.1.1 Failure in Time
		4.1.2 Failure of the Self
		4.1.3 Computation is...
	4.2 Computational Failure is Negative	4.2.1 There is No Time
		4.2.1 There is No Time

Topic	**Theme**	**Subtheme**
5. Defining Risk: Computational Unpredictability	5.1 The Nature of the Machine	5.1.1 Computation is What You Make it
		5.1.2 Computer Beings
	5.2 Unpredictability is Not Randomness	5.2.1 Design and Control
		5.2.2 Internal/External
		5.2.3 Creative Randomness
6. Making a Metaphor Real	6.1 Metaphorical Success	6.1.1 Internal and External Harmony
		6.1.2 Feels Really Real
	6.2 Metaphorical Failure	6.2.1 Form and Function
		6.2.2 Internal and External Conflict
7. Effects of Metaphorical Risk	7.1 Positive Musical Impact	7.1.1 The Benefit of Limitations
		7.1.2 Creativity and Expression
		7.1.3 Realizations and Reflections
		7.1.4 Engaging with the Other
	7.2 Negative Musical Impact	7.2.1 Disruption
		7.2.2 Metaphorical Uselessness
	7.3 Potential Futures	

8.2 Conclusion

The number of codes produced through each study differ: 1141 initial codes in the *Torpere* study versus 818 in *null/void*. It is important to consider these numbers relative to the sample size, with nearly double the number of participants in the former (7) and only four in the later. With that in mind we can consider the process of thematic analysis, from rough coding to collation and finally to the finished codebook:

Codes	**Torpere**	**null/void**
Number of Participants	7	4
Rough Codes	1141	818
Individual Collation	697	462
Cross-Collation	241	178
Rough/Final Difference	-79%	-78%

If divided equally across the sample size (this is not an accurate depiction of the actual distribution of the codes, but will be helpful for comparison) the *Torpere* study had 163 codes per participant, and the *null/void* study 204. After codes were collated *among* participants, that number shifts to 100 and 116, and upon correlation *across* participants totals 34 and 45. The difference between the initial data set and the final codebook is a reduction of rough codes by 79% and 78%, respectively.

CHAPTER 9

FINDINGS: TORPERE

The eight themes presented in the *Torpere* codebook provide points of entry into discussions regarding how musicians understand, define, and engage with risk on multiple registers. In the following sections risk will be considered based on the definition developed in the previous chapters of this dissertation; that is: risk is a level of unpredictability and the potential for failure. Before we can discuss these issues, however, another theme must be discussed: 7. Creative Modes.

While the Creative Modes theme describes the motifs found across participant experiences, its subthemes are more closely tied to the individual codes drawn out of the data corpus. Subthemes provide a bridge between the rich detail of code clusters and the broader implications of the formal themes scaffolded upon them. By nature, subthemes draw the borders of code clusters, encapsulating what makes the codes contained within them unique and valuable; we can look to subthemes to better understand the boundaries of a particular theme and how it is distinct within the larger corpus.

Both the *Torpere* and *null/void* studies were designed with an improvisational activity in mind. As analysis of the data progressed, however, it became clear that *improvisation* is a concept with considerable variability across participants, each with distinct understandings of what an improvisatory musical performance is. While it can be tempting to focus on content that adheres closely to the research area of interest (the relationship between risk and expressivity within improvisational musical performances), what emerged from the data should not be disregarded.

Understanding the varied frameworks through which musicians structured their experiences has the effect of contextualizing and reinforcing the layers of meaning contained in more obvious discussions of unpredictability and failure. The first finding presented in this chapter, then, is a thematic framework for understanding how creativity and expressivity emerge in performative, compositional, and exploratory modes of engagement. The codes produced through analysis of participant data show distinct criteria for these different modes of creative expression and reveal different priorities and values embedded within each space.

9.1 Creative Modes: Performative, Compositional, Exploratory

Patterns of language emerged from deep analysis of the data from the *Torpere* study that describe not only how participants identify themselves, but also how they describe different parts of their improvisational experience. These categorizations did not necessarily reflect the interpretive data findings, particularly when taken as a whole and combined with what was observed in the lab experiment. Not only did participants self-identify in roles that were at odds with their descriptive reflections of their experiences, but many also defined their practice with language that did not accurately play out in their improvisatory actions. In fact, in almost all cases the way participants described themselves had no correlation at all to how they are categorized in this work. It should be recognized, then, that the three creative modes presented here are not derived exclusively from the language that participants' used to describe themselves and their practice (precisely what the pre-testing interview was designed to do), but instead represents the *observed* behavior of participants during their improvisation, and their own self-guided reflections after each performance.

Participants in the *Torpere* study approached their improvisations in one of three ways: as an *exploration*, a *performance*, or a *composition*. There is overlap in each of these categories, and because the *Torpere* was completely unfamiliar to all seven participants there were inherent periods of exploration, learning, and discovery. Further, because each musician created an original improvisation in real-time they can all be considered as both performers and composers. Participants themselves would undoubtedly consider themselves some combination of the three, and did not necessarily voluntarily identify themselves more with one category or another (though some did). However, the balance and duration of different musical priorities sets these three creative modes apart, with two extremes and one middle-ground.

At one extreme were the *composers*: individuals who prioritized applying their existing skills and knowledge to the *Torpere* in order to form a cohesive musical structure as quickly as possible. The improvisational process, for a composer, was aimed toward an end goal. At the other end of the spectrum were the *explorers*: individuals who drew no distinctions between the process of discovery and composition in their improvisations. For explorers, there was no concrete product or end goal, only a process of traversing through an unknown musical space. Between these two extremes was the most populous group, the *performers*: these individuals tended to segment their improvisations into discrete stages of discovery/learning and implementation/action. For performers, a successful improvisation was one in which musical capabilities are identified through a learning process, and employed to form a clear compositional arc.

9.1.1 Exploration

As a creative process, exploration is most often guided by learning and discovery. Where it begins and ends is nebulous, as there is not necessarily a concrete "end goal" involved. The most open-ended of the three creative modes, exploration was often directed by what was personally interesting or compelling to the performer rather than conventional performative or compositional objectives and motivations. Simply put: exploration was a process of uncovering the affordances and constraints of an unknown system and following a path through emerging points of interest.

Table 9.1: Torpere Exploration Codes

7.1 EXPLORATION

7.1.1 Bounded Exploration	7.1.2 Exploration as a Process	7.1.3 Exploration Unbound
Exploration is focused on and driven by what is personally interesting/compelling	Exploration is a continual process of searching, finding, developing, repeat	Exploration driven by desire to know the range and depth of instrument's affordances
Exploration requires safety, comfort, and familiarity	Exploration is a learning process: making the unknown known, curating content, following curiosity	Exploration accepts the affordances and constraints of the unknown
Exploration is less valuable than composition	Exploration develops into composition, or is a process of curating compositional elements	Exploration is an open space with which to safely engage with unpredictability
Exploration and composition are incompatible	Improvisation and exploration are inherently linked	Exploration reveals emergent points of interest, both in terms of music, instrument, and interaction
Exploration is driven by objectives, exists to serve those needs	Exploration can produce control states	Exploration happens outside of metrics/frameworks for "good/bad," "right/wrong"
Exploration within performance is only positive if it doesn't compromise the end goal	Exploration is a familiarization process	Exploration happens at the edge of discomfort, boundary of the known and unknown
Exploration prevents performance	Exploratory improvisations with new people is positive because others bring in new and unexpected ideas	Deep exploration can cause a loss of sense of objective, time
Low familiarity with an instrument allows for exploration, but not performance or composition	Exploration is a process of continually searching for new interesting spaces	

Bounded Exploration: Certain boundaries emerged through thematic analysis that set exploration apart from other musical activities. Most participants describe initial encounters with the *Torpere* as exploratory, with physical interactions generally geared toward developing a foundational understanding of the novel and unknown elements of the instrument. This initial exploratory state was a stepping stone toward other compositional or performative activities in most cases, suggesting a division between a stages of learning/familiarization and an application of knowledge.

When facing the unfamiliar *Torpere* instrument all of the musicians in this study took time to explore and identify the affordances and constraints that were readily available to them through physical and material interactions. For some, that exploratory process was utilitarian and purpose-driven: identify existing skills that effectively transfer to the *Torpere* and move on from there. For others, exploration functioned not only as an information-gathering mechanism, but also as an element of an iterative creative process balanced with more concrete musical objectives.

Many participants—*composers* in particular—used the term "exploration" to define activities that were in *opposition* to their personal objectives. The term was used by one composer as a way to highlight the value of composition, which was (for them) inherently higher; exploration was useful only if it served the needs of their compositional goals. In describing the difference between musical exploration and composition, they state:

> **P6:** I would say that I have trouble thinking up interesting music for music's sake...I approach music like scoring, almost always...I very rarely ever approach music as its own venture, which is maybe weird. The stuff that I do is always directed at a project. It's never really for improvement or exploration or something...I don't have the mental space to just do things for 'funsies'.

P6 places "fun" at odds with their personal practice, wherein musical exploration is considered a frivolous activity that prevents the more valuable compositional process. Engaging with music "for music's sake" does not interest P6 because their mental bandwidth is fully engaged with other creative priorities.

For *performers*, exploration was at times identified as a barrier to performance: following personal curiosities down a rabbit hole can distract one from more formal musical objectives. P1 described their segmenting of exploratory and performative processes when reflecting on their low-risk improvisation, contrasting the openness of exploratory "play" with a more structured performance modality. Here, exploration prevents a transition into performance:

> **P1:** I had meant to do, like, five minutes getting a handle on things and five minutes trying to do a performance, but I kept on finding new stuff, so I was just in play mode the whole time.

Exploration was also given definition by way of self-identified needs for a sense of safety and comfort during creative processes. Because expression is a deeply personal demonstration of the self, and because it is, by its nature, open-ended and unfamiliar, some individuals found it difficult to overcome feelings of discomfort and anxiety. P3 contextualizes musical exploration by describing the comfort and familiarity of existing creative tools (in this case, a loop pedal):

> **P3:** [The loop pedal] definitely makes me more comfortable...I know what to expect from using it. It creates repeating rhythm and that it would be very nice to have, but...I think it's [a] very limiting factor in terms of exploring sound or make interesting chord progression. With any constraints, my exploration [is limited]. I think [using the] pedal would be nice, but it's also cheating to some extent, right? It's something I'm very familiar with...I think I intentionally avoided using it. [I] wanted to explore more.

Here, P3 situates exploration as an engagement with the unknown, which can be limited and constrained by control and familiarity. Without the challenge of unfamiliarity, exploration is stifled within the creative process. Participant 1 similarly touches on the interconnected dynamics of exploration as "play" in unknown spaces and the comfort of familiarity in performance:

> **Interviewer:** I noticed a trend of you trying new things, but then going back to picking and slide, and trying new things, and back, and I wondered if that was [because of your] comfort zone.
>
> **P1:** Yeah. That's definitely what it was. Kind of playing around with stuff and then actually I saw the pedal, I was like, "Oh this is another thing I know," and then so much of [the rest of the performance] was playing around with that.

P2 describes a process of intentionally returning to a comfortable and familiar interaction in order to move *away* from exploration and *into* performance. Here, they rationalize the decision to abandon the unfamiliar metal slide in favor of a familiar violin bow:

> **P2:** I [go] back to the bow...I feel comfortable, like in the first [low-risk] round. I'm comfortable with the bow. So it's good to start in something you knew very well, then when you play it you can start to think of, what should I do next?

Exploration as a Process: Through analysis we are able to roughly define exploration based on what musicians clarify it is *not*: it is not performance or composition, it is not highly familiar or comfortable, and it is not driven by rigid objectives. From this, we can extrapolate a bit about what exploration *is*: it is relatively open-ended, driven by a desire to learn, and guided by personal curiosity and interest.

Exploration engages discovery and learning; it is a continually unfolding process of searching, finding, and developing musical content. There is an inherent level of flexibility, as exploration can transition into performance or composition based on the desires of the musician. Exploration can produce the control states required by a *performer*, or be a curatorial process for a *composer*. Alternately, exploration can be a venture unto itself, demanding no justification or rationale at all.

Participants who engaged in highly exploratory improvisations often described their improvisational activities as a repeating process of finding organic spaces and "sitting" in them for a brief period of time before continuing on:

> **Interviewer:** You were getting different textures out of moving your hand around percussively, changing the sound. And then you moved back to more melodic material. Do you have any idea why?
>
> **P5:** I really liked the whole muted percussive part. It felt a lot like just hitting the wood. It was different. But, I kind of just explored it enough to do something else. That's about it.

> **P7:** I was really digging the two different rhythms sitting on top of each other that weren't really lining up. So I went to sit on it.
>
> **Interviewer:** So this was definitely a shift, change. De-tuning way down, what made you try that out? Were you bored with what you were doing before, or you just wanted to try something totally new, or...?
>
> **P7:** Yeah. I just wanted to try something completely different.

Exploration Unbound: It is clear that exploration is distinct from other creative modes, and can potentially prevent a transition into more conventional musical activities. As a process, exploration is more circular than linear, and relatively unstructured. It is a useful tool with which to scaffold usable knowledge and skills for application in performance or composition, and to begin a process with more focused and directional momentum. Despite its open-ended nature, however, the coded data shows that exploration *does* achieve something unique and produces something that does *not* naturally emerge through other creative modes.

Exploratory participants were unique in that they readily accepted the *Torpere* as an unknown entity and were creatively driven by a desire to engage with the range and depth of the instrument's unique characteristics. Those participants who engaged in prolonged periods of exploration became much better suited to move beyond an identification of the *Torpere*'s natural affordances and constraints into a space where novel elements were allowed to emerge organically. When exploration is deeply embedded in the improvisatory process—where improvisation *is* exploration, and vice versa—there seems to be an increased likelihood that positive events will occur spontaneously—that is, in a way that could not be planned or designed for. For example, when using a metal slide on the high-risk *Torpere* instrument, Participant 1 realizes that the electrical signal causes the slide to roll across the strings:

> **P1:** I was super captivated by [that]. I was like, "Wait, it just goes up on its own!?" [laughs]

Participant 4 describes their own disbelief when, after manipulating the electrified strings through a loop pedal, unexpected sonic qualities emerged:

> **P4:** I think it just happened because I put the really conductive thing on it, and had my hands all over it...[the sound got] really bubbly. Yeah, I was like, "What!?" It's very cool. I still don't know how I did that.

Participant 7 describes a similar emergence of novel sonic content, which emerged from an extended exploration of the electrical signals of the *Torpere*:

> **P7:** [The electricity] felt really good. Sort of sounded like bells after a while...That was the first time I had gotten that timbre out of it.
>
> **Interviewer:** That was a great sound.
>
> **P7:** Yeah, it's incredible. That was so cool.

Compared to other creative modes, exploration also tended to produce reflections in which participants were less critical of their own musical output and described less rigid definitions of what was or was not musically valid/valuable. Notably, the two participants who engaged in the highest levels of exploration in the *Torpere* study drew clear distinctions between internal and external metrics for "good/bad," and "right/wrong." For them, an empirical judgement had no bearing on the actual value of the music produced as part of an improvisation:

> **P5:** It was fun the whole time–I could have kept going for ages. I don't think it's, like, a "perfect" performance, but definitely it was fun. Yeah, there was no bored or frustrated. It's just fun.

> **P7:** I think it was more fun to perform with [the high-risk *Torpere*], and I think it led to a...I feel like I was maybe trying to explore the intricacies of different sounds I could get, and not thinking as much about how I'm trying to fit together a piece, in the second one.

High levels of exploration also involved the use of a wide range of playing implements. In the chart below, all of the participants' use of playing implements can be observed, both in cases of a single tool (e.g. a hand or a bow) as well as combinations of tools used simultaneously (e.g. a hand + a bow)[1].

[1]No interactions undertaken for the sole purpose of preparing the improvisational conditions were recorded (e.g. plucking a string to ensure the volume of the amplifier is high enough, placing hands across strings to mute sound before beginning, etc.)

Table 9.3: LR Tools Used: Key: **[x]**: Yes, **[-]**: No, **[o]**: Prepared Piano

Participant	P1	P2	P3	P4	P5	P6	P7
Fingers							
Two Hands	-	-	x	-	x	x	-
One Hand	x	-	-	x	-	-	x
+ Palm	-	-	x	-	x	x	-
+ Pick(s)	x	-	-	-	x	-	-
+ Slide	x	-	x	x	x	x	-
+ Bow	-	x	-	-	x	x	-
+ Snares	-	-	x	x	-	-	-
+ Chopsticks	-	-	-	-	-	-	x
+ Snares+Slide	-	-	x	-	-	-	-
+ Bow+Slide	-	-	x	-	-	-	-
Palm							
+ Bow	-	-	-	-	x	-	-
+ Slide	-	-	-	-	x	-	-
+ Chopsticks	-	-	-	-	x	-	x
+ Pick(s)	-	-	-	-	x	-	-
+ Wire	-	-	-	-	-	-	x
+ Wire+Chopsticks	-	-	-	-	-	-	x
Chopsticks							
Alone	-	x	-	x	x	-	x
As Pick	-	-	-	-	x	-	x
+ Slide	-	-	x	-	-	-	x
+ Pick	-	-	-	x	x	-	-
+ Wire	-	-	x	-	-	-	x
Slide							
Alone	-	-	-	x	-	-	-
+ Slide	-	-	x	-	-	-	-
+ Pick	-	-	x	x	-	-	-
+ Pick+Snare	-	-	-	x	-	-	-
+ Snares+Slide	-	-	-	x	-	-	-
Bow							
Alone	-	x	-	x	x	x	-
+ Chopsticks	-	-	-	x	x	-	-
+ Slide	-	-	-	x	x	-	-
+ Snares	-	x	-	x	-	-	-
+ Pick	-	-	-	x	-	-	-
+ Chopsticks+Slide	-	-	x	-	-	-	-
+ Snares+Slide	-	-	x	x	-	-	-
Snares							
As Pick	x	-	x	x	-	-	-
Clay Wire							
Alone	-	-	-	-	-	-	x
+ Slide	-	-	x	-	-	-	x
+ Slide+Chopsticks	-	-	-	-	-	-	x

Table 9.4: HR Tools Used: Key: **[x]**: Yes, **[-]**: No, **[o]**: Prepared Piano

Participant	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**
Fingers							
Two Hands	x	-	x	x	x	x	x
One Hand	x	-	-	x	-	x	x
+ Palm	-	-	x	-	x	-	-
+ Pick(s)	x	-	x	-	x	-	-
+ Slide	x	x	-	x	-	-	-
+ Bow	-	x	-	-	x	x	-
+ Snares	-	-	-	x	-	-	-
+ Chopsticks	x	-	-	x	x	-	x
+ Bow+Slide	-	-	x	-	-	-	-
Palm							
Two Palms	-	-	-	x	x	-	x
One Palm	-	-	-	x	x	-	x
+ Bow	-	-	-	-	x	-	-
+ Snares	-	-	-	x	x	-	-
+ Chopsticks	-	-	-	-	x	-	x
+ Pick(s)	-	-	-	-	x	-	-
+ Snares+Chopsticks	-	-	-	x	x	-	-
+ Snares+Bow	-	-	-	-	x	-	-
Chopsticks							
Alone	x	-	x	-	-	-	x
+ Slide	-	-	o	-	-	-	x
+ Snares	-	-	-	-	x	-	-
+ Wire	-	-	o	-	-	-	-
Slide							
Alone	x	-	-	-	-	-	x
+ Slide	-	-	o	-	-	-	-
+ Pick	-	-	o	-	-	-	x
Bow							
Alone	-	x	-	x	-	x	-
+ Chopsticks	-	-	o	-	-	-	-
+ Slide	-	x	-	-	x	-	-
+ Snares	-	-	-	x	x	-	-
Snares							
As Pick	-	-	-	-	x	-	-
+ Chopsticks+Slide	-	-	o	-	-	-	-
Clay Wire							
Alone	-	-	o	-	-	-	-

There are some interesting patterns to note when looking at the playing implements that participants used in their high-risk *Torpere* improvisations compared to their low-risk ones. Perhaps the most drastic difference is the change in direct bodily contact. In low-risk improvisations, not a single participant used either one or both palms (alone) on the instrument, while in the high-risk improvisations P4, P5, and P7 all did both. The use of palm(s) and playing implements together is present at more than twice the frequency in high-risk scenarios, and the use of fingers (alone, on either one or both hands) occurred 67% more often.

The use of fingers and playing implements together is roughly the same across improvisation sessions (24 instances in low-risk and 27 in high-risk), and the use of chopstick(s), bow, slide(s), snares, clay wire, and pick(s) in various combinations was, in fact, a *minimum* of 50% *lower* in high risk improvisations. It is quite likely that the steep drop in playing implement combinations is at least in part due to participants' trading breadth for depth: having explored a plethora of tools in the first improvisation, participants had a better understanding of what they did and did not like, and therefore focused on what they preferred. However, the data shows that while many combinations were dropped between the low- and high-risk improvisations, several combinations also appeared for the first time.

The use of playing implements can be seen in the two charts below. The x-axis shows the implements that were used in a dominant role—this almost always means it was used first and other implements were added in. In the case that a musician began using implements at the exact same time, the articulating hand is considered dominant. The y-axis contains the secondary implements used and also accommodates for each tools' use in isolation (the 'X' that begins the y-axis). The size of the circles reflect the number of participants who utilized each particular combination of tools (the largest circle being all seven and the smallest being one). An 'x' indicates that the particular combination was used in a prepared-piano style, while a '-' indicates that an implement was used solely in a picking technique. By comparing these two plots we can observe a relatively similar spread in terms of diversity, but a shift in weighting toward bodily involvement in the high-risk improvisations.

Table 9.5: LR Playing Implements

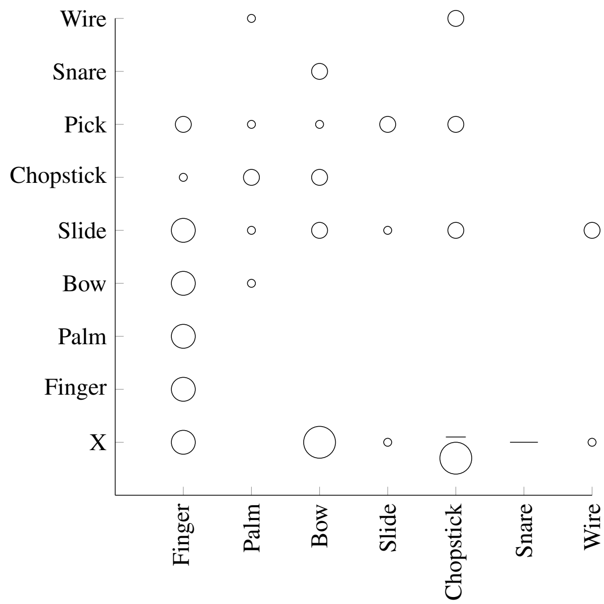
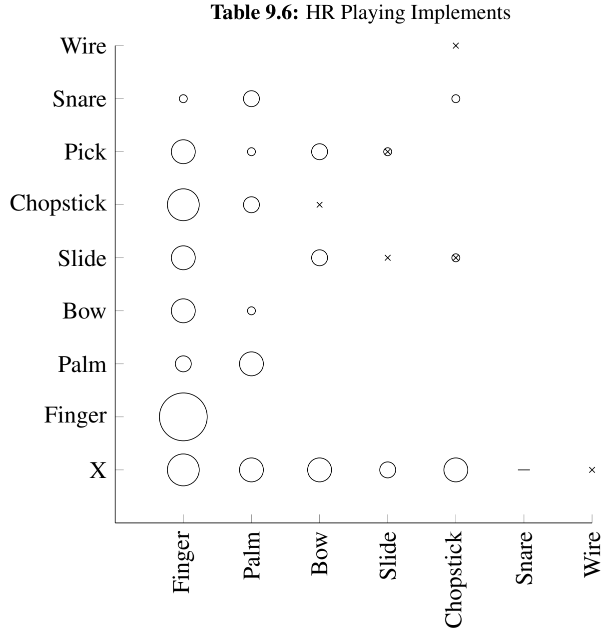
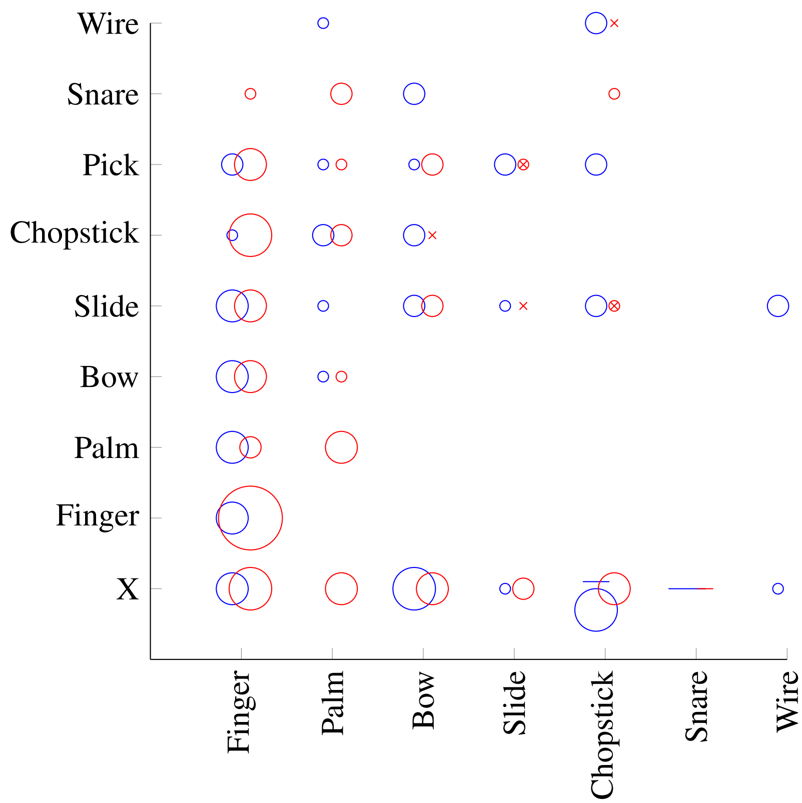


Table 9.6: HR Playing Implements



This shift can be seen more clearly when the plots are combined: while the low-risk (blue) spread is slightly wider, the high-risk (red) distribution across the finger and palm categories is equal to or greater than the low-risk nodes, with the single exception of finger + palm.

Table 9.7: Combinations of Low (blue) and High (red) Risk Playing Implements



These findings suggest that the high-risk *Torpere*'s physical unpredictability may have been a more compelling element for musical expressivity using the body. The interaction with the maximum amount of physical contact with the *Torpere* is the use of two palms, followed closely by one palm (alone, or with playing implements). Both one- and two-palm interactions are absent from the low-risk improvisations entirely, and even with the addition of an articulating object such as a pick or slide, high physical risk states seem to be compelling elements of musical expressivity.

9.1.2 Performance

Table 9.8: Torpere Performance Codes

PERFORMANCE	
7.2.1 Performance, Bound	7.2.2 Performance Objectives
Performance requires more thought and planning than exploration	Performance has an end goal of meeting expectations of audience, which raises pressure and cognition
Performance requires visible skill and mastery	Ideal performances involve organic development of material, creating and sitting in interesting "spaces" before moving on to new material
Visible technique and form are criteria for "good" performance	Performance process shaped by exploring "just enough" to move on
Performance inherently requires control, comfort, familiarization and composition	Improvisation in performance involves not only exploring, but also an awareness/consideration of the audience
	Objectives are based on social context

The creative processes in performance-based creative modes can be considered a bit more conventionally, at least in terms of balancing exploratory and compositional activities. While participants tended to test their existing skills and knowledge against the capabilities of the *Torpere* instrument in exploratory modes and then quickly modify their interaction modes based on novel affordances and constraints, performance was more likely to involve testing and then pivoting away from interactions that were not useful. In improvisational reflections, many participants identified performative moments in which they struggled to maintain a familiar playing style in the face of physical discomfort, eventually abandoning the activity and employing a second or third methodology:

> **P4:** I was trying to just get a drone going and I'm like, "Okay, maybe I'll use a pick to play over the drone." I'm just exploring that, trying to find something rhythmic I could do, that's why I had the chopstick and was testing different things...I know I don't have the dexterity to do anything rhythmic with a melody because I'm not that good of a picker. So, if I could tap a rhythm it would be more interesting. This is just me trying to use the slide and see what happens. Again, I just try to play this bowed drone and it doesn't really last...I tuned these strings a bit and went to plucking this drone because it is easier than picking up bow, even though I like the sound of the bow better. And then

> I'm like, "How can I get something to stay?" I tried to use [the slide] as a capo, but it rolls, of course. It's a cylinder. Then I'm like, "Okay, well I can hold it like this and pluck notes here and then I can just kinda do stuff with that." I couldn't get it to stay on the one bottom string. I like the sound a lot like this. But when I try to get [the slide] on just the bottom strings, it falls through, right? It doesn't stay on the strings. Then I just was playing it on the drone with my thumb. There's so much space here to do things. I know what things I can probably do better than others, so that's why I lean into a pick and a slide.

In this description of their experience, P4 describes an iterative loop of applying a familiar playing style, running up against the natural affordances of the *Torpere*, experiencing frustration, and restarting the cycle. First, they identify an interesting sonic characteristic of the instrument (the drone), and attempt to pick a rhythmic melody on top of it. Unable to do so, they turn to metal chopsticks and attempt to tap a rhythm on the strings, but find that their skill and dexterity prevent a satisfying outcome. They then attempt to use a metal slide and find the musical result to be uninteresting, and so turn to a violin bow to engage the droning sound more effectively. They then make a second attempt at picking a melody with their fingers, explaining that, although the bow was more musically appropriate to the affordances of the *Torpere*, a picking methodology was a more natural skill for them. They then begin a second attempt to incorporate the metal slide (this time as a capo) but find that its cylindrical nature conflicts with the form factor of the *Torpere*. Despite their positive reaction to the sounds that they were able to produce with the slide, they return to a modified picking technique, using the thumb alone to play the bottom string.

While this exercise may appear to be highly exploratory, P4 is at all times attempting to force a compatibility between their existing skills and knowledge and the unknown nature of the instrument. Where the boundaries of creative possibilities are drawn is determined by their own definitions of what they believe the instrument is capable of, constrained by the effectiveness of their existing musical abilities. When attempting to utilize the slide as a capo across the strings of the *Torpere*, a musician in performance mode sees the cylinder roll away and concludes that they are unable to use the slide as a capo. In exploration mode, on the other hand, a musician might venture to turn the slide 90-degrees, positioning it parallel to the strings and using what *seemed* to be an incompatibility as a launching point for an unforeseen playing style.

Performance, Bound: As a creative mode, performance has more boundaries than exploration, but fewer constraints than composition. Because performance can emerge from both exploratory and compositional processes, it was most often mentioned explicitly when participants described what they were *not* doing:

> **[Low-Risk] P4:** I'm just kinda playing. I couldn't get anything to really stay...I finally figured out [the snares are] something to play with. I really like the sound that this makes when it's on here like that, really cool sound. This is a little bit closer to actually composing something.
>
> **[High-Risk] P4:** I don't think I have any notion of what I wanted to do. So, it's still exploratory. But what I was doing at the moment definitely didn't really work.

> **P1:** I was like, "Oh, if I can get these two [musical elements] together I can really do something with it." If I had gotten that, that would have been enough for me to go into, "let's do like a performance." I would have hit that level of control, comfort, whatever.

> **Interviewer:** Do you ever perform, improvise with instruments that you're not super familiar with?
>
> **P2:** [Not] improvisation, but maybe just play around with it. Because you have a new instrument. You start to learn it. I don't think that's improvisation.

These qualifiers—*experimenting, playing, learning, composing*—are used by participants at times to distinguish improvisational performance from other creative activities.

Performance Objectives: In describing performance a higher level of consideration was given to the social context in which a musician is situated, including the expectations and judgements of audiences and collaborators:

> **P7:** In general, when I'm performing for an audience I'm thinking about the audience.

> **P1:** [Performing involves] making something decent that fits an ensemble or audience's expectations...if I'm in front of an audience or I know that, "Hey they might be into that," I'll be more into that myself, but pleasing audiences

is a big thing I think about. I do care about the audience liking it.

P1: It's like sound experimenting versus just performing. Those are kind of the two modes in my head...My [recent work] has been finding some non-zero intersection between doing strange experimental stuff and things where I feel like I'm having exploration fun, but in some way that that can still be interesting for an audience...If [I'm improvising] with a new instrument or an interface I haven't played with before–if it's something more open-form like this, really freely playing–[I'm] not thinking about it too much. If it's with people in a stage environment, I always start with something I know how to do and kind of move out from there. If there's no sort of audience involved, I'd probably just jump right into the things that are most unfamiliar to me, learning what I can do as fast as possible.

P2: [Improvising in a collaboration] with other people is different than improvising alone, I think. I find that an ensemble has a structure. [We] get more practice for a performance.

P4: I follow a lot [in a group improvisation]. I'll listen, feel out what the groove is, feel out the general...how the jam session's going, and fit in as I can. It's mostly thinking about listening and thinking about what's going on around me, because I'll be totally honest, I don't have the expert level saxophone of finger to absolute note–that completely correct coordination. So, it's a lot of listening to other people, playing what I think I should be playing, fingers-wise, hearing myself, and then doing the very improvisatory thing where I play a wrong note, okay find the nearest note that's actually in the chord, and come back down. It's a lot of listening, so it's iterative listening between the rest of the group and myself.

9.1.3 Composition

Composition, as a process, is distinct. Not only does the word "composition" describe an activity, it also describes a self-contained end product. Unlike performance and exploration, composition's process and product are distinct: the activity may happen in real-time, but the process ultimately manifests as an artifact that can be abstracted from a creative environment. The presence of this "record" of creative activity tends to have an effect of raising the stakes of an improvisation: because a composition "should" be a complete, self-contained musical expression, musicians who leaned toward a compositional style of improvisation described the activity based on its formal requirements.

Table 9.10: Torpere Composition Codes

COMPOSITION	
7.3.1 Composition Bound	7.3.2 The Composition of Composition
Low familiarity with an instrument allows for exploration, but not performance or composition	Composition requires the identification and control of repeatable musical elements
Exploration and composition are inherently incompatible	Composition as highly structural requirements (layers, repeating, contrast, etc.) and organized
Composition is highly temporal and actively constrained/defined by time	Composition inherently requires full control, exactness, precision
Compositional mindset can define entirety of an engagement (in a negative way)	Compositions are formal and require cohesion, logic, and objective metrics/frameworks, and are judged by others as "good/bad"
Improvisation is more compatible with exploration than composition	Composition requires plans and objectives, a lot of thinking
Composition involves utilizing the unique characteristics of an instrument's materiality	
Compositional structure can be developed through creating different musical spaces	

Composition, Bound: Of the three creative modes, composition was defined in the most rigid terms and was most likely to be described as existing in a binary relationship with other creative modes. Composition was described by several participants as incompatible with exploration and performance; however, improvisation in particular seemed to present a unique creative conflict. Participants who prioritized composition—whether because of their training, exposure, or comfort level—tended to offer highly defined boundaries around the direction and progression of their musical endeavors, and deviation from that musical map was seen as a point of frustration.

Compositional creativity was also described as requiring more thought, planning, and coherence than other musical activities:

> **P6:** I don't think I personally can do this, but I listen to composers–or I know at least one composer–where kind of their shtick is something changes every two seconds. Or scoring changes. I don't know if I would call that the *apotheosis* of composing, but...[trails off] My instinct [improvising with the *Torpere*] immediately was that the whole thing needed to have an arc and there needed

> to be some kind of repeated section for it to have logic as a composition. I was trying to use the character of [the *Torpere*] in a way that made sense, but I was not good enough at doing it quickly enough for it to sound logical.

The Composition of Composition: In defining what, exactly, composition *is*, structure and repetition emerged as non-negotiable elements of the process. In particular, composition was considered to be inherently incompatible with exploration due to these formal requirements. Compositionally-focused participants tended to explore the *Torpere* instrument primarily—if not exclusively—in order to find reproducible musical units with which they could scaffold a performance. Because repetition requires full control of an instrument, many participants further defined the need for exactness and precision in their improvisational process. When describing their experiences improvising with the *Torpere* instrument, many participants identified their struggle to express themselves in the absence of such repeatable elements:

> **P3:** For the majority of the [high-risk] improvisation I was either trying to produce and replicate something [musically] similar, or something contrary.

> **P6:** I was playing a lot with dynamics in the [low-risk version], and in [the high-risk] one, it's binary; if you touch it, it is immediately making a loud sound. I can't control it over the curve of the composition...*The problem was I didn't know how to do more with that because I didn't know how to reproduce it.* [emphasis added]

Participants who were inclined toward compositional modes of creativity demonstrated the greatest level of frustration in their inability to identify and control musical elements during their improvisations, and much of the content of the codes found in Theme 2.2: Constraints and Affordances are Barriers (and Subtheme 2.2.2: Constraints and Affordances Lead to Abandonment in particular) were the result of statements made regarding such states during participants' low- and high-risk reflection periods.

9.1.4 Summary - Creative Modes

An acknowledgement of these distinct creative modalities allows us to move forward with an analysis of the role of risk that is bolstered by an understanding of musical practices across multiple creative frameworks. Presented in the next section is a discussion regarding *how* participants define the elements of risk within their own practices. Through this data we can begin to unpack the underlying values and priorities of performers engaged in musical expression, and analyze how these risk elements come to be realized within low- and high-risk musical improvisations. With an understanding of how participants in this study define risk, we can then examine how risk *feels* to a performer during musical improvisations, and evaluate its productive (and unproductive) consequences within expressive musical activities.

9.2 Defining Risk: Unpredictability

9.2.1 Unpredictability, in Theory

When discussing unpredictability in pre-testing interviews with participants, initial points of entry into the topic tended to revolve around social dynamics. When thinking about "musical unpredictability" musicians tended to connect the concept immediately to human behavior. When asked how unpredictability related to their computational musical practices in particular, participants were eager to point out the overlaps and divergences of human and computer behaviors:

> **Interviewer:** I know that some people will build randomness or chance or unpredictability into the system that they're working with. If it's computation, they'll add randomness there, or if they're working with acoustic instruments they'll push themselves to do something new, or work with someone new. Do you do any of that in your own practice, where you are intentionally putting in things that could go wrong or be unpredictable?
>
> **P3:** For the software, like live-coding side of stuff, I actually have theories [that] you do need randomness in terms of the amount of activities happening...This chaotic–the amount of energy coming from randomness. I think, at least for software improvisations, it's very important.
>
> **Interviewer:** I find it interesting that you do both live-coding and acoustic-instrument-plus-computing. Do you feel like there's a difference in how you approach improvisations when you're doing just computer versus a physical instrument?

P3: Yeah, definitely. I personally haven't reached that point where I can replicate gesture or tweak the subjective kind of control of whatever I'm trying to create in real-time, sculpting the sound. I still have to think a lot when I'm live-coding and trying to make something musical.

Interviewer: When you think of analog or physical instruments, can you think of any parallels for that?

P3: I think of it being more [about] intention. I don't want to keep repeating what I [play], so I throw in some random gesture here and see how it evolves. In terms of a jazz ensemble, I think that every take is different; Something happens and all the musicians, including myself, will try to build up on accidents.

Several participants in the study had extensive experience working with robotic systems for musical creativity; not only did they work on developing and implementing the computational technology involved, they had also performed with the robot on stage. With extensive knowledge of the theoretical and practical elements of human-computer musical expression, these participants were able to share valuable insights regarding the role that unpredictability can play during engagements with non-human systems:

Interviewer: How does [performing with a robot] compare to performance with a human being? Is it totally different?

P5: It's not totally different. It depends.

Interviewer: Can you expand on that?

P5: I guess the idea is that it's close to being like a human. The ideas that you program aren't the same. You don't know exactly what's going to be happening, it depends. The thing to me is that we're doing lots of deep learning stuff, so all the data means we don't necessarily know what will happen. So it's kind of more like a human.

Interviewer: If you think about improvising with [a robotic musician] versus improvising with human people, can you think of any stark differences? Do you feel more comfortable with–are there fewer variables with a robot than human, or vice versa? What's that experience like?

P7: It's definitely different. I'm sure its different depending on your situation, because everything that [the robot] was playing, I knew all of her capabilities because I created them. So she would never really surprise me like you'd be surprised if you're playing with a new musician you've never played before. So I guess it was kind of like playing with somebody that you've played with before, and you know how to play with them. There is definitely some kind of chemistry, I guess.

9.2.2 Unpredictability, in Reality

In terms of unpredictability, each participant offered a unique set of criteria for defining what risk meant to them. Across all participants, however, two primary themes emerged to define elements of creative musical engagements as inherently "risky." The data shows that risk is most often directly connected to:

1. A lack of control, and/or
2. An incompatibility with existing schema/paradigm

9.2.2.1 Lack of Control

Perhaps unsurprisingly, by far the most consistent entry point into discussions of what risk *is* involved elements of control. In almost all cases, control was identified as a *prerequisite* to creative activity for the three reasons that can be seen within Theme 8.1: Control is a Requirement. In each instance, control was connected to a distinct element of the creative process and is categorized through the following subthemes:

Table 9.12: Torpere Control Requirement Codes

CONTROL IS A REQUIREMENT

8.1.1 Control is Skill and Knowledge Made Visible	8.1.2 Control is Required for Creative Expression	8.1.3 Control or Bust
Positive creative engagements require skill and knowledge to be actuated through control	Control is required for comfort, and comfort is required for creativity and expression	Imposing control drives the entire process
Virtuosity, skill, and mastery are impossible without control	Control is required for stability, and stability is required for creativity and expression	Control is more important than aesthetics
Control is an observable, judgeable element of performance	Control is a prerequisite for creativity	Inability to obtain control leads to random interactions, Random interactions as lacking value/meaning
	Control is required for an objective, and an objective is what creativity serves	Lack of control results in chaos, and chaos is an undesirable element of musical creativity
	Lack of control results in return to familiar	Lack of control leads to frustration and abandonment
	Control is required for the unknown and unpredictable to be positive	A lack of control and precision is inherently negative

Control is Skill and Knowledge Made Visible: For some, control is inextricably tied to a successful "end product," functioning as the vehicle through which to demonstrate skill and knowledge. A creative musical improvisation requires a visible demonstration of skill and knowledge, and therefore a lack of control prevents positive outcomes for them by default. Many participants expressed this sentiment through statements regarding what they believe to be the objective value of musical performances:

> **P5:** I like to have control of how I'm playing. I think I prefer performances with the whole mastery thing, where you can see some kind of mastery.

> **P1:** That's one of the few things where I feel like I actually really have enough control and familiarity where I can react informedly. That's a big thing. I've dabbled in so many things that I have basic familiarity, but not that kind of mastery where I can respond.

In many of the reflection periods musicians cast judgements on their improvisations based on what they were able to observe, visually, on the video playback of their improvisations. P2, for example, began the low-risk video reflection with the preface, "Okay, so first of all, I very seldom, or never kind of play the fret-less instrument. Which is hard to determine the pitch. So this is first thing. So I feel a little bit challenged, at the beginning." P3 expressed a similar caveat with their very first statement: "All right. Maybe before I start–I was feeling like, "Okay, I'm really bad.""

Because control is so intimately coupled with a musician's ability to demonstrate their skills and knowledge, a lack of of control is likely to have a profoundly negative effect. Entering a performative space is quite literally *putting yourself center-stage* for judgement and evaluation; everyone in the room presumes that you have something to say—and that it is worth listening to.

Demonstrating musical skills is deeply personal, and for most musicians the skills and knowledge they wish to demonstrate are bound to a specific instrumental paradigm. Although control is realized through a wide variety of form factors and interactions (pressing the correct keys, working your diaphragm and vocal cords, pressing down a string in exactly the right spot), it is also a powerful *conceptual* force. If you ask two virtuoso violinists, one with 40 years experience and the other a child prodigy, to perform at Carnegie Hall, the level of skill each possesses will be forced into an encounter with thoughts and emotions that may be foreign, frightening, perhaps even paralyzing.

Control is Required for Creative Expression: Control was cited by participants (often quite bluntly) as a non-negotiable element of creative expression. The opinion expressed by many participants was that in order to produce something of value one must be able to exert control within a creative space. Practically speaking, control thrives in environments that are stable and familiar—if control is connected, at least in some part, to skills and knowledge, then a connection to the known and predictable follows.

Without control actions can feel as though they lack intentionality and meaning, and therefore expressivity can seem difficult (or impossible) without it. When describing their experiences with the high-risk version of the *Torpere* instrument many participants described their frustration at an inability to reach an expressive space due to a lack of control:

> **P6:** I think after about a minute of not being able to control what sound was coming out of it, I started–it's like the suspension of disbelief was away. It's like, "Okay I can't express myself with this. So now I'm just kind of stuck trying to pretend like I know what I'm doing." I feel like if I could use it more, or if I could get...If I was in control of the [TENS unit], and in control of [the *Torpere*] and I controlled [the effects unit], and I was using them all together and I was using them for a longer period of time I would be able to come up with something to say.

> **P3:** I was just struggling to get the notes sustained...at this stage, I think I was more frustrated than really free to do anything. [I'm] still trying to control the pitches, getting a little sick of trying to control the pitch. More struggling than doing something intentional.

> **P5:** [I need] control over my instrument...when you can't play the instrument, and you want the music to go somewhere, its very frustrating, instead you can't do anything.

Control or Bust: At times, participants' descriptions of a lack of control within their high-risk experiences concluded with a determination that the struggle to remain creative within an uncontrollable system ultimately led to disinterest and abandonment:

> **P1:** I spent a lot of time trying to figure [the electricity] out...eventually I was like, "This is gonna take the full ten minutes just to really isolate," so I gave up.

> **P6:** I was actually nowhere near as invested this time because I couldn't control what I was doing. I think this is about where I gave up on tonality altogether.

For the majority of participants, this *a priori* control condition resulted in a process that was highly observable in real-time. The persistence of the need for high-level control was a singular driving force in multiple participants' high-risk improvisations, resulting in a circular loop of attempting to impose control on the uncontrollable and abandoning interactions in the face of failure.

More so than any other objective, the search for control was given singular priority, even over aesthetic concerns. While participants were willing to shift objectives in terms of composition, physical interactions, genres, and even come to terms with fear and anxiety, most were absolutely unwilling to embrace a lack of control. This phenomena was so strongly present that it was given a unique subtheme (2.2.1: Control Hinders Creativity), in which the following codes can be observed:

Table 9.14: Torpere Control Constraint Codes

CONTROL IS A CONSTRAINT	
8.2.1 Control Hinders Creativity	
Searching for control can limit exploration and creativity	Control imposes objectives onto musical explorations
Ease and controllability trump innovation and interest	Searching for control can place the performer in conflict with the natural affordances of a novel instrument
Desire for control outweighs creative exploration	

These codes emerged from a wider view of the low-risk and high-risk performances, as well as through participants' subjective descriptions of their creative processes. In cases of participants who had a very positive low-risk experience and very negative high-risk experience, a lack of control was the most critical element differentiating the two engagements.

Without exception, instances of "abandonment" (in terms of exploration, composition, and interaction) were the culmination of a long struggle to impose control on unpredictable and unknown instrument affordances.

> **P6:** I can't remember what I was doing at this point. I can't remember because I wasn't as engaged. So this is me just trying to find something to do, as opposed to before where I knew exactly what I was doing. Even if I didn't know what I was doing moment-to-moment, I know how music sounds and I can generally produce music.

9.2.2.2 Incompatibility with Existing Schema/Paradigm

The second criterion of unpredictability is an *incompatibility of an experience with an existing schema and/or paradigm*. In this work *schema* and *paradigm* are terms used to represent two related but distinct frameworks employed by participants as a way to relate to and engage with the *Torpere* instrument.

Schemata are akin to mental models in that they are formed through subjective experience and comprised of networks of understanding and interpretation. Schemata are used to manage unknown or unfamiliar elements of an experience through a familiar or known framework for understanding new information, and they are flexible in terms of expanding to account for new data. Schemata are not *applied* to an experience so much as they are *drawn upon* in order to understand new experiences. [48]

Within this work schema refers to the experiential knowledge employed by participants to guide the arc of their creative engagements—vast networks of knowledge amassed over years of musicianship, which contribute to how a musician understands what it means to be "musical" in different situations. Participants most notably relied on schemata for the purposes of selecting a genre or compositional style that seemed well suited to support the *Torpere*'s assumed sonic and interaction capacities; they were also utilized across varied creative modalities (composition, performance, and improvisation), whereby participants consciously/intentionally accessed known idioms from classical, jazz, or experimental musical practices to direct their approach to the activity at hand. [144]

Paradigm, on the other hand, is a term used to describe a preexisting model of *a priori* beliefs that define and direct physical interactions. Paradigms do not necessarily reflect the actual experiences or knowledge of a participant, but rather direct activity based on what is *assumed* to be true. They are more narrow, specific, and rigid than schemata, and are *applied onto* an experience by the actor. If schemata are conceptual models through which new information is filtered, paradigms are bounded systems of prescribed interactions, less likely to be adapted or abstracted in novel situations. [145]

Many participants applied a guitar paradigm to the *Torpere* instrument, despite the fact that it is fret-less, the strings are drastically distanced from the body, and the playing implements that were available included a violin bow, metal snares, wire clay cutters, and steel chopsticks. With the exception of one participant, whose first interactions with the *Torpere* involved lifting it to their chin like a violin (and promptly abandoning that technique), and then attempting to hold it like a guitar (and abandoning that as well), all physical interactions with the *Torpere* were constrained by a guitar paradigm: it was not placed upright like a bass, lifted up like a violin, or even laid across the lap like a dulcimer.

Paradigms are especially relevant to this study due to a condition that can arise from an incompatibility between expectation and reality: *paradigm paralysis*. As will be apparent throughout the next several sections of this work, an inability to successfully apply a known paradigm onto a novel situation can, in extreme cases, prompt physically painful brute-force maneuvers and general disdain for the *Torpere* instrument itself.

The data shows that relating an unknown experience to an existing schema and drawing upon familiar paradigms for control often precede any physical interactions and remain a foundational element throughout the entirety of a novel engagement. Much of what was described by participants regarding the beginning of their performances—both low- and high-risk—demonstrates how fundamental schemata and paradigms are to achieving creative expressivity. In general, reflections on the improvisations involved references to schemata/paradigms in the ways described by two of the three subcodes:

Table 9.16: Torpere Schema and Paradigm Subcodes

5.1 Schema and Paradigm are Required	5.2 Schema and Paradigm Scaffold Creativity
Performance and exploration requires existing foundation of skill and knowledge, defined by schema/paradigms	Previous experiences with instrument provides materials for expansion, development
Safety and stability of paradigms/schema are necessary for creativity, exploration	Known schema can provide space to begin exploring new techniques
Safety and stability of paradigms/schema are necessary for positive engagements with unknown systems	Schema/Paradigms provide transferable elements of control across multiple systems
Interactions with unknown inherently begin with relating to known paradigm/schema: Unknown/unpredictable must inherently be understood through known paradigm	Unfamiliarity and unpredictability are only positive when contained within known schema/paradigm
Schema/Paradigms define what positive and negative interactions/music are	Relating novel experiences to existing schema results in positive new experiences
Schema/Paradigms shape and direct musical engagements	Previous experience reduces hesitation when confronting unknown and unpredictable

Schema and Paradigm are Required: A desire for control was often given top priority by participants; however, it should be mentioned here that in most cases these notions of control were filtered down through existing schemata/paradigms, coupling the two tightly. A search for control was most often "a search for control like a guitar" and not "a search for control of the unpredictable electrical signal."

Paradigm/Schema and control were interconnected elements that contributed to the definition of unpredictability for most performers:

> **P2:** When I try to play with the bow, it's hard to–it's not like violin where you have a curved bow, it's all flat. So, I think the only string in this case I can use is, like these two...I try my best to figure out, to change the instrument, but it doesn't work.

> **P6:** When you push the string on the fingerboard it's too low to actually use...I tried pushing down the string hard enough where I could actually play notes without having to do this, and it hurt my fingers so much that I stopped.

In both cases P2 and P6 are attempting to force a violin and guitar paradigm, respectively, onto the *Torpere*, and in both cases the failure to do so results in frustration and discomfort. Rather than surrender these paradigms, both participants continue to search for ways to brute-force what they believe to be the "correct" interaction onto the instrument, with P2 concluding that they, ”Tried to get used to it, but it didn’t work.” P6 similarly sums up their experience, saying that it was, “Not as compelling because it didn’t make sense in a way that I wanted...The dissociation that I had from it was like, “I can’t play with this. I don’t know what I’m doing. I don’t know what’s good or bad on this.””

Schema and Paradigm Scaffold Creativity: While schemata and paradigms were most often functional constraints around participants’ improvisational experiences, there were instances in which a participant was able to abstract a known framework as a point of entry into exploratory activities. Participant 7, for example, drew upon extended guitar techniques (a uniquely open-ended paradigm due to its cross-pollination, particularly with percussion) to explore a method of interaction that was signaled through the *Torpere*’s form factor:

> **P7:** I really enjoy hitting strings with things. Like being percussive with a guitar. So, it felt like...that mindset of being percussive with a guitar, but it was just easier laid out for you here. It’s like this is meant to be hit. It’s just right here. There’s lot of sticks. This [metal chopstick] was definitely my favorite tool.

Instead of seeing the *Torpere* as a guitar and applying a guitar paradigm to it (as most other participants did), P7 instead saw metal strings, a wooden body, and metal chopsticks and drew upon an extended guitar techniques that take advantage of those same physical components. They allowed the affordances of the instrument to define the limits of an existing paradigm, rather than the other way around.

P2, who was insistent on approaching the *Torpere* with the most familiar tool at their disposal (the bow), describes much of their low-risk improvisation as frustratingly inexpressive due to the constraints of the instrument, which did not lend itself to a violin-bowing technique. However, they do describe a singular positive element of the high-risk improvisation, which emerged from pushing past the violin paradigm and using the bow in a way that took advantage of the *Torpere*’s affordances:

> **P2:** I didn’t think [that bowing the strings] could be so nice, as a sound, but it’s interesting that if you keep bowing on these kind of string[s], it does sound

> nice. when you just like hit it and kind of attack it, it will ring longer...I think it's quite interesting–it's weird, I didn't try [playing with] the bow on the guitar strings, and actually it sounds really nice! It grips.

Schema and Paradigm are Limitations: The third subtheme related to schema/paradigm developed from an analysis of the latent codes embedded in the textual and observational data of the study: 5.3: Schema and Paradigm are Limitations.

Table 9.18: Torpere Schema and Paradigm Limitation Codes

5.3 Schema and Paradigms are Limitations	
Paradigm and objectives can be rigid and restrictive, limit creativity/exploration	Attempting to force paradigms/schema can be obsession, constrains/limits entire creative experience
Inability to successfully apply/force paradigm can lead to novel engagements/objectives	Failure to impose existing schema/paradigms on unknown results in frustration, brute-force, discomfort, and abandonment
Pushing past limitations of existing paradigm prompts physical and conceptual adaptation	Existing schema/paradigms are inherently uninteresting
Suspension of objective and forcing paradigm can open up space for creativity	Rigid frameworks do not allow for "good" mistakes, demand perfection

While participants did not generally refer to schemata/paradigms as limitations *per se*, this condition became clear through a deep reading of the subtext of participants' comments and privileged access as an "audience" member during participants' performances. While codes supporting the premise that schemata/paradigms are required for musical creativity are relatively explicit and maintain the language used by participants, they do not accurately represent the conditions observed in the low- and high-risk improvisational performances. Considering the performance and reflection content in tandem is crucial to contextualizing the consequences that searching for schemata and brute-forcing paradigms imposed onto the participants' performance experiences.

From a research perspective, the consequences of schemata and paradigms were quite clear: much like their struggles for control, a frustratingly circular *apply paradigm – fail – force paradigm – fail* process consistently unfolded during improvisations. The powerful role that a paradigm can play in an engagement with a "risky" instrument can be observed in P6's description of what occurred when attempting to relinquish a comfortable paradigm (which was successfully applied in the low-risk *Torpere* experience) and embrace the affordances of the high-risk *Torpere*:

> **P6:** When you give me [the low-risk version of the *Torpere*], I'm like, "Okay, I know I can tune these. I know I can play it here or here, or I can beyond the bridge. I know I can play harmonics. I know I can do pizzicato." I know that language, and so even if its like weird or different, but there's strings. I can make something that sounds like music with strings...I definitely did not feel anywhere near as ready to do the second one as I did the first one, because I didn't know enough about it. I was immediately a little bit less comfortable.

The introduction of the unpredictable physical sensation pushed P6 out of a productive space (as experienced with the low-risk *Torpere*, which was unfamiliar but compatible with a known paradigm) and into a place of discomfort and hesitation. Even though the physical form of the instrument did not change, P6's paradigm was suddenly rendered incompatible, and this lack of guidance resulted in a less expressive performance.

9.2.2.3 Constraints and Affordances

Much of what emerged through coding exploration involved engagements with existing and emergent physical and material affordances and constraints. This topic was so prevalent that it presented as its own dedicated category, 2: Constraints and Affordances. In discussing the productive role that exploration can play we can see significant overlap between Subtheme 7.1.3: Exploration Unbound, and Theme 2.1: Constraints and Affordances are Productive.

Subtheme 2.1.1 describes the fundamental role that constraints and affordances play in musical engagements of any kind. The physical properties of any instrument—musical or non-musical—will offer information regarding how it can be used and what it can produce. This ranges from immediate (a piano is a box that has a bunch of black and white rectangles, you can push them down and they make a sound before popping back up) to more nuanced (you can press a bunch of rectangles down at once, keeping them depressed makes longer sounds, you can push them forcefully or softly, you can run a hand from end to end in one gesture), to very complex (opening the box will reveal a bunch of strings and hammers you can add to your musical toolkit). At the foundation of any musical engagement is an understanding (full or developing) of how a human body can actuate an instrument in order to produce sound, and this relationship between physicality and materiality give definition to the aesthetic and gestural choices of the musician.

Theme 2.2 contains codes that represent the *negative* role that constraints and affordances can play in an interaction with unfamiliar and/or unpredictable instruments. This includes codes that describe participants' experiences both with the constraints and affordances they *assumed*, as well as those they *experienced*. Pre-existing beliefs regarding what the *Torpere should* do often shaped the improvisational experience: musicians struggled to reconcile the ways in which they desired to interact with the instrument and its inherent capabilities. There is overlap here between paradigm and engagement: participants who wanted to play single notes on the *Torpere* applied existing skills and knowledge from their experiences with guitars and violins, often going to great lengths to attempt to find physical affordances that simply were not there. Despite the absence of frets and the significant distancing between the *Torpere*'s body and strings, participants placed themselves in uncomfortable, even *painful* situations, driven by the need to impose physical methods of control on an instrument that did not support them.

In this way, existing skills and knowledge defined how useful the existing affordances and constraints of the *Torpere* could be. When forcing unnatural physical interactions onto the instrument, participants inevitably arrived at a place of emotional frustration and annoyance. Most often, this negativity caused participants to abandon their engagements and return to something more comfortable and familiar rather than provoking new ways of considering possible interactions. This was particularly clear in the video reflection portions of the study, where participants were forced to watch themselves struggling (and failing) to effectively use the *Torpere*. For several of them this observational process sparked a realization:

> **P4:** I need to try to figure out a way to get this [the snare] on here. Maybe–Am I allowed to weave?
>
> **Interviewer:** Oh, yeah.
>
> **P4:** Is this cool? Actually I should have done this. That would've made a lot of sense. I should have used these guys! I thought to myself before I wanted to use these.

> **P5:** I didn't feel like I used that many tools, actually. I left, like, half of them unused. I should have used these.

> **P1:** Actually, touching the pickups and going through the feedback could have been a thing to explore...Yeah, I didn't use this at all. And that would have been cool to play with, just leaving things on, kind of like prepared instrument-y stuff. This is very well suited for that.

In some cases, however, reaching the boundaries of existing skill and familiar physical interactions opened a door to fresh explorations of the unknown. Subthemes 2.1.2 and 2.1.3 catalog the ways in which participants' actions were guided, prompted, or enhanced by existing *and* emergent characteristics of the *Torpere*. Participant 4 describes a process of discovering and utilizing an emergent property of the *Torpere* over the course of their low-risk and high-risk improvisations:

> **[Low-Risk Reflection] P4:** I don't think I realized that the electricity sound is something to, like, play with yet.
>
> **[High-Risk Reflection:] P4** I realized I can play this electricity...[I started to] listen to the strings, what sounds can I get to feed back a lot, that will sound cool. I'm like, "Okay, I should do something more heavy." So, I'm using [the strings] a lot more, I was trying to use it.

9.2.3 Summary - Defining Risk: Unpredictability

Unpredictability can be many things, and is highly dependent on each musician's personal criteria for musical performance. The rigidity or flexibility of a musician's preexisting schemata and paradigms, acceptance or rejection of control parameters, and inclination to explore or ignore unknown spaces all contribute to how unpredictability will be defined and encountered. With an understanding of these interconnected elements we can examine the effect that unpredictability had on participants' expressive engagements and consider the potential that physical unpredictability might have in computational musical practices.

9.3 The Effects of Unpredictability

Much of what was revealed through the Thematic Analysis showed complex interconnected relationships between how unpredictability is defined, incorporated, and avoided within creative activities. Broadly speaking, we can separate these networks of connections into two distinct categories:

1. Unpredictability is Negative
2. Unpredictability is Valuable

Though much of the content produced through analysis overlaps between these two areas, participants tended to describe unpredictability either as a valuable tool for deeper creativity, or else a destructive force with no worth at all.

9.3.1 Unpredictability is Negative

When participants spoke about unpredictability in a negative light they generally did so in one of three ways. In describing *why* their experiences with unpredictability were negative or undesirable, participants reported the following:

Table 9.20: Torpere Negative Unpredictability Codes

1.2 UNPREDICTABILITY IS NEGATIVE		
1.2.1 Unpredictability Kills Creativity	1.2.2 Unpredictability Kills Performance	1.2.3 Unpredictability is Uncontrollable
Unpredictability is inherently negative: causes anxiety, fear, pressure, discomfort, stress	Performance inherently requires familiarity, control, and stability	Unpredictability becomes something to control, process is frustrating (often impossible)
Unpredictability is overwhelming, disruptive, causes creative disconnection	Predictability/familiarity are necessary to make skill/mastery visible to audience	Physical risk/unpredictability imposes hard limits on possible objectives (crux of musical engagements)
Overload of unfamiliarity/unpredictability prevents ability to shift between creative modes (composing, improvising)	Unpredictability prioritizes process over product	Unpredictability leads to lack of control, prevents intentionality; unintentionally can not be meaningful
Inability to identify repeatable/reproducible elements leads to hard boundary on creativity/exploration		Emergent affordances facilitated by unpredictability lack meaning, value without control
Familiarity is a prerequisite for exploration, composition, and creativity		
Dealing with unpredictability is a skill, can be foreign/uncomfortable		

Unpredictability Kills Creativity: When discussing the relationships between unpredictability and creativity participants tended to describe internal emotional and mental states. For many, unpredictability caused negative feelings of anxiety, fear, and stress. Mentally, unpredictability was described negatively as overwhelming and disruptive. The codes within Subtheme 1.2.1 catalog the internal states described as incompatible with creative processes, wherein unpredictability can not only serve to "kill" existing creativity, but potentially prevent one from beginning at all.

When reflecting on their high-risk instrument experiences some participants described emotional and mental distress when engaging with the unpredictable and/or unknown system. Some participants struggled to engage in creative musical improvisations in the face of the stress, anxiety, and fear that were induced by risk, overwhelmed to the point of paralysis:

> **P2:** It makes me [feel] kind of stressed. That's why I can't bow it, it's kind of strong [laugh]. It makes me [feel] nervous and stressful, and I feel like...I

can't play this kind of droning, Indian melodic [music] because it's a very peaceful thing. But [if] you play it with a nervous feeling–it effects my playing performance.

For P3, the struggle to find control while confronting an unpredictable physical sensation caused not only frustration and an abandonment of creative interactions, but was so extreme as to sever physical interaction almost entirely:

P3: I want to introduce a stable sound here and obviously I'm not doing it, cannot do it. So, I'm holding multiple picks and not really liking what I'm doing here. I'm scared of the shock, so I cannot commit so much, [laughs] so I'm going towards a more contact[less] options. The first two, three minutes was just a state of confusion, like I don't know how I should engage. And here I'm going to maybe drop stuff...like, okay, I cannot really control with my hands, so I need some kind of source of physical [way to touch/play]. I don't want to pick and keep my hands here. Actually, I'm trying to avoid that situation. I'm dropping things on the floor, and it's more musical than what I've been able to play. [laughs]

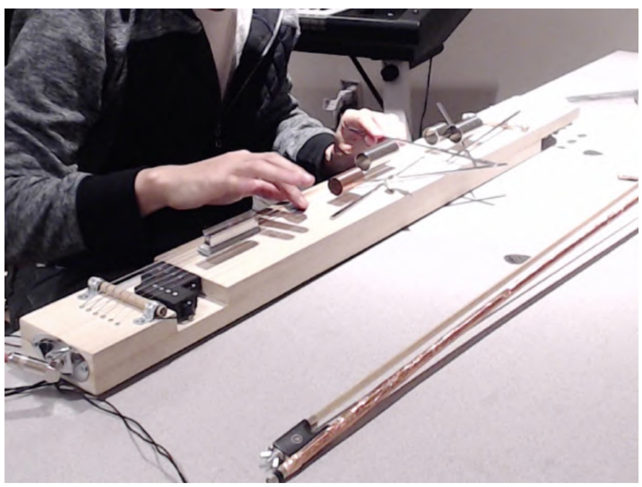


Figure 9.1: P3, surrogate connections

The physical risk state of the high-risk *Torpere* could only be engaged with through surrogate connections for P3: dropping items on the strings from several inches away, gingerly placing items on the strings and manipulating them with as little physical contact as possible.

In particular, participants with a strong background in classical training tended to struggle with accepting risk—both as elements of unpredictability and a potential for failure—as a usable quality in their performance. P3 discusses this disconnect and recognizes their struggle in terms of their own classical conditioning: "The thing is...some people who actually abuse instruments–like, original acoustic instruments–they know with instinct how to operate with new interface like this. I felt like I'm lacking in that respect."

Unpredictability Kills Performance: Similar to the sentiments described in Subtheme 8.1.1: Control is Skill and Knowledge Made Visible, the codes within Subtheme 1.2.2 describe conditions that are required for musical performance. Elements of control, familiarity, and stability were described by several participants as inherent features of performance (again, particularly as vehicles for the demonstration of skill and knowledge), and when unpredictability removed one or more of those elements, performance was made impossible.

Those participants who took a more compositional approach to performance seemed to face additional challenges where unpredictability was concerned. P6, for example, explains that, while unpredictability can be accepted in exploratory or learning processes, composition is an expression of a finished product—dealing with unpredictability prioritizes process over product, rendering composition impossible:

> **P6:** [The high-risk experience] is me trying to learn how to express something rather than me expressing something, which I did pretty okay [in the low-risk version]. This is just me trying to make sound, rather than using sound for something. I can't–I don't know enough about this to make an arc or make a structure. So let's just make sounds, I guess.

The rigidity of some musicians' compositional objectives can come into conflict with the nature of unpredictability itself. If considering a musical performance as a compositional process, the likelihood that unpredictability will be interpreted positively is very low. Further, because structure and form are fundamental elements of a musical composition, a disruption to those constitutional elements makes recovery extremely difficult.

Unpredictability is Uncontrollable: In addition to its incompatibility with certain compositional and performance activities, unpredictability was sometimes described by participants as a chain of events that spiraled more and more out of control. Participant 3, for example, describes a series of attempts to mitigate the unpredictable physical sensation of the high-risk *Torpere* and develop a sense of control that ultimately culminates in a feeling of being physically paralyzed:

> **Interviewer:** In the first version I know you were frustrated with what you wanted to get out of it, you couldn't quite get it. Is that the same experience you had here?
>
> **P3:** It's even more than that I think. Almost like not being able to control my body. Kind of like I cannot walk. [laughs]

This "risk-stacking" process can be observed in the reflections of multiple participants. It often runs a path beginning at unpredictability and moving through a struggle to enact control, and experience of frustration over a lack of agency and intentionality. The path often concludes at a space in which a musician feels that they were unable to produce anything with meaning or value.

9.3.2 Unpredictability is Valuable

In terms of the more positive effects that unpredictability can have on musical expression, several themes emerged that describe participants' productive engagements with physical risk. In particular, the ability unpredictability has to be both an incentive to try new things and emerge as surprising behavior of an instrument itself can make a musical experience more exciting.

Table 9.22: Torpere Valuable Unpredictability Codes

1.2 UNPREDICTABILITY IS VALUABLE

1.1.1 Unpredictability Pushes Beyond the Known/Familiar	1.1.2 Unpredictability is New/Revealing	1.1.3 Unpredictability is Human
Unpredictability is productive for exploratory processes: can prompt shifts, re-considerations, new directions	Unpredictability can reveal emergent control/interactions of instrument	Unpredictability is an organic, human element
Unpredictability can present creative challenges, push past constraining boundaries of convention and comfort	Unfamiliar, uncontrollable elements of instrument can become new dimensions of experience	Unpredictability can offer sense of otherness, interactivity; a force to respond to; a reciprocal relationship
Stability, familiarity, control, and comfort can be boring and reduce/limit exploration and creativity	Unpredictability can reveal emergent affordances of an instrument	Humanness involves error and unpredictability
Unpredictability can prompt novel physical interactions	Unpredictability can prompt search for extremes of an instrument, exploration of range and depth of affordances	

Unpredictability Pushes Beyond the Known/Familiar: Unpredictability can serve the purpose of breaking musicians out of habits and conventions that are have been utilized so consistently that they have become default elements of a performance. Much of what musicianship is involves developing muscle memory and a deep familiarity with certain instruments and/or musical traditions, both of which depend on repetition and internalization. As these experiences develop into skill and knowledge over the course of years or decades, mastery and virtuosity emerge as an ability to rely on automatic musical skills, freeing the musician to consider aesthetic and creative goals with the confidence that their mind and body will work in conjunction to make those conceptual ideas a reality. As we have seen in earlier chapters the ability to self-engage with unpredictability and failure through consciously-imposed challenges moves from stressful to satisfying when a level of confidence is securely in place; barring that, it is difficult (if not impossible) to enjoy a lack of control or familiarity.

Participant 1 provides evidence for this in their statement regarding the incorporation of risk into their personal practice:

> **P1:** Recently I've been putting random tunings on my guitar just to break my normal guitar muscle memory. So, [the *Torpere*] is actually the right amount of unfamiliar to play with for it to be fun.

Participant 2 describes the value that they see in using physical systems for musical improvisation in which the control parameters are less precise and deterministic than computational systems:

> **P2:** A little bit of randomness will direct you to other paths [that] maybe you've never seen before. Then you can start from there. In computer it's so perfect, you can make sounds super great and precise–I'm always interested in new sounds, new possibilities. I like [to] push the bar, otherwise it's boring.

Participant 7 speaks similarly about the positive impact that improvising with other musicians as a way to use unpredictability to spark new creative directions:

> **P7:** I like some of both [unpredictability and surprise]. I like all kinds of different situations. And I like it when I play with people that I've played with

> a lot before, and people that I like playing with, frequently, are people that incorporate unpredictability into their playing. As far as always bringing new ideas and being a dynamic musician, not just doing the same thing that they've always been doing. Last night I had practice with my jazz combo, and after everyone left, me and the drummer stayed and were just jamming, basically, and it was the first time we had just played one-on-one. I got to see all kinds of new ideas that he was bringing, and then that sparked new ideas from me. We did that for 20 minutes, it was a lot of fun.

Unpredictability can be implemented as an impetus for breaking out of habits that have simultaneously supported the development of skills and reinforced conventions. When a musician has a high command of their instrument and practice they may benefit from the implementation of novel challenges to stimulate the imagination and prompt new paths of creativity.

Unpredictability is New/Revealing: Unpredictability can also serve as a valuable process that manifests as new and revealing musical characteristics and behaviors that are not readily apparent by visual observation. Particularly with an instrument such as the high-risk *Torpere*, physical unpredictability can function as a deep space for bodily exploration, where interactions can reveal a layer of interactivity that were not expected. These findings can provoke novel creative actions and are often surprising in positive ways. Participant 7 in particular found that, as they were exploring the sonic range of the high-risk instrument, interesting physical interactions emerged that sparked creativity on an entirely different register:

> **P7:** In the first half I would say, the [thing that most] changed my creative process significantly was the sound. The rhythmic sound of [the instrument]. It was really obvious, and incessant, and I didn't want to just ignore it. I wanted to use it. I wasn't really thinking about–I wasn't processing the way [the *Torpere*] made me feel. Then in the second half, I started realizing that [the physical sensation] felt different on different strings, and especially if you're touching metal in some parts and touching certain strings in another part, it changed the way [the instrument] felt. Some of them hurt in a good way, and I really like that, because I'm kind of a masochist. I just got really interested in the feelings, too.
>
> **Interviewer:** Were you looking for new sounds, or were you trying to feel out what those feelings were?

> **P7:** If you [touched] a different combination of the strings–they're all a little bit different, so I was exploring those, and also just seeing which ones hurt the most. [laughs]

The unpredictable physical characteristics of the instrument began to slowly emerge as layered potential, and P7's improvisation developed from a familiar interaction mode into a foreign process of probing the materials of the instrument itself, investigating the self-contained potential embedded in the unique material characteristics of the unknown. Through this process P7 was able to identify a new dimension of expressivity that, in some ways, outweighed the more conventional objectives of crafting a musical composition:

> **Interviewer:** That was a cool technique I hadn't seen.
>
> **P7:** I guess this [new musical material] came about because right before I was touching different strings, and seeing how they felt, and what the sound was, and then I decided I wanted to bring something more melodic back into it. But I wanted to keep touching it, so I realized that I could just basically mute four or three of the strings, and then activate the other two. That's what I was doing.

Participant 7 isolates a novel affordance of the *Torpere*—the ability to bridge electrical circuits across different string combinations—and that mode of physical interaction not only drives deeper physical engagement but also contributes to the improvisatory process of producing music. The musicality of physical touch becomes a property that can be harnessed and developed in real-time.

Participant 1 describes a similar process in which they acknowledge the surface-level presence of the high-risk properties of the *Torpere* and make a plan to identify potential ways to incorporate it into their improvisation. Upon deeper bodily engagement, they realize that the body can be utilized as a control mechanism for the unpredictable behavior of the instrument:

> **P1:** [The electricity] was definitely a fun positive. Even before we started, I was like, "Oh I'm gonna use this." And then figuring out it wasn't a conscious buzz and, depending on where I touched it stuff happened–having that upped the fun. I was like, "Oh, this is a very controllable new dimension to the sound."

The unpredictable physical sensation was, in and of itself, a tool that could be used both as a compositional element and interaction modality. In cases that musicians were able and willing to work the instrument's natural affordance into their schema and/or paradigm (or create an entirely new one) they had access to a novel set of possibilities that could be explored and applied to their expressive activities.

Unpredictability is Human: Both unpredictability and failure were contextualized by participants as innately human behavior, and this dynamic played out in the improvisational experiences of several participants. Some describe moments of engagement with the high-risk *Torpere* that felt collaborative and organic, where the instrument felt as though it had a sense of agency and autonomy. In comparing the low-risk and high-risk *Torpere* instruments, Participant 5 contrasts the direct interaction of the former with the reciprocal responsivity of the latter:

> **P5:** The first one, I was just playing an instrument, straight on. Next time was more like it was responding to me. It was like more of an interaction with the thing. As opposed to direct. Cool. That was fun.

These findings suggest that physical risk has the ability to manifest as more than a *quality* of design, to a point where it is considered as *behavior* that feels integrated and unique to the instrument itself. We will see this in the experiences of the *null/void* participants as well: the difference between *reaction* and *response*, *activity* and *behavior* can have a drastic effect on the relationship a musician has with their instrument.

9.3.3 Summary - Effects of Unpredictability

Participants spoke about risk across a spectrum, and it would appear that elements of risk can be defined and considered in both positive and negative lights. This was apparent not only in the wide array of perspectives offered across participants, but also in the conflicting and sometimes contradictory insights from individuals themselves. Taken together, the need for control and familiar schemata/paradigms form the boundaries of creative expressivity within unpredictable situations. Though each musician's criteria and thresholds differed, we can consider these findings within a framework that positions intersecting spectra of familiarity/novelty and control/unpredictability.

Unpredictability and unfamiliarity can be seen as positive or negative elements of creative expressivity, depending on their contextualization within the boundaries of familiar schemata/paradigms and control. When unpredictability and novelty are balanced either with a sense of competent control or a familiar schema/paradigm, they can be a productive boon to the creative process. If, on the other hand, performers are faced with unpredictability and unfamiliarity at the same time, the sense of risk is simply too high to create a space of creative freedom. Alternately, high levels of familiarity and control can constrain creativity, as these spaces are often boring and/or unexciting.

9.4 Defining Risk: Failure

9.4.1 Failure, in Theory

Failure is a multifaceted concept. For musicians, failure can occur on many registers—sometimes simultaneously. It can be emotional: a shaken sense of self-confidence, feeling as though you've let down a collaborator, a reflection that you did not put your best performance forward. It can be corporeal: pushing the wrong key, injuring the body, shaking or losing breath. It can be mental: forgetting a line, having trouble focusing; or material: breaking a string, dropping a stick.

Participants in the *Torpere* study spoke to a broad range of definitions for what failure looks and feels like. For some, "failure," "error," and "wrong" (henceforth abbreviated as *FEW*) are immediately and clearly identifiable, even if the definitions themselves are quite hazy. Because "good" and "bad" can be judgements of internal *and* external activities, failure can take form by way of a complex network of subjective and objective evaluations.

Many participants acknowledged not only the need for subjective and personal goals and objectives, but also the importance of outside expectations. Much of what was revealed through the analysis of participant pre-testing interviews and improvisational reflections revealed objective *and* subjective qualifications for failure. Musicians tended to be consistent in their understanding of failure, error, and wrong within group dynamics, where they are expected to contribute productively to musical improvisation with many independent collaborators. When improvising alone, FEW take on a more personal definition, closely tied to personal goals and objectives. Participant 4 described the difference between the consequences of failure in these different creative modes:

> **Interviewer:** Is failure different when you're improvising in a group versus when you're just by yourself?
>
> **P4:** Oh yeah, definitely. When I'm just [by myself], then I don't really care. I'll do a lot more of listening and finding something that I like and trying to derive what I did, what is that compared to everything else, how would I do that again in context with other people? So [I] don't care about making "mistakes" nearly as much.

Participant 3 similarly describes the difference between experiencing FEW with others, as compared to experiencing it alone:

> **Interviewer:** When you improvise are there many things that happen that you know are like, "Okay, things are going wrong" or like, "Oh, this is working really well?" Are there any triggers that you just know, "I need to do something different 'cause this is not working," or vice versa, like "Ah, this is really good"?
>
> **P3:** With someone else it's kind of easy [to say it's positive] if it triggers another person to start playing on top of what I just played, starting [a new musical path] kind of thing. If something is clearly a mistake, I tend to recognize that as a mistake and feel really bad and want to stop there. But if I don't feel like that, I think any sound material is a good motive and I try to maybe repeat that.

In the pre-testing interviews in particular individuals tended to reference a musical *spectrum of wrong*, wherein "mistake," "error," "right," and "wrong" were highly dependent on context. Unsurprisingly, classical music tended to be used as the *de facto* example for highly rigid frameworks in which precision and accuracy are of the utmost importance. Jazz most often provided the counterpoint, illustrating a wider creative space with looser definitions:

Interviewer: I've talked to other people about their improv practices: people who have classical training, and people who have jazz training, and people who don't have any formal musical training. It's been really interesting to see–when people are going into an improv moment, and something goes wrong, or it's unexpected, or the wrong note comes out–it seems like some say, "Okay, that's wrong, let me move back and get back to where I was and correct," but some people say, "Oh, wrong note, guess I'm going to play that 10 more times and it's not wrong not anymore."

P4: That is true, there is some of that. I think it depends on how wrong it is, right? So if you're playing a color note that is close enough to the chord progression, yeah you can lean into it, you can play it over again and be like, "Dammit, I meant to do that." But if you're like me and sometimes you play shit that really doesn't make sense, it's like, "Okay, let's try to resolve it as fast as I can," and get out of it...I think that comes from my own self-confidence. I'm around a lot of really, really good musicians, especially who are better improvisers than I am, so I'm like, "Dammit I wish I didn't do that because I didn't intend to do it," right? Because you can play wrong notes and that's a lot of what jazz and improv is, breaking the rules artistically. But when you do it on accident, it's a lot less, "Oh cool, I meant to do that," and more like, "Oh shit, how do I get outta this," kind of thing.

Interviewer: Do you try and build elements of chance and randomness into what you're doing, or do you try and safeguard against that?

P4: I think, probably, I would lean towards the conservative side of trying to safeguard against it, just because I wanted to avoid risk, wanted to not be embarrassed on stage. And that definitely comes from my classical training background, because you don't do that, right? I've played concertos and things in front of bands and orchestras before, and you don't go up there and leave any room for chance. You practice forever until it's perfect and you do the one thing you're supposed to do, and you do it as well as you can, but you don't leave room for error.

P3: Miles Davis and [John] Coltrane, those people might not have the same set of rules but they definitely...They go really deep, to the point they have music theories but also they know what is musical and what is not. They try to explore those vocabularies and they do communicate with those vocabularies to each other...I forget who said this, maybe Davis or someone, that players want to intentionally make more mistakes and go out of compositional scales and whatnot. But in the end, they will come back to the right note and solve their mistake. [For Miles Davis] everything is a mistake until he solves it.

While the classical-jazz dichotomy was most common, some participants offered personal insights into their own practices as well, touching on the different ways that failure emerge in acoustic and computational musicianship. These conversations provided highly relevant data to support the broader implications of this dissertation, which is intended to speak to a community of musicians who incorporate computational technology into their practice. Much of the content of these discussions placed acoustic and digital practices in distinctly different creative spaces, with obvious delineations between acoustic and computational failure:

> **Interviewer:** When you're improvising, are there any specific events or outcomes that happen where you feel like, "that's going right," or "that's going wrong"?
>
> **P1:** Specifically with electronic stuff, if I see some error screen when I'm live-coding that's–basic instrument failure is a big [instance of] going wrong. Within a group it's definitely–I have a bunch of jazz friends and I try to keep up with them, but there are a lot of times where I'm like, "I don't...I can't hear what's going on and don't know what to do."

> **P2:** Some people say you can do most of the stuff [that you can do with analog instruments] on the computer. Some people say it's even [more] convenient on the computer to do. But, I feel like [with an analog] modular synthesizer, because everything is controlled by audio patchers and you're turning the knobs–sometimes it's not that precise. It could go wrong any time. You turn it [and] every time [there's] a little bit of randomness, which will direct you to other paths that maybe you've never seen before. Then you can start from there. Actually, the physical thing in front of you can give you more inspiration.

> **P6:** I used to do a [full-on analog synth aesthetic] digitally, just 'cause I kind of like that sound. I actually got a MicroKorg [recently], so, now I have a real one that I can play with. I can make really bad sounds really authentically. [laughs] Instead of fake good ones. It's fun. It makes the experience of exploring those kinds of sounds a lot more tactile, which actually makes me feel a lot more creative than just twiddling a fake knob.

9.4.2 Failure, in Reality

While participants cast a very wide net regarding how *right, wrong, mistake, failure, correct, incorrect, good, bad, error*, and many other terms materialize in musical performances, it was only by examining their personal reflections of their low- and high-risk performances that more intimate details emerged. The conditions set by the study removed much of what participants described when talking about failure as an abstract concept: there were no ensemble members to consider, no genre or playing style to adhere to, no preexisting music to accurately reproduce, and no audience to play for (though it would be ludicrous to imply that improvising in front of a stranger who is pointing a camera at you is without pressure). With no objective rubric to follow and no metric by which to be judged, the question was not, "What is musical failure to this performer?" The question was, "What is failure going to be for this performer *right now*?"

Given the same instrument, identical tools, and 5-10 minutes to improvise, participants described failure in surprisingly consistent terms. In particular, they experienced failure in one of two ways:

1. An Inability to Achieve an Objective
2. A Conflict Between Expectation and Reality

An inability to achieve an objective was highly connected to the conceptual and theoretical schema that each improviser brought into the testing session. In compositional modes objectives tended to center around producing something polished and highly-designed, while in performance they were more likely to be guided by a desire for natural, dynamic physical engagements with the instrument in real-time. Conflicts between expectation and reality were similarly idiosyncratic, but most often were related to the paradigms that each musician relied upon. Simply put, this type of conflict involved a disconnect between the presumed and actual behavior of the *Torpere* itself.

9.4.2.1 Inability to Achieve an Objective

While the search for control certainly became a powerful motivator for some participants, many musicians were also driven by pre-existing goals and objectives regarding their musical experience—even when they were unaware of what instrument they would be using. Objectives seem to be a powerful driver of musical engagements and the data shows a strong correlation between an improviser's creative mode and their goals and expectations.

As one might expect, musicians most interested in compositional activities experienced the greatest levels of stress in the face of failure and spoke most negatively about their overall experiences with the *Torpere*, while more exploratory participants' experiences were the most positive and least driven by goals and expectations.

In the most extreme case, P6 describes the presence of an objective as bestowing value on musical experiences in general:

> **P6:** If I don't have an idea that I'm trying to create I'm not going to sit down at the piano at all...If I'm composing something, I'm not really ever going to start composing without either an idea of what I want to create or someone else telling me that they have an idea that they want me to create. So, I'm never not going to have a clear idea of what I'm trying to do. I always start from there and would never be like, "I'm starting this but I'm not sure what I'm doing," because if I didn't know what I was doing I wouldn't be...I wouldn't have started.

Given this philosophy, it is not surprising that P6's desire to compose colored the entirety of their improvisational experience with the *Torpere*:

> **P6:** I approach this like a performance, so I was most concerned with making something that sounded competent immediately. Even if I don't have a complete grasp on what I can do with this or even if I'm not a good enough string player to make it perfectly when I reverse the bow, or even if I can't use as many notes as I would like to...I want to make something that sounds competent/beautiful, which is actually not something that all artists are trying to do. Which is like a goal that you have, and I think my personal taste is I wanna make something that sounds polished or finished and not necessarily because I'm doing it for other people but because that's just the language of music that I know. So when I make something, I want it to sound good. Which is an aesthetic goal, it's not an objective scale.

The inability to move beyond existing schema produced a space in which "success" was unlikely to occur; when personal objectives remain rigid in circumstances that are incompatible with those goals, that inflexibility restricts the freedom to move into unknown (and potentially fruitful) musical territory.

9.4.2.2 *Conflict Between Expectation and Reality*

In addition to the issues that conceptual schema introduced into the creative process, participants also struggled with "letting go" of instrumental paradigms. In many cases, failure resulting from a conflict between a participant's expectations and reality was the product of problematic deductive reasoning. Participants began with a reasonable premise (e.g. you can play a guitar by bowing/strumming/touching its strings, and the *Torpere* is like a guitar), but reached a false conclusion (the *Torpere* can be bowed/strummed/touched like a guitar). While it's true that the *Torpere* can indeed be played like a guitar, it is intentionally designed to be different enough in its constraints and affordances as to be at least mildly unfamiliar. Participants' reasoning often placed them in a passive relationship with the instrument: statements often followed a "*I* tried/wanted/did..., but *it* wouldn't/couldn't/didn't..." formula:

> **P2:** This [metal snare] is like the back of a snare drum. It sounds like white noise. [I] think about white noise, think about rain. The only place you could pick up something [from the snare] is around the pickup, but it doesn't work. *I want to* have a noise like raining, but *the Torpere didn't* work that way.

> **P4:** I was just *trying to* [be] able to bounce off the string. Didn't really work. *I'm just trying* to get the sound, and there's no way, *the Torpere can do it.* Nope.

> **P6:** Here *I'm trying* to use some kind of traditional bow technique. *I kept trying* to get sharp cut-offs of the sound, but I kept dealing with the problem where I would lift the bow off and *the Torpere* would still be resonating and *I would try* to dampen [the strings] quickly with my hand...*I was trying* to cut it off again and I couldn't, because *the Torpere* is binary. I can't control it.

These examples do not demonstrate failure on the part of the *participants*—after all, there is no way of confronting the unknown without testing hypotheses. However, the conclusions that each participant reached were done with a sense of finality that limited further exploration and creativity: the snare *can* be used effectively in places beyond the pickup, and was employed precisely in that manner by P4 and P5. A "bouncing" string technique was applied extensively by P2, and P1, P4 and P7 all discovered ways to mute the strings of the instrument.

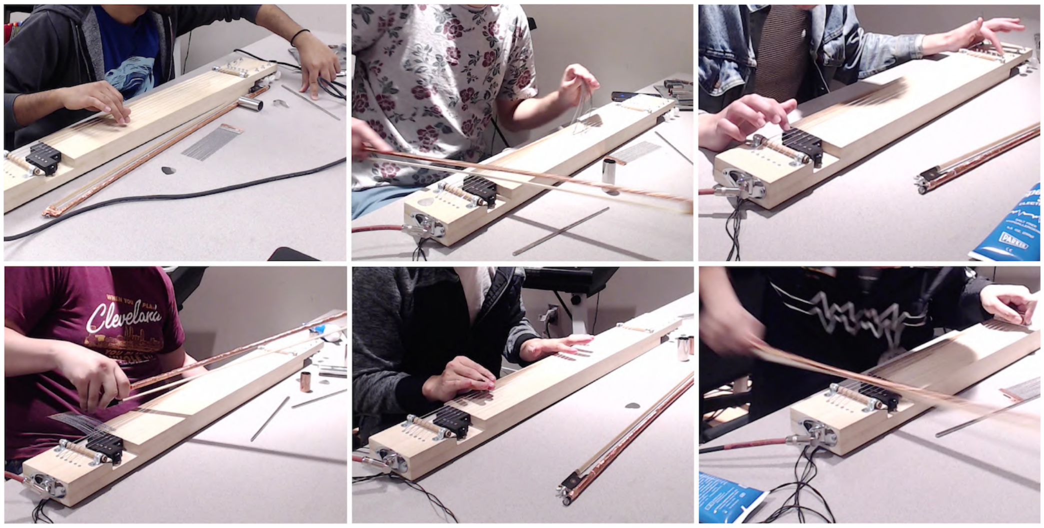


Figure 9.2: Torpere participant interactions

9.4.3 Summary - Defining Risk: Failure

It would seem that the process of testing one's expectations against the affordances of the *Torpere* and failing to produce the predicted response contributed to the creative process in one of two ways: participants either railed against constraints and attempted to brute-force their desired outcomes, or else accepted the failure and adjusted their expectations accordingly. In both conceptual and practical capacities, some musicians simply seem more naturally inclined to pivot away from objectives and expectations and embrace the unknown in a positive way. Those who were unable to relinquish their schema and/or paradigm engaged in what I call "forced paradigm looping," a process of repeated attempts to apply a paradigm through brute force. This will be discussed further in Section 9.7.

9.5 The Effects of Failure

Simply put, the data suggests that failure can be considered as negative *or* positive disruptions to expressivity. Though initial discussions about risk tended to be fairly clean-cut descriptions of the negative role that FEW play, there was a great deal more nuance when interrogating the actual experiences of participants during their improvisations. Here, FEW were often welcomed as points of positive, productive musical interventions that prompted creativity in ways that could not have been planned or designed for. Participant 7 gives an interesting mathematical breakdown of the balance of the positive and negative effects of failure in their high-risk improvisation:

> **P7:** [The improv was] maybe 20 percent random, and then using the random stuff to trigger the next thing I wanted to hear. 80 percent of it I was actually shooting for something I had in my mind, but not always getting it.

The fact that P7 spends 80% of their improvisation moving toward a musical objective—and often failing—would seem like a barrier to creativity. However, the unpredictable behavior that emerged from these failures seems to contribute to a positive element of "randomness" that often triggers positive new creative paths.

When participants spoke about FEW in a negative light they tended to do so in one of two ways. In describing *why* their experiences with FEW were negative or undesirable, participants explained the following conditions:

Table 9.24: Torpere Negative FEW Codes

3.1 FAILURE, ERROR, WRONG ARE NEGATIVE

3.1.1 FEW are Objective	3.1.2 FEW is Incompatibility/Conflict	3.2.1 FEW Ruin Everything
"Error/wrong" is objectively discernible	"Bad" is incompatibility between expectation and reality, objective and result	Mistake/Error results in inability to continue performing
"Wrong" defined by assumptions, expectations of existing framework of performers, audience; objectively identified, evaluated by existing metrics	"Failure" is an un-obtained objective/goal	Exploration is incompatible with error/wrong
In collaborations "right" and "wrong" can be defined by others' responses, reactions	"Failure" is inability to develop control	FEW is something that must be fixed
Not knowing "right" and "wrong" leads to confusion, disconnection	Error/wrong and sounding "bad" are inseparable	Performative "mistakes" "ruin" things
Personal objective are inherently "right" and/or "correct"		Fear of FEW limits range, pacing of musical creativity
Error can not be intentional, and intentionality is required for "good" musical creativity		

9.5.1 FEW is Negative

The majority of participants in the study initially spoke of failure as inherently negative. It would seem that the word itself has clear-cut and rigidly defined connotations that can be difficult to depart from. In particular, FEW were seen as embarrassing displays of a lack of skill, and the internalization of these blunders override the satisfaction of navigating an expressive space. If a musician is gripped by feelings of anxiety or shame at the inability to manifest their desired musical outcome, the innate need to "fix" whatever the source of the FEW was can become so overwhelming that the musical engagement can be ground to a halt, and the path to expressivity closed.

FEW Are Objective; FEW is Incompatibility/Conflict: Despite the complexity of failure—what it is, how it impacts the expressive process, what to do when confronted with it—some participants described it quite objectively in their own practice. In these cases, musicians pass judgement on "right" and "wrong" musical processes and outcomes, often resulting in harsh evaluations of their own expressivity:

> **Interviewer:** When you're improvising, can you think of things that happen that make you go, "This is going really wrong," or "This is going really right." Are there certain things that happen during your performance that make you feel like, "Yes, I feel like I'm expressing myself," or "No, I feel like this is going totally wrong"?
>
> **P2:** I think I can notice.
>
> **Interviewer:** Can you give me an example?
>
> **P2:** Because it sounds bad sometimes...I play wrong with my synthesizer, or I try to go into a new direction, [and] I realize, "Wow, it sounds bad."
>
> **Interviewer:** When you say it sounds bad, do you mean it sounds bad compared to what you thought it would sound like?
>
> **P2:** Mm-hmm (affirmative). Yeah. Compared to–maybe I hear it in my mind and try to reach it. I fail, it's not what I saw. It doesn't suit that well, or something like that.
>
> **Interviewer:** When you experience failure, do you feel like, "Okay, I've just got to go back to what I was doing," or, "Well, I guess I'm just going to have to follow this road..."
>
> **P2:** Most of the time I think I need to figure it out.

Here, P2 describes failure on several registers: the sonic quality of the music, the inability to produce an imagined musical goal, the compatibility between existing and new material, and the desire to "fix" something that they are unhappy with. Failure is complex, and can mean many things simultaneously.

Statements such as these reflect deeply-rooted beliefs regarding musicians' personal visions, as projected in their mind. Often these beliefs are coupled with opinions of musical activities as inherently "right," which means that failure can be objectively judged even in others. Participant 6 puts this very plainly when describing the effect of failure in musical engagements involving other musicians who are entrusted to realize their own compositional music:

> **P6:** I'm like the top-down, "I'm going to organize this chord and this group of instruments exactly to play this chord." And if someone is missing on the day of the rehearsal I'm like, "God damn it I need a "G" and it wasn't there." You ruin the chord 'cause it wasn't there.

These definitions of failure convey value judgements that have little room for negotiation: either something is successful ("right") or failure ("wrong"). Failure, as a negative musical outcome, can present as an internal or external evaluation and is often identified as a division between expectations (of the self or others) and outcomes. In most cases, this can be reduced to a simple conflict: what is planned is "good" and a deviation from that plan is "bad."

FEW Ruins Everything: Participant 6 describes FEW from the standpoint of both acting musician and composer-overseer. When they experience failure during their own musical improvisations the effect is so negative as to be impossible to overcome. The point of failure prescribes a future that can not be salvaged:

> **P6:** Trying to do something and failing [means] working with whatever malformed blob you created until it's close enough to what you pictured that you want to show it to other people...It's like, when I'm live and I'm performing [with the high-risk *Torpere*], I can't make a change that's going to throw me off so much that I can't keep performing. So I have to very, very slowly–especially in something that's [so] unfamiliar–I have to very slowly make alterations and

> steps that are just kind of instinctual. I know that if I play one bad note, it's probably not gonna stand out that much, but if I re-tune the entire instrument and now it's unusable, I'm like, "Oh, pardon 20 seconds of silence while I fix it." [laughs]

For P6, re-tuning the *Torpere* incrementally—slowly, one string at a time—is as much of a risk as they are willing to take. Making more high-risk decisions, such as drastically changing the tuning of all of the *Torpere*'s strings at once, can have no positive outcome, only failure. It is unclear whether this belief (that they would be incapable of adapting to a high-risk state and producing something of value) stems from experience, self-confidence, or fear.

In all of the of case studies presented here regarding the inability to achieve an objective and/or experiencing incompatibilities between a musician's expectations and conflicting reality, the emotional subtext was exclusively negative. In describing such experiences participants seemed to find no redeeming qualities in their confrontations with FEW, only frustration and disruption. Participants tended to quickly and easily point to the obvious, highly-observable FEW of their improvisations and express their displeasure with the effect on their improvisations; however, as an observer of both the real-time improvisations and the reflections themselves, I found myself able to draw valuable insights from participants regarding FEW that they did not necessarily assume to be relevant. Perhaps due to the participants' aforementioned assumptions that "failure" is exclusively negative (and could only possibly be judged negatively) it was an challenge to see if there was more to be gleaned from participants' initial descriptions of their experiences with FEW.

9.5.2 FEW is Valuable

Fortunately, it required very little in the way of encouragement in order to draw deeper and more nuanced discussions of the positive consequences of experiencing something that seems, on the surface, to be failure in the negative sense. Simply asking musicians to expand on their initial thoughts and prompting them to reflect on what came *after* their FEWs opened the door to identifying value creative processes that were born from seemingly undesirable roots.

Table 9.26: Torpere Valuable FEW Codes

3.1 FAILURE, ERROR, WRONG ARE VALUABLE		
3.2.1 FEW Prompts Creativity	3.2.2 FEW are Human	3.1.3 Failing at Failing
Low-level error/mistake can be prompt for new exploration	FEW is inherently human: humanness is "deviation from perfect"	Something interesting is inherently not failure
Intentionality can make mistakes/error positive creative elements	There are no "mistakes" that you can "fix" in improvisation, it's real-time human activity	Musical expression outside of rigid framework allows for wider definition of "wrong"
Skill and mastery of framework/rules/practice allows mistake/wrong to be creatively valid and "wrong" in good way	Physical FEW is social (incompatibility between skill/experience levels among performers), aural, more internal	Improvisation allows for error and wrong
Error/wrong can be productive to creative process, creatively valid	"Mistake" in improvisation is more subjective feeling than objective element	Low-level error/wrong can be reconsidered as not-error/wrong
Mistakes are opportunity to "find something else"		FEW is fluid, spectrum, based on context
Mistakes can reveal something interesting		Self-confidence determines how "wrong" is defined and understood
Low-level error/wrong can be incorporated into process		Mistakes can be intentional, intentional is good

FEW Prompts Creativity: When participants self-identified moments of their improvisations as "failure," the immediate inclination was to explain *what* they had been trying to accomplish, and *how* they failed in their attempt to accomplish their goal. While this process of identification and clarification was extremely helpful for developing a taxonomy of the *meaning* of failure (and certainly understanding the negative emotional consequences of such events), participants were unlikely to consider the effects that failure had on what came *after*. As a researcher, I was able to leverage an emotional and experiential distance from the musical activity in order to see the larger chain of events that preceded and followed moments of failure. In encouraging musicians to expand on their thoughts and comment further on *why* their subsequent actions were undertaken, facets of failure emerged that illustrated a different, positive consequence.

Participant 3's reflection on their low-risk improvisation with the *Torpere* involved a moment in which they attempt to use a metal slide to sustain a note. When they are unable to achieve their desired goal they describe their failure as being "frustrated" and "not free to do anything." Mere seconds later, they turn the slide 90-degrees and place it on the *Torpere*'s strings, which produces an unexpected rattling sound and facilitates a new plucking style:

> **Interviewer:** What gave you the idea to use those slides between the strings?
>
> **P3:** It just happened I think. It doesn't stay on top, as I try to do here. I wasn't really thinking when I did this. It just happen[ed].

Participant 7 describes a similar moment where, in the process of attempting to use their hand with the metal chopsticks, they experienced a physical failure that led to an entirely different creative activity:

> **P7:** I wanted to use [the chopstick] with just one hand and do something else with the other hand, but I realized it wasn't gonna work. [laughs]
>
> **Interviewer:** So this was definitely a [musical] shift. What made you try that?
>
> **P7:** Dropping my stick was a sign that I had to do something else. I just wanted to try something completely different.

After dropping their playing implement, P7 takes the failure in stride, considering it as a "sign" to try something completely new. They continued to use the chopstick, but dropped the tuning of the instrument's bottom string to the lowest pitch possible, and threaded the clay-cutting wire through the strings to produce an entirely novel set of sounds and physical interactions. Perhaps due to their general philosophy regarding FEW, P7 seems very uninhibited in their concept of failure. As they state: "I probably lean towards embracing [mistakes]...It doesn't stress me out. It's more of a [positive] challenge."

FEW Are Human: Some of the most unexpected discussions regarding failure, error, and wrong came from participants who had experience designing and improvising with "intelligent" computational systems for musical expression. Even as they self-identified as minimal risk-takers, participants seemed to offer a conflicting view on the need for risk in the design of robotic systems for musical co-creativity:

> **Interviewer:** When you're working with these robotic systems, co-creativity with human-computer, are you trying to build in any...I'm thinking about when

> you're making drum loops and you can turn up the "human" knob, where it varies a little bit to give it a little less sterile feel. Do you have to consider that stuff with robots?
>
> **P4:** One hundred percent. I do much more of the gesture side of it, but I've had this kind of question a lot. I'm trying to mimic human gesture so I–all of what I'm writing, all the algorithms to have this very robotic machine computer do, is influenced by the human side of things, which clearly has error. So yeah, there's randomness put in there, there's different things to emulate that. Deviation from perfect.
>
> **Interviewer:** It's interesting that you recognize that that's an important part of playing like a human, but in your own practice you try and avoid [risk].
>
> **P4:** Yeah, well because [risk] is going to happen anyways, right? 'Cause for the most part everything that I'm doing, especially composition-wise, is played by humans. And then I think from the generative computer music stuff that I've done, the system is complex enough that it isn't about the error, it's about what's gonna come out of it.

> **Interviewer:** When you're performing, either with humans or robots, and things go wrong–you want to play a note and it comes out wrong, or you think it's going somewhere and it goes somewhere else–how does that make you feel? Is that an interesting challenge, or something you feel you need to fix, or...?
>
> **P5:** It can be interesting. Yeah, for sure. I like to have total control over my own stuff, but unpredictability from others is good. In the case of [the robot], I consider it as like a separate being. So, I guess you can place an instrument outside of yourself. It's not a "person," but...it's like an extension of yourself, but also really it's a separate thing.

P4 and P5 talk about failure in distinct but overlapping ways. First, there is a recognition of the fact that FEW are an inherent part of being human. Second, they make distinctions between failure on their own part versus failure on the part of others. Within their personal practices failure is a risky element that they work to gain control over, in the hopes that they can prevent it from happening. Failure on the part of others—be it human or computational collaborators—is more welcome in the creative process, and is also more likely to be interesting or productive. Lastly, FEW are functional elements that can and *should* be designed into computational systems in order to facilitate more expressive musical collaborations. Failure is risky, and taking on personal risk is a daunting proposition. However, the risk is worth the reward—especially if you can offload it to others.

Failing at Failing: When taking all of these elements into consideration it is difficult to accept FEW as one objective thing or another. Is an incompatibility with expectations that causes frustration, but that leads to an interesting new interaction valuable, or not? If a note is unintentionally produced and it is more interesting to a performer or audience than what had been planned, is that a failure? What is it that drives a musician to attempt to "go back" and fix a mistake that exists only in the past? As Participant 7 puts it, "I definitely don't think that you can fix a mistake, if you make a mistake in improv–that doesn't make any sense to me. 'Cause it's in real time. [Laughs] You can't stop."

Many participants acknowledged this contradictory reality in their own reflections. Participant 7 describes moments in which failure has no negative connotation at all, only positive effect:

> **P7:** I was exploring the electrical signal then I realized [the chopstick] was not in good contact the whole time based on how hard I was pushing it. Then it slipped and it sounded cool, so I slipped some more. [Laughs]

Even Participant 6, a musician with one of the lowest thresholds for acceptable FEW, isolates moments of improvisation in which a failure produces something more valuable than what had been planned:

> **P6:** I'm not perfect at [tuning], so I was trying to guess how far I needed to tune it. Then you could kind of hear the note gliding while it was still resonating, which I actually thought sounded really cool. 'Cause you could hear it like [singing] as I was trying to find where the new note needed to be–at least once I did it completely wrong and I [used] whatever note came out as what the ground was.

For all of their metrics for "successful" musical expression—precision, form, repeatability—P6 presented the most compelling argument in support of the value of failure: the fact that failure can nullify itself:

> **P6:** I'm not aesthetically against randomness, but process-wise I feel like I kind of must be. And yet, at the same time I'm saying that I know that I often make a lot of mistakes or will just straight up play a chord wrong and I'm like, "Oh, that's more interesting." So, I'm aware that I'm not good enough to always execute what I want, and sometimes what comes out is better or different or interesting and I don't feel like that's a failure when that happens. I kind of just feel like that's what being creative *is*...?

This statement is complex. P6 first makes it clear that randomness is not inherently damaging to the aesthetic value of music, but in the same breath pivots to say that they "must" actually find randomness to be inherently negative to a musical process. They then identify their own personal failings—clear-cut failures that are direct results of physical error—as sometimes interesting and possibly "better" than what they had intended. In those instances—over which P6 has no control—the failure is not a failure at all, it is creativity at the core. The objective moment of failure and the subjective evaluation of what it produces can exist in two opposite states at once.

9.6 Conclusion: The Effects of Physical Risk

By examining the positive and negative impacts that unpredictability and the potential for failure can have on creative expressivity, several themes have emerged to form a complex network of risk and expression. Through deep analysis of participants' experience in this study, it is clear that the personal needs and values that each musician brings to their improvisation define, in many ways, how positive or negative risk will be.

Several areas of interest emerged by querying the role of risk within computational performance practices. Much of what was revealed through the thematic analysis showed complex interconnected relationships between how unpredictability is defined, incorporated, and avoided within creative activities. Broadly speaking, we can separate these networks of connections into two distinct categories:

1. Risk is a Disruption
2. Risk is a Prompt

Though much of the content produced through analysis overlaps between these two areas, participants tended to describe their engagements with physical and material risk either as a barrier to creativity or a prompt for new modes of exploration.

9.6.1 Risk is a Disruption

For musicians with highly structured performance goals and objectives, risk tended to disrupt the creative process, prevent expressivity and flow, and produce negative emotions such as stress, frustration, and anxiety. When unpredictability presented negatively (Theme 1.2), musicians felt unable to overcome emotions that disconnected them from positive expressivity, demonstrate their skills and knowledge, explore unknown constraints and affordances, and act with a sense of intentionality and meaning. The pressure to mitigate unpredictable physical behavior became overwhelming, leaving little emotional, physical, and mental bandwidth for expressive activities. Participant 3 illustrates this when reflecting on the difference between their low-risk and high-risk improvisations:

> **Interviewer:** Comparing the [low-risk] and the [high-risk] versions, obviously a lot of wasn't a super fun experience for you–you weren't getting the sounds that you wanted and you felt a lot of frustration. Are there any insights you can give me about how you felt about using one that was pretty predictable and one that was very unpredictable?
>
> **P3:** Regardless of if it's painful or not, having this additional [unpredictable] element interfering–that was really disturbing for me. It's multiple things going on at the same time: I'm trying to learn, trying to compose, trying to improvise, and then trying to circumvent this shock. And that definitely is intense. Not a creative [kind of] intense. It was not pleasant.

Participant 3 was attempting to find stability and control while being bombarded by unpredictability from every angle. Unpredictability could be understood only as chaos and disruption, a roadblock to any kind of expression at all.

When failure presented negatively (Theme 3.1), musicians spent their time struggling to obtain musical objectives and resolve conflict between their expectations and reality. In these conditions failure was inherently "wrong," as it was always an unintentional product. Unpredictability and failure could not be accepted or used productively because they were deviations from the schemata and paradigms that were prerequisites for musical expression.

The boundaries of these known frameworks were different for every musician, and while the high-risk version of the *Torpere* was more likely to function problematically outside of such boundaries, the low-risk version was, for some, the “right” level of risky. For Participant 6, who had the least experience with musical improvisation and no personal exposure to novel instruments for musical expression, the high-risk *Torpere* was *so* risky as to be unapproachable. The low-risk version, however, was unfamiliar and unpredictable *enough* within their personal schema and paradigm to *become* high-risk at a productive level:

> **P6:** It really was just about working with more familiar material versus non-familiar material. Even though [the LR *Torpere* was] not very familiar, it let me express myself. The [HR version], when I was so unfamiliar with the language that I did not know how to use it yet, I was like, “I can’t do much with this, but babble.” Like a toddler trying to make sounds that sound coherent. So, when something came out that sounded coherent it was like, “Oh! [clapping] Musician’s first word!” But I didn’t feel like I [could] say a sentence or something. I think it does come back to: I don’t have enough control to feel like I know what I’m doing. And if I played this for longer, I might actually have an opinion. But because it’s so new, I was still processing more, “how can I use this to do anything?” rather than “how can I use this to make music that sounds coherent?” The first time it was close enough to familiarity where I felt like I could talk in a language I knew, even if I was using tools I didn’t know.

P6 uses metaphors of speaking to illustrate musical expression. For them, expression through music is like speaking coherently: it requires not only a robust known vocabulary, but also a control mechanism to physically articulate their inner thoughts. When those elements are present, new words can be understood through contextualization, worked into sentences, and appreciated for their useful contributions. Without those things, P6 can only try to speak a foreign language, where the vocabulary has no meaning and the rules of grammar and syntax are unknown. For P6, the high-risk *Torpere* was an entirely foreign language, but the low-risk *Torpere* was simply a new dialect—comprehensible in P6’s foreign tongue, but novel enough to produce unpredictable and interesting new sentences.

9.6.2 Risk is a Prompt

It is clear that the conditions in which risk becomes a positive force are somewhat narrow; conditions must be *just right* in order for risk to enable and enhance expressive outcomes.

However, when those conditions are met, the benefits are valuable in a way that can be very special—that is, expression in high-risk states is distinct, and the novel outcomes are highly unlikely to occur in low-risk states. In Participant 7's reflection on his experiences with the low-risk and high-risk versions of the *Torpere*, they identify a rare form of expression that came from playing the high-risk instrument:

> **P7:** There's a lot of things that I didn't try in the [low-risk] version that I would have wanted to, given more time. Some of those things I did try in the second version. But there were a lot of things that I did in the [high-risk improvisation] that I know I would have never thought of to do in the [low-risk improvisation], because honestly the [physical] feeling of [the high-risk *Torpere*] put my mind in a different place, and I was just coming at it from a different angle because there was the added information of sensation in my fingers. That definitely changed how ideas triggered in my mind.
>
> **Interviewer:** That's super interesting to me. Do you have any idea as to why that might be?
>
> **P7:** I do have some ideas. I think there's a lot if things. A lot of reasons why. I'm sure there is a lot of reasons why. They're probably different at different points in the piece, but I know that at one point I was more focused on how [the high-risk *Torpere*] felt than how it sounded. There was a switch where I was really focusing on the feeling, and not on the sound that was happening.

Participant 5 describes their experience with the low-risk and high-risk *Torpere* in a similar way, where the high-risk instrument not only prompted novel physical interactions, but changed their creative process entirely:

> **Interviewer:** Did the sensation effect the musical choices that you made? Or the way that you were playing them?
>
> **P5:** Yeah, definitely, both for those. Sometimes I would let it affect it, but sometimes I would ignore it if I didn't want to be changed by it. I never really tried to work out why it was happening. How it was happening. It was more...it just prompted me to consider what I was doing again.

For P5, risk was a valuable musical element that enabled new forms of creative expressivity. Though, by their nature, the unpredictable physical behavior of the high-risk *Torpere* could not be controlled, P5's engagement with that risk was *self-controlled.* P5's sense of agency was not hampered by risk, and they felt empowered to ignore or embrace risky elements at will. Rather than attempting to *bind* risk with the boundaries of existing schemata and paradigms, some participants allowed risk to *expand* their definitions of what could be expressed. With less strict borders dividing what is *believed* to be possible and what *is* possible, expression takes a form that is not presumed.

Lastly, in Participant 4's reflection on the entirety of their experience in the study, we can see the significance that unpredictability can have on a fundamental level:

> **P4:** I think it was way more interesting, I think, using a foreign instrument when it had the potential to shock you or do these weird things. Or it had something that wasn't inherent to just what I understand this instrument to be. So, this is a stringed instrument with pickups that's going through an effect pedal, right. I pretty much know exactly what that sounds like. But as soon as you put the electricity through it, it was way more interesting because a) it felt weird when I did certain things. And b) it had this musical thing, it had a side effect right? It had the sound. It made the playing experience much more engaging, I think. Yeah.

9.6.2.1 Risky Flow States

When risk enabled extended creative expressivity, participants described something very similar to Csikszentmihalyi's *flow state*. In their descriptions of their most engaging moments of improvisation many performers convey a suspended sense of time–or no perception of time at all.

> **P6:** [In the low-risk improvisation] I was like...I started to hear–I started playing and immediately was like, "Alright, bye! I'm in music-land now and I don't care about what happens." That time did not exist, for that period of time...I had a very profound musical experience using [the low-risk *Torpere*]. I had a really good time. [laughs] I was in bliss. It's so nice, I had a really–I like it. I like it a lot, honestly. The [low-risk improvisation] I was like, I would have got super in love with this thing.

P6, who had previously described in great detail their disinclination for "music for music's sake," finds themselves so deeply engaged with the improvisation that they reach the end of their compositional arc and finds that they are unable to leave the expressive state that has emerged:

> **P6:** I've arrived at my final chord and I'm just kind of playing with it and it's very, very, very slowly decreasing tension until there's, like, absolutely nothing. And then I kept going a little bit after that, 'cause I was still emotionally invested and wanted to add something else.

> **Interviewer:** So when you say "emotionally invested," what do you mean? What kind of emotions were you feeling?
>
> **P6:** Just kind of a flow of playing an instrument and enjoying what comes out. Which, I guess is what improvisation is.

Moments of deep expressivity also had the effect of reducing cognitive processes, and participants describe a "space" that seems to be somehow untethered to the world around them:

> **P7:** Here I'm disregarding–not really thinking about the TENS unit anymore. I was just *there*, you know? With the wood and the string sound.

9.7 Frameworks for Considering Risk and Expressivity

9.7.1 Risk-Expressivity Paradigm Binding

When entering a risky environment, one begins at a point of existing knowledge. From there, expression can take many forms and travel many paths. In low-risk spaces, expression is confined to the boundaries of what is presumed—these environments are bound by existing paradigms, which direct and constrain activities. Known schemata and paradigms are tested against the constraints and affordances of an instrument, and compatibilities are operationalized in order to demonstrate existing skills and knowledge. Where incompatibilities are encountered, expression is disrupted and failure is experienced. The process is unidirectional: the musician *applies* a paradigm onto an instrument.

Pushing beyond the presumed capabilities of a risky instrument and exploring unknown affordances and constraints—elements that are outside of one's schemata and paradigms—can expand an expressive space. New expressive capabilities can be discovered where familiar modes of interactions fail, and those discoveries can be used as prompts for further exploration. Discovery draws new boundaries around an experience, a new paradigm that accounts for both known *and* novel affordances and constraints. Instead of a unidirectional relationship, where a musician accepts or rejects an instrument's behavior, a bidirectional dynamic can exist—an instrument's behavior can cause a musician to change their own activities. In this space risk has the potential to play a productive role, as there is room for a new paradigm to develop over time. However, if risk becomes unmanageable or undesirable to the musician, they can shift out of discovery/exploratory mode and step back into the familiarity and stability of a presumed space.

Expressive engagements with risk at the highest level require a willingness to depart from a qualifiable paradigm altogether, including expectations regarding what human-instrument relationships look and feel like. While a novel paradigm developed through discovery and exploration enables a reciprocal relationship between a musician's actions and an instrument's response, agency resides with the musician alone. Though the creative process may be bidirectional, it always begins and ends with human action.

In rare cases of high-risk expressivity, novel constraints and affordances were not only discovered and exploited, but also allowed to *direct* a creative process. Unbound by existing or nascent paradigms, creativity occurred in an *emergent* space that allowed for something I call an *idio-paradigm* to form. In these spaces, risk itself took on agency *of its own*, and an instruments' behaviors, affordances, and constraints became *emergent* properties of an autonomous "other." This process of reciprocal interaction between a musician and risk could only be understood through an emergent idio-paradigm defined and re-defined in real-time.

> **P5:** It felt, for me, like it added another voice telling me what to do at times.
>
> **Interviewer:** Another voice telling you what to do?
>
> **P5:** I can't help embodying some kind of intelligence into it. And this idea of telling me when to do things...It definitely changed the process.
>
> **Interviewer:** How's so?
>
> **P5:** For me, I kind of imagined something saying, like, "Think about what you're doing more." It was like that for me. It was like I stopped and then re-evaluated if I should keep doing what I was doing–if it was worth doing...at the end, I was just trying to experience what it was like.

> **Interviewer:** It sounded like you were getting some interesting textures out of it, but you abandoned it pretty quickly. But then it kind of came into play again.

> **P7:** [The sound] found itself a new place. *[The instrument] was like, "Do some stuff with the high strings."* [Emphasis added]

9.7.2 Risk-Expressivity Pathways

Risk represents just one point of entry into understanding the complex system that is human creativity. It can be defined as unpredictability and the potential for failure for the purposes of this work, but in reality risk and expressivity intersect with a multitude of formal and informal metrics, some observable and some not. Taken together, the *Torpere* study presents valuable insight into how risk manifests within different creative activities—where it is valuable and where it is problematic. From the discussion presented in this chapter it is possible to consider a risk and expressivity through a novel framework scaffolded on the findings from the *Torpere* study.

When approaching an improvisation with high risk states each musician brought a unique model for musical creativity to the situation. For some, this framework was very loose and flexible (e.g. explore as much musical content as possible). For others, schemata were blueprints for an improvisation that could not be deviated from (e.g. create a 5-section, 8-minute improvisation with repeated motifs). The schema of each participant bound their engagement and set conditions for what "unpredictable" and "failure" would be in each of their experiences and set the point of departure for each improvisation.

In the Risk-Expression Pathways below we can see how unpredictability and failure are enacted at three nodes on a path to expressive outcomes. A "+" indicates a high presence, while a "-" indicates a low presence or absence. When an element is highly present, unpredictability and the potential for failure are generally absent, and the introduction of risk would be a disruption. When an element is not highly present, risk is a productive force, and it is more likely to be productive than disruptive.

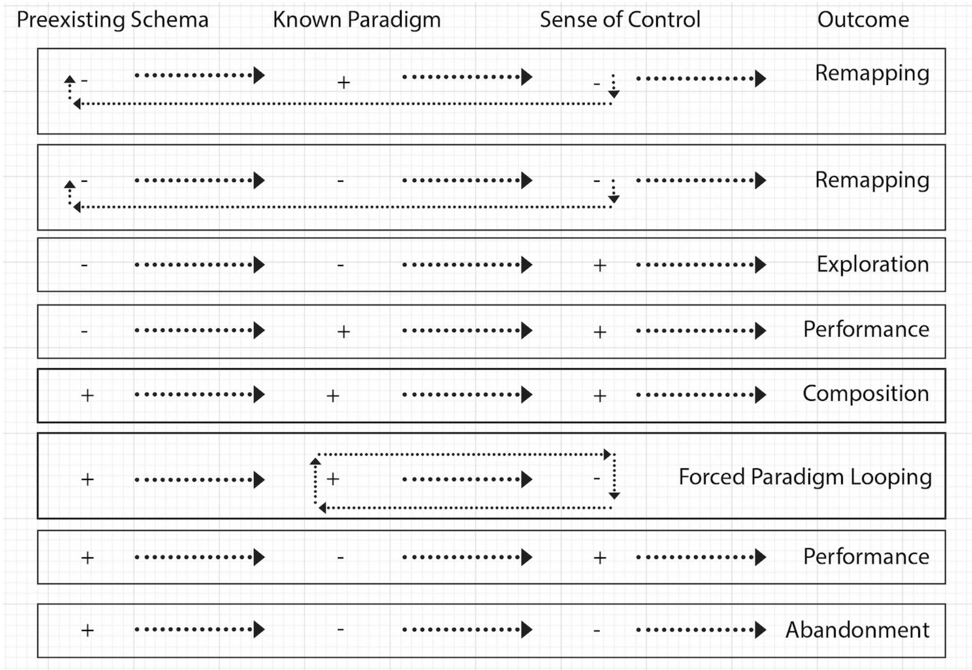


Figure 9.3: Risk-Expressivity Pathways

9.7.2.1 [+, +, +]

In this work we have seen that musicians focused on compositional goals experienced the lowest levels of positive musical creativity and expression in high-risk states, at least in part due to the need for control and stability in the pursuit of formal compositional goals. A highly constrained schemata set conditions in which musical expressivity could only be attained through the successful application of a familiar paradigm *and* high levels of perceived control. If musicians were able to maintain the motivations defined by their schemata, effectively apply a known paradigm to the *Torpere* instrument, and secure a sense of full control, they were much more likely to experience positive musical expression.

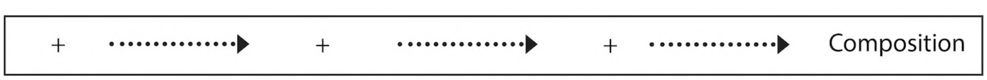


Figure 9.4: Compositional Risk-Expressivity Pathways

9.7.2.2 [+, -, +/-]

Unfortunately, many participants—trained composers in particular—began their improvisations with highly defined objectives and expectations (informed by existing schema), and then found themselves unable to effectively apply a known interaction paradigm. This would result in one of two outcomes depending on whether or not a sense of control could be obtained. If the musician was willing to accept risk (paradigm shift) and identify novel control elements for the *Torpere* they were likely to experience positive expressivity in their improvisations—this was more likely to occur in a performative mode of creativity. If the musician was unable to identify elements of control—and was unwilling to reconsider their schemata or paradigm—they had no choice but to abandon their engagement.

Performative expressivity was also a likely outcome of a process in which a participant began with a very open objective and was successfully able to apply a known paradigm and sense of control.

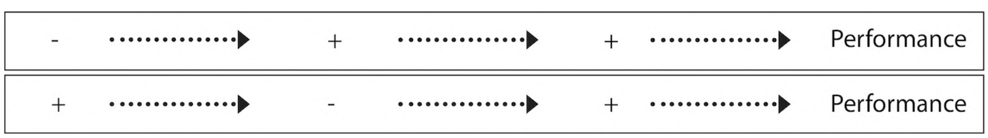


Figure 9.5: Performative Risk-Expressivity Pathways

9.7.2.3 [-, -, +]

In cases of creative improvisations that began with no clear schema and a high level of openness to flexible or novel paradigms, expressivity was available to musicians through the identification of control parameters inherent to the *Torpere*. Participants who discovered that the unpredictable electrical signal could be directed and manipulated through different touch interactions, for example, had little need or use for the boundaries of a guitar or violin paradigm, and were quite satisfied to follow emergent behaviors of the instrument through novel expressive spaces. One participant even describes a moment of surprise as they “snap out” of their deep engagements with the high-risk *Torpere* and remember that they can apply known paradigms if desired:

> **P7**: I realized that I had forgotten that it's a string instrument, and you can play harmonics and things. I just discovered that. [laughs]

Their engagements with the new and unknown in a high-risk space actually facilitate a "re-known" application of a string instrument paradigm; because they have created a new set of interaction, control, and musical modalities, they are able to apply previously-known models to a newly-known system, and vice versa. Further, these new and old paradigms can inform each other in ways that re-define what "new" and "old" mean, in a continually unfolding creative process.

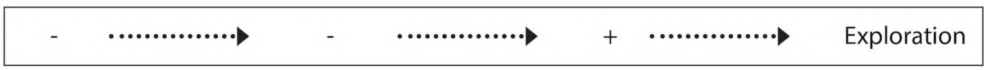


Figure 9.6: Exploratory Risk-Expressivity Pathways

9.7.2.4 Forced Paradigm Looping

In some cases, participants found themselves with highly rigid schemata *and* paradigms, and a *lack* of control. In the event that the musician was unwilling to accept a riskier schema and/or paradigm state(s), the absence of control prompted a process that I call *forced paradigm looping*. In this state participants entered a bounded process of *testing* control parameters (as defined by their existing paradigms), failing, attempting to *force* those control parameters, failing, and repeating the process until either abandonment or paradigm shift. Because the rigid schema often presumes a single known paradigm, the paradigm is itself unlikely to be let go, and the musician is likely to continually attempt to brute-force control parameters that simply will not work. Forced paradigm looping can span the entirety of the creative process, and is most likely to end at a state in which the musician "gives up" on both the paradigm and control states altogether, abandoning the engagement.

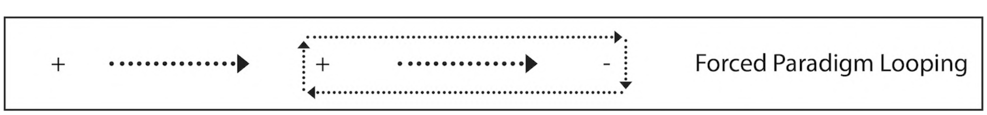


Figure 9.7: Forced Paradigm Loop

9.7.2.5 *Remapping ([-, +, -])*

Participants who began with very loose or open schemata also experienced a type of looping: Remapping. In this process, an individual begins with an open schema, applies a familiar paradigm, and is unable to achieve a sense of control. Without any sense of control, the creative process loops back to a "neutral" schema state: an individual can either form a new objective, or attempt to apply a new/different paradigm. If, in either case, they are unable to develop control despite shifting their schema and/or paradigm, the participant is likely to abandon their musical engagement.

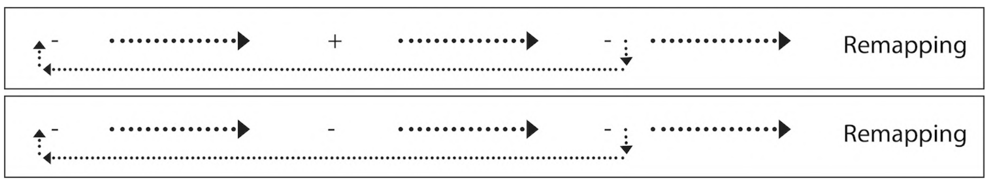


Figure 9.8: Remapping Pathways

What separates Remapping from Looping is the scope and flexibility of the iterative process. In a Remapping process, all three element states can be reconsidered and shifted, and there is a high chance of remapping an abandonment path to one that ends at expressive, performative, or compositional expression. Though compositional outcomes are the least likely, as they require the most remapping, exploratory and performative outcomes are quite probable with relatively minor adjustments.

9.7.2.6 *Abandonment*

Abandonment is a path that can result from many creative engagements, but is formulaic in its overall structure: it is always the result of a highly present schema and lack of control. Schema and paradigm can be remapped into productive configurations (+, -) or (-, +), but if those shifts do not enable a musician to find *some* sense of control, there will be no path to creative expressivity.

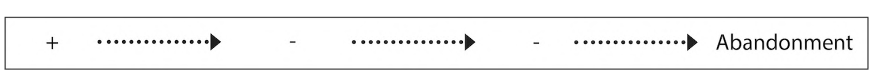


Figure 9.9: Abandonment Pathway

9.8 Torpere: Conclusion

The search for and application of known schema, paradigm, and control allow musicians to confront and engage with risk in ways that are unique to every individual. For some, an engagement with a risky instrument such as the *Torpere* begins with an exploration of unknown affordances and constraints and requires the development of a full sense of control (as defined by known paradigms) within their personal schema in order to experience creative expressivity. Engagement with risk is productive in early explorations of the novel instrument, but beyond that point it becomes disruptive. Without total paradigmatic control and full compatibility between a schema and musical objective, expression is unlikely to be experienced.

For others, risk can be a productive element to explore on the path to creative expression. For these musicians, a full understanding of constraints and affordances, high level of control, and complete compatibility with existing schema are not *necessarily* required in order to navigate through creative spaces. Engaging with risky affordances—within and outside of the scope of an existing paradigm—can occur more freely, and do not necessarily disrupt an expressive process. A semblance of control may be enough to successfully improvise new material, and the boundaries of existing schemata may be more flexible and adaptable to novel engagements.

Lastly, some musicians demonstrate an affinity for risk on multiple registers and seem to welcome it as a part of the creative process. These individuals are able to experience expressivity along a more flexible path that can account for the presence and absence of control, paradigm, and schema much more fluidly. Risk is more likely to play a productive role for these individuals, and contribute to or enable the emergence of new and surprising expressive capabilities.

The *Torpere* study provides a multitude of insights into computational musical practices. Through the findings we are able to consider the role that physical risk states can play in expressive musical improvisation, not only in terms of unpredictability and failure, but as interconnected elements of a larger network of musical factors. The role of schemata and paradigm, control and familiarity, and objectives and goals are all critical to engagements with risk. With these findings it will be possible to not only consider the potential value that physical risk can bring to computational musical expression, but also scaffold new considerations for the design of future instruments. These discussions will be presented alongside the *null/void* study's findings in Chapter 11.

CHAPTER 10

FINDINGS: NULL/VOID

The seven themes presented in the *null/void* codebook provide points of entry into discussions regarding how musicians understand, define, and engage with risk in computational musical practices. The data produced gives insight into what separates computational musicality from other creative modes, and how practitioners within the computer music community approach expression and risk through their instruments.

This work will first offer an overview of musical creativity in computational practices: how exploration, composition, performance, and improvisation manifest through the use of digital instruments. We will then examine how elements of risk are experienced by computer musicians, and where failure and unpredictability play positive and negative roles in the musical process. Finally, we will examine how the application of conceptual material risk impacted the expressive engagements of participants within the study.

10.1 Creative Modes: Performative, Compositional, Exploratory

In speaking about their own practices participants were fairly split in their self-identifications: P1 and P2 considered themselves to be a composer-performers, P3 a performer, and P4 a composer-maker.

10.1.1 Composition

Although participants spoke of composition throughout the interviews it was almost exclusively tied to the *role* of composer rather than the *process* of composition. In fact, in all of the reflections given by participants composition was only mentioned by Participant 1, and only in terms of composing a *performance*. While the reasons behind this are not entirely clear, it is possible that the "un-instrumental" nature of the *null/void* interface created an environment in which participants felt less inclined to steer their improvisations toward compositional objectives. It is also possible that the freedom to use the interface in their own personal spaces reduced the pressure to produce something polished or self-contained, a more finished work that would be judged by others. Lastly, the duration of the study may have encouraged engagements that were shorter and more frequent than the *Torpere* study, reducing the incentive to engage in longer-form compositional activities.

Regardless of the cause, the creative modes that emerged from the thematic analysis of the *null/void* study were *Exploration*, *Performance*, and *Improvisation*. Within these three general categories are overlapping and diverging creative processes; the language that was used by each participant contributed to a set of criteria that allows each creative mode to be understood on its own terms and also illuminates the interconnected nature of different activities. In particular, improvisation was described not only as a process with distinct requirements and goals, but also as an activity *within* other creative modes (improvisation *as* exploration, improvisation *in* performance). Before we examine these facets of improvisation it is worth first establishing the roles that exploration and performance play independently.

10.1.2 Exploration

In describing the unique characteristics that set exploration apart from other musical engagements, participants defined very few conditional requirements. As opposed to improvisation and performance, exploration was used to describe a process of learning and experimentation, developing an understanding of the unknown, and identifying the behavior and purpose of the interface itself.

For all participants, engagements with the *null/void* systems began from a place of exploration. This natural information-gathering process was compatible with the lack of knowledge regarding the behavior—and *purpose*—of the interface; as such, exploration was identified and defined as a space that must be free of stress and pressure, where activities that would be considered high-risk in performance settings could be safely engaged in. Most often participants spoke of their explorations in a way that drew a distinction between exploration (learning) and performance and improvisation (doing).

In the following excerpts we can see explicit descriptions of participants trying to "figure out" the behavior of the *null/void* interface before moving on to any musically expressive activities:

> **P3:** The first one or two days I just set up a simple Max patch and tried to figure out what the interface is and see how it works. What are the pitch resources, and the amp...I was just trying to figure out what it was actually doing. And then I would try to improvise.
>
> **Interviewer:** So, the first part of your experience was figuring out what the control parameters are, how does this work, how does that work, how do they work together. Is that what you're saying?
>
> **P3:** Yeah, yeah.

> **P2:** I realized, "Okay, I should just set everything up how I normally would, and then I'm just basically putting this in as like an interference layer." There was definitely some time that I spent just like, "I don't really know what it's supposed to do." I realized after a while that my task was basically just to sit there and listen and try to figure out what this was doing.

In some cases exploration consumed the entirety of the duration of the study. The data suggests that when a participant was driven by the desire (or need) to understand the inner workings of the interface they were much less likely to move from exploration to improvisation or performance. Participants were also unlikely to move into a space in which exploration *became* a musical improvisation—the need to understand outweighed the desire to express. In the case of Participant 4 (who never left exploratory mode at all) the musical process began and ended with a procedural approach to gauging the impact that *they* had on the interface, and not the other way around. P4 puts this at the front of their descriptions of their earliest engagements with the interface:

> **P4:** I was at first trying to figure out what I would play through [the *null/void* interface], and I went with something I was familiar with. I figured [my instrument] would be good because if I had any confusion or anything like that I could eliminate all the steps. I know what to expect from [my instrument].

Before P4 even turns the device on they set an environment in which they have as much control as possible, knowing that having a high level of control will enable an expedited process of understanding the unknown. From that place of stability and control they begin a uni-directional engagement, the dynamic of which will persist throughout the entirety of the study:

> **Interviewer:** In those initial engagements, would you say that you were intentionally playing "normally" to learn how the interface works? Or would you say that you were just playing, and seeing how it responded?
>
> **P4:** I think the first time I ever performed with [the interface], I was playing normally to see how it responded. But then out of curiosity, the later ones, I was trying to get a specific response from it.

P4's creative trajectory over the course of the study evolved from exploratory information-gathering to a quasi-performative mode geared toward applying that information as a control mechanism. While they do describe a shift from engagements driven by *learning* to *curiosity*, their interactions are entirely directional: first they play to observe and understand *null/void*'s behavior, and then they then use that understanding to provoke a *specific* response from the interface. On every level P4 has a full sense of agency and is not involved in an interaction as much as they are controlling the interface with intention. When explaining the more performative engagements P4 maintains a consistent active-to-passive dynamic between themself and the interface:

> **P4:** I understood how [the *null/void*] was going to react. There were more times where I was like, "Let me see if I can predict when this will happen," or, "Let me watch the monitors and keep track of what's happening." Because I understood the process and it was basically just: you set your maximum value and then you whittle away at it. Depending on how you perform, one of [the resources] is going to run out versus another. So, I think having that familiarity, I did sort of play around then. Trying to elicit a response.

P4 uses the interface as a passive system that functions in an entirely informational, utilitarian way. As the interview progressed this dynamic was explicitly addressed and confirmed:

> **Interviewer:** It sounds like what you're saying is that your experience with the interface was more that it an informational system showing you what you were already doing rather than something that was prompting you to change directions or try something new.
>
> **P4:** Yes. There was a recording where I was a bit more like, "Ooh, I'm running out of the pitch resource, so let me try and minimize how many I'm doing." Or, "The first recording I didn't do much amplitude change. Let me see if in this other one I can have more moments where I have sudden or gradual amplitude changes." Because I want to see how I can make that amplitude resource bank react.

10.1.3 Performance

Exploration and performance were the modes of creativity with the least amount of overlap for participants. Performance was often defined as conflicting with exploration, the two musical modes inherently bound to opposing criteria. Where exploration requires freedom, flexibility, and the ability to make risky decisions, performance demands a strong structural foundation and clear directional movement. In Participant 1's description of their experience performing with the *null/void* system in high-risk mode, they highlight the incompatibilities between exploratory and performative musical functions:

> **P1:** [I had to do] some preparations before actually performing with the device. A lot of material came from previous experiences–not replicating the exact performance every time or anything, but yes. So, with five minutes–one session–I didn't have too much freedom to explore completely new ideas. I wasn't taking too much of a musical risk here, let me say.

The performance of P1 is facilitated by prior explorations in which they identified and "prepared" musical content for implementation in a real-time performance. They suggest that in a performance space there is no room for exploration—a performer does not have the time to test or waste musical material, they must manage and manipulate it with their existing skills and knowledge. The demand of musical structure over time is only made more risky by the presence of the audience; with these two elements combined, exploration (a risky engagement in and of itself) is simply pushed beyond the threshold of manageability. While exploration can occur in confrontations with the unknown, where a musician can feel out the affordances and constraints of a musical space, performance is scaffolded upon an understanding of the full range and depth of a system's behavior and an ability to intentionally engage those behaviors over time.

Performance was also differentiated from exploration in terms of producing a final product (Subtheme 1.2.2). Exploration can happen privately and be done for any reason—or no particular reason at all. In contrast, shaping the arc of an expressive musical performance requires intentionality and agency, and the process is bookended by clear beginnings and endings. Performance and exploration differ in both their objectives and temporal structure. The decisions a performer makes are pointed toward a musical conclusion and scaffolded on existing skills. The objectives of exploration are more fluid: it can serve the purpose of developing new skills, gathering information, or simply exploring the unknown.

10.1.4 Improvisation

Improvisation was the mode of musical expression defined with the most diversity. Not only was it discussed in terms of its fundamental nature and function, but also in ways that are dependent on creative context. Improvisation was discussed both in *theory* and in *practice*, but most interesting were the participants' perceptions regarding the differing role of improvisation within performance (Subtheme 1.3.2) versus exploration (Subtheme 1.3.3).

Improvisational exploration contains elements of freedom and risk-taking similar to those seen in exploration alone. Although participants described this particular mode of improvisation as requiring skill and knowledge, the criteria were far less rigid in terms of expectations and demands. For example, Participant 1 describes the negative impact that planning and structuring can have on an expressive musical improvisation:

> **P1:** The more expressive capabilities you have, the less limited the performance becomes. Composing and rehearsing a musical piece a lot before performance defeats the value of [improvisation] a bit.

They go on to differentiate between exploratory improvisation and improvisational performance, explaining that the former allows for the "wasting" of musical content while the latter does not:

> **P1:** There's an unavoidable element of wasting notes as part of improvisations. This is not the case for live performance, but in private settings, one might spend or waste some notes and reflect (consciously or unconsciously) on what was good or bad about them.

In describing their experiences with the *null/void* system P1 outlines how improvising in an exploratory manner develops content for use in improvisational performance. This process begins with "wasting" musical resources—an activity that would not be welcomed in performance:

> **P1:** I start playing some stuff, and then I naturally want to basically spend some resource just experimenting, not worrying about anything. I need to pull out some notes before starting to construct any [performative] improvisation, [which] needs some initial wasting of resources. Not just initial, but a constant theme of that, due the type of improvisation I do.

Participant 3 provides additional insight regarding the role that improvisation plays in a formal performance setting, drawing lines between productive and unproductive improvisational activities:

> **P3:** It is my style to have sections in [improvisational] performance. Like, "Okay, for the intro section I'll do something like this, and then I'll go into here and then blah blah blah, and this is how I'll end it." I have different sections already set–but loosely, so that I'm not rigidly trying to follow my rehearsal. I do leave room to just play freely, but at the same time I try to not go too far. Not get too caught up with the improvisational, like, noodling.

These descriptions suggest that improvisation can be productive or unproductive based on context: In exploration it can be playful, experimental, and worry-free, while in performance it must be reined in and used to serve the larger performative objective.

10.1.5 Summary - Creative Modes

The *null/void* and *Torpere* studies both produced themes that contribute to the development of varied models of creative behavior. One difference between the themes produced in each study is worth consideration: Composition had a strong presence in the *Torpere* data, but was almost entirely missing from *null/void*'s.

There are many factors that might contribute to this difference, one of which is the fact that it is more common to describe oneself as a composer or performer than improviser—they are simply more descriptive. Additionally, having almost double the number of participants in the *Torpere* study increased the likelihood that composers would be represented and interested in speaking about their compositional practices. It is difficult to ignore some of the more intriguing implications of the findings as well: Are composers more vocal about their practice when confronting unpredictability and failure? Is composition less compatible with computation than performance is? Do physical instruments serve compositional goals better than digital ones?

Unfortunately, the limited sample size in both studies prevents concrete conclusions from being drawn. Even so, the divergent themes are valuable to keep in mind when considering further findings presented in this work.

10.2 Defining Risk: Computational Unpredictability

When asking musicians in the *Torpere* study to define their understandings of unpredictability many discussions centered around human behavior. Unpredictability is a human condition, one we all experience and can relate to. It is *so* human, in fact, that it is intentionally designed into robotic systems in order to make them feel more "real." In this work unpredictability has been tightly coupled to notions of human agency and autonomy: unpredictable risk is the feeling of being unable to exert control over an instrument, or a struggle to relate the unknown to existing knowledge.

Asking participants in the *null/void* study to speak about unpredictability was a more challenging endeavor. When performing with a computational instrument, autonomy and agency come into focus differently than with acoustic ones. While a musician may experience unpredictable behavior from an acoustic instrument as a result of their physical engagements, it is far less likely that a computer musician would be surprised by the response of a computer (unless the computer was intentionally designed to respond unpredictably). Further, if a computational instrument *does* exhibit unpredictable behavior (that was not intentionally designed) it is more likely to be catastrophic than inspiring: if a guitar string breaks, an improvising musician can shift to using other strings. If a computer program crashes, clicking around in an open Word document will be of no use. So, what does computational unpredictability look and feel like to the person who designed it into the system in the first place?

Unpredictability can not be transposed perfectly between acoustic and computational instruments. However, musicians in the *null/void* study were quick to lay valuable groundwork for understanding unpredictability in computational musical practices.

10.2.1 The Nature of the Machine

Table 10.1: null/void Nature of Computational Unpredictability Codes

5.1 THE NATURE OF THE MACHINE	
5.1.1 Computation is What you Make it	5.1.2 Computer Beings
In acoustic, future is created; in computation, future is certain	Agency is intelligence
Computation inherently lack a natural structure with which to start musical activity	Agency is autonomy
Computation requires more preparation of an environment than acoustic	Agency feels meaningful
You can not do something truly unexpected in coding	Behavior of a musical system can seem like a response to actions
Computation is inherently predictable/logical	Otherness can involve senses of time, intentionality, and intelligence
Computer systems are inherently open-ended	A musical system can feel like an "other"
In computation, the system defines the note. In acoustic, the note builds the system.	The presence of an "other" has a huge impact on musical expression
Computation involves more thinking and planning than acoustic	Computers are in a gray area between extension and autonomy
Live-coding "can't" involve taking very big musical risks	

10.2.1.1 Computation is What You Make it

Participants were fairly united in their perspectives regarding the differences between acoustic and computational risk and unpredictability. Computational and acoustic musical instruments were often situated at opposite points of an "unpredictability spectrum:" organic ideation at one end, procedural iteration at the other.

Musical expression in a computational environment is scaffolded on a space that is predefined. Much of what we would consider to be "skills" in acoustic traditions (bodily coordination, physical precision, the manipulation of a full range of expressive capabilities of a limited material instrument) do not translate directly to computer music performance. Similarly, the "skills" of a computer musician (programming and coding, hard- and software integration, digital instrument-building) do not necessarily have an application in acoustic musical performance. Because a coded environment must be created before it can used, it could be said that musical expression happens as much *before* a computer performance as during one; the expressive capabilities of a digital instrument are determined by the code that is compiled to define them.

This comparison is intended only to highlight some fundamental differences between computational and acoustic music; in reality there is much more gray area than what is presented here in black and white. However, multiple participants in the *null/void* study expressed sentiments that address these particular dynamics:

> **P1:** When you program music involving a big noise or a single note, it's almost backwards from the [process with an] acoustic instrument. With an acoustic instrument, say you play a single note. You hear, you adjust, and maybe you are surprised with the result. [In] live-coding, you're already laid out the structure of a certain future, [even just] one minute later. Just for one single note. You plan how the envelopes should be drawn, or how to control the complexities, intensities, densities, those kind of parameters. So, with live-coding, it [feels] like you can not really do something truly unexpected. The usage of time with live-coding isn't always directly connected to the musical expressions of performance, I don't think. Sometimes it happens much before that, having to prepare all of the materials that you might or might not be using.

It is important to avoid suggestions of technological determinism here that might de-value the talents and skills of computer musicians. The reality is, computer musicians are well aware of the affordances and constraints of their computational systems and are able to engage with unpredictability and expressivity in ways that are unique to computation. Participant 2 offers a valuable case study regarding this skill-set:

> **P2:** I'm sure you've had that experience, or you've heard other people say that when you're improvising with a computer, you're in this kind of gray area between whether the computer is an instrument and it's extending from your body, or whether it's some other autonomous being that you're performing with. Unpredictability is kind of a way of acknowledging the fact that the computer has its own behavior, and part of my responsibility is to modify the way that I'm responding to it.

10.2.1.2 Computer Beings

Unpredictability can not only be designed into a computational system, it can be a representation of a computer's unique behavior. When computer musicians develop their digital instruments it is often over months or years, and the relationship can become so intimate that the system develops a sense of autonomy. The external behaviors of a computational system can appear to reflect internal complexities that border on sentient, interpreted as intelligence, agency, responsiveness, and more. As will be discussed in Section 10.7, when experienced positively these qualities provide opportunities for interaction and expression that go beyond uni-directional cause-and-effect toward reciprocal, reflexive expression.

10.2.2 Unpredictability and Randomness

Because unpredictability can be considered as a design element within computational musical systems, one of the most important findings from the data involves a differentiation made by many participants regarding *unpredictability* and *randomness.* Randomness, and its relationship with unpredictability, was far more prevalent in discussions with *null/void* participants than those in the *Torpere* study; this topic was explicitly tied to the musicians' understanding of the native behavior of computational systems, which are inherently designed (acoustic instruments are, of course, design objects, but it is not usually the practitioner who has done the designing).

Table 10.3: null/void Computational Unpredictability and Randomness Codes

5.2 UNPREDICTABILITY IS NOT RANDOMNESS		
5.2.1 Design and Control	5.2.2 Internal/External	5.2.3 Creative Randomness
Randomness is unpredictability that is designed	Randomness is a decision made internally	Randomness can be overused and/or over-relied upon
Unexpected randomness and unpredictability are inherently negative	Unpredictability is an outer state	Randomness is doing things "without thinking"
Unpredictability is something that has an inherent lack of control	Unpredictability requires mental bandwidth	Randomness can be a creative choice
Randomness without control is disruptive	Randomness and Unpredictability cause fear and anxiety	Randomness frees you from thinking
Predictable unpredictability can be positive		Randomness can introduce interesting results

10.2.2.1 Design and Control

As in the *Torpere* study, the interviews with *null/void* participants included questions regarding whether or not unpredictability was intentionally designed into their software systems. The research motivation for this is straightforward: if musicians do, in fact, make a conscious decision to build such states into their instruments, then there is a high probability that risk is a value element of expressive engagements. *null/void* participants' responses to these questions were surprisingly consistent in an immediate pivot to *randomness* as a design element; the language used showed a strong distinction between risk as a concept and randomness as a vehicle for practical engagements with unpredictability in a computational environment.

The distinctions between unpredictability and randomness were most often defined by the criteria of design and control. Unpredictability—an event or behavior that is not expected—is *inherently* random. In unpredictable situations, a musician faces the pressure of giving a quick and meaningful response; that response is contingent upon their ability to adapt to changing situations in real-time and access the full range of their skills and knowledge with no hesitation. Naturally, this makes engagements with unpredictability particularly high-risk, and many participants described feelings of stress, anxiety, and a monopolization of creative bandwidth in expressive activities. These findings align with those found in the *Torpere* study: unpredictability requires a certain level of control and familiarity to be a positive element of musical expression. The threshold for expressivity in high-risk situations is subjective, but rigid: too much unpredictability is "scary," disruptive to expressive flow, and has the potential to "kill" a performance entirely.

Randomness, on the other hand, is not *inherently* unpredictable. Several *null/void* participants described building systems of randomness into their software instruments, the general sentiment being that randomness is *designed unpredictability* intended to function in a creative space with musician-defined boundaries. When speaking about the productive role that designed unpredictability can play in musical expression, Participant 2 described the need for constraints:

> **P2:** The randomness I introduce into [my computational instrument] never impacts whether there'll be sound or not. I always have some kind of backup way to keep making music and keep doing the performance and keep telling the story that I'm trying to tell...I have to mitigate the randomness somehow, to continue to tell the story that I'm tying to tell on stage. It's very rare where I've had to use any of these backup systems, but it was always very important for the sake of the music that I'm doing–especially where I'm [using] investigational technology–that there's some element of it that's going to work with 100 percent probability, so that I can concentrate on being the human performing it.

Randomness, as a component of a computational instrument, is a kind of predictable unpredictability. It is a way to engage with the valuable qualities of risk in a way that is manageable and protected from the power unpredictability has to completely ruin a performance. For an improviser, striking a balance between unpredictability and dependability in high-risk states is central to successful musical expressivity.

10.2.2.2 Internal/External

While P2's focus on mitigating unpredictability is driven by a personal desire to deliver a compelling, intimate musical performance to an audience, P3's need to constrain unpredictability was described in much more personal terms:

> **Interviewer:** When you do improvisations with your computer, do you ever build in unpredictable or random elements?
>
> **P3:** It depends. At least for this experiment, I did try to have a lot of control. There was some randomness in [my software instrument], but it wasn't anything that was going to be disruptive. I think it's valuable to have a little bit of unpredictability, but not to an extent where I'll always be on the edge of like, "Okay, what's going to happen in 10 seconds?" It's never so unpredictable that I scare myself. [laughs] In my normal set up I have a sequencer that triggers random notes, or I'll have random patterns, but that's probably the extent of how far I go in terms of live performance.

While P3 touches on the potential for unpredictability to disrupt the flow of an expressive performance, they describe feeling of high-risk states much more internally than P2. Some elements of randomness and unpredictability are clearly considered valuable to P3, but the presence of control is a hard prerequisite. Without control they are quick to experience fear and anxiety, pushed to the "edge" of discomfort in situations that feel uncontrollably high-risk.

P1 also touches on the effect that randomness can have on the subjective experience of musical expression, describing it as a way to offload some of the mental demands of music-making to a computational system, allowing for more expressive musical elements to emerge:

> **P1:** Random is good. I overuse randomness, because it frees you from thinking, in a way, and it contributes to the dynamics [of an improvisation].

There is an interesting relationship that emerges here between internal and external unpredictability. If a musician makes a decision to build randomness into their computational instrument it seems there is a tacit agreement between intentionality and chaos—the ability of a musician to adapt and react to the behavior of the instrument is compatible with the limits of their creative bandwidth. The unpredictability is confined to the internal design of the instrument itself, stripped of the anxiety-producing potential of an unpredictable outside force.

10.2.3 Summary - Defining Risk: Computational Unpredictability

Understanding unpredictability in any musical practice involves the consideration of both musician and instrument. It emerges from the space between what is *expected* and what is *experienced*. With physical instruments, unpredictability is bound to the physical world and emerges through the materiality of the instrument itself—we expect a guitar string to feel like wound metal (or nylon), not an electric fence. In contrast, unpredictability in computational instruments can be metaphysical, understandable only through the mind. With no natural physical or material constraints (beyond what hardware is capable of) computational unpredictability can be designed and redesigned, written and rewritten into the instrument itself. There is no traditional acoustic instrument that has been intentionally designed to respond unpredictably to human interactions (at least none that this researcher is aware of), but a computer's function is to be whatever we need it to be at any given moment.

For these reasons, defining computational unpredictability is a challenging but critical element of this research. Through the *null/void* study it has been possible to develop an understanding of some of the ways in which computer musicians conceptualize unpredictability in their practice. From here we can analyze participants' experiences with material risk through an informed lens and consider the role of material risk in computational musical expression in terms that will be valuable to the larger community.

10.3 The Effects of Computational Unpredictability

The data from the *null/void* study shows that computational unpredictability is distinct, not only in its relationship to the procedural logic of digital systems but also in its ability to be designed. Each *null/void* participant provided different perspectives on the conceptual and practical forms that unpredictability takes in their musical practice: for P1, unpredictability is most productive in the form of controllable units of randomness; For P3 the presence of low-level randomness—even at a minimal level—in a musical instrument has anxiety-producing effects. P2 is unique in their consideration of unpredictability as a behavioral quality of musical interaction–something to not only be designed and implemented in a digital instrument but deeply embedded in the human-computer relationship. In contrast, P4 generally speaks of unpredictability simply in terms of their creative motivations to learn about the unknown. The effects of unpredictability will be revisited in the discussion of participants' direct experiences with the *null/void* system; at this point we are at least able to conclude that, generally speaking, unpredictability can provoke or suppress musical expression.

10.3.1 Unpredictability is Valuable

Unpredictability is a positive element of performance when it is a *behavior* exhibited by a human performer or a computational system. It offers an opportunity to engage with creativity at the edge of the known and unknown and respond to unfolding conditions in real-time. Subtheme 1.1 contains codes that represent expressivity as facilitated through the response to unpredictable behavior.

Table 10.5: null/void Valuable Unpredictability Codes

2.1 UNPREDICTABILITY IS VALUABLE	
2.1.1 Expression as Response to Unpredictabil	2.1.2 Unpredictability is a Prompt
Expression is a response to the unknown	Unpredictability prompts expressive changes, prevents repetition
Expression is the response of one agent to another	High risk states are "on the edge" of creative boundaries, prompt engagements with unknown
Expression is adaptation	Unpredictability has value in both aesthetic and behavioral capacities
Expression is a response to behavior	Expression in high risk states is more compelling
Part of being a performer is engaging with unpredictable behavior	High familiarity of a musical system results in a move away from exploration and critical listening
Unpredictability is valuable because it gives them something to respond to	

10.3.1.1 Expression as a Response to Unpredictability

When a computational system for musical expression is designed in a way that supports unpredictable behavior, a relationship can be fostered between human and computer that moves beyond a unidirectional action-response dynamic and toward an interactive process of expression-*through*-response. Much as the physical response of an acoustic instrument can feed back into the experience of a performing musician, a computer can support complex interactions the move a musical engagement forward. While DMIs may inherit the "limitness" capabilities of computation and can seem disembodied or impersonal, it precisely this flexibility that allows for expression to emerge. As Participant 2 describes, it is often in the development of constraints and limitations that computation finds its own "voice" and becomes an active collaborator in the musical process:

> **P2:** I never like to view an electronic music system in terms of having all of these capabilities that are wrapped into it because that's very overwhelming...The more that you can limit the possibilities, the more something truly interesting and creative happens. I like to limit myself to very few kinds of

> processes that are actually happening and really listen very intently to what their actual behavior is, and then respond to that.

When asked how they express their own creative voice through live-coding, Participant 1 challenges the question itself, coming to the defense of their own musical instrument:

> **P1:** I feel this is not applicable with live-coding, where I'm more creating a voice for the computer.

When two autonomous agents—human or not—function together within a creative musical environment, the space between them contains potential that evolves and changes over time. In responding to the behavior of another agent, unpredictable futures come in and out of focus, and the reciprocal process of action and reflection becomes an expressive act in and of itself. Expression is not a simple confrontation with unpredictability, but rather the *result* of adapting and reacting to a system with its own uniquely unpredictable behaviors. P2 describes the expressive power of response in their personal practice from a strong perspective:

> **P2:** My practice is all about setting up these pieces of software that have unpredictable behavior, and then me learning, as a performer, to deal with that...I think [unpredictability] provides something for me to respond to. I enjoy creating an expressive arc out of the way that I'm responding to something...I'm convinced my expression happens from me needing to adapt to the behavior of a system.

For some performers, musical expression is not only a vehicle for their own story but also a way to demonstrate their individuality through unfolding actions and reactions over time. A compositional arc can be pre-planned, but it can also emerge organically from the unplanned improvisational process. A computational system can be an instrument, an extension of the self, an external collaborator, or something in-between—its behavior is may be defined, but the space it creates for reaction and response is wide open.

10.3.1.2 Unpredictability as a Prompt

Subtheme 1.2.2 contains codes that describe the qualities of musical processes that emerge from engagements with unpredictable behavior. If expressivity emerges through a performer adapting and responding to the behavior of other autonomous agents, then it can be said that unpredictability is a valuable prompt for musical expression. The language used by participants exposes a point of divergence: unpredictability *made, forced, encouraged, prompted, caused...* them to do something *new, different, unexpected...*. In some cases a prompt is considered beneficial due to its ability to break a musician out of undesirable habits or patterns (e.g. repeating the same material over and over); in other cases prompts lead to explorations of novel musical spaces or provide an opportunity for a musician to step back and reconsider their creative decisions.

When asked to describe their feelings in uncertain musical situations, Participant 1 calls unpredictability a “creative oppoortunity” and “driving force,” and in Participant 3’s notes from their study journal they reflect on the ways in which using an unpredictable interface prompted them to push past their normal playing style:

> **P3:** [It] was actually an engaging take to record. It was nice to be conscious about playing differently and taking some break[s] between notes to think about how to play the next note with timbral and gestural variations. [Using] the [*null/void*] made me aware about making each note count...It was a good idea to not adjust the Max patch according to the limitation and instead I tried to play differently.

P3 reveals something very interesting in this statement—something that will resonate with most (if not all) computer musicians. In the experience they describe, P3 makes a conscious choice to “not adjust the Max patch” in response to the behavior of the *null/void* interface. This is a laudable resolution—the flexibility and highly-customizable nature of digital instruments make iteration an expected component of the musical process. I know of no practicing computer musician who does not make modifications to their computer music environment when entering novel situations involving unfamiliar external contributors. This is not a character flaw, it is a skill and it is standard practice. However, it can also prevent the development of new skills and creative potential (why struggle against incompatibility when you can code it out with minimal effort?). The reason can be seen in P3’s reflection: sometimes forcing yourself to adapt in uncomfortable situations leads to valuable change.

10.3.2 Unpredictability is Negative

When unpredictability has a negative effect on musical expression it is generally cited as the beginning of a chain reaction that results in the death of a performance. When something occurs on the stage that is so catastrophic that the piece can not go on, it is almost always accompanied by a sense of surprise, and the extreme negativity of such experiences can condition one to fear and avoid unpredictability wherever possible. In order to focus on creative expressivity, unpredictability must be replaced with familiarity and stability.

Every individual has a personal level of creative bandwidth, and for many musicians the pressure of engaging with high-risk unpredictability—being continually alert to change, determining appropriate reactions as quickly as possible, evaluating the result of those reactions—pushes past the threshold of manageability. Combined with the pressure of being on stage and submitting yourself for judgement by an audience, unpredictability can seem like the last thing anyone would need (or want).

At one point or another all four participants described unpredictability's ability to kill musical expression. Whether it is a cognitive overload, state of fear, lack of control, or inability to adapt and respond, unpredictability has the potential to disrupt or destroy the creative process. Though this may seem obvious, examining the nuances of different practitioners' thresholds for unpredictability is an important element in understanding how and where unpredictability can be productively designed into future computational musical instruments.

10.3.3 Summary - The Effects of Risk: Computational Unpredictability

From the findings presented above it can be concluded that unpredictability can be very valuable to musical expression in computational practices—with some caveats. When considered as a behavioral component of a responsive system, unpredictability can give a performer opportunities to express themselves through *response.* Much like improvising with a human collaborator, a computational system (particularly one that is responding to the performer in real-time) can contribute to the expressive arc of a musical performance, driving the development of content and presenting new paths for exploration. If a musician feels as though their personal expressivity is tied to responding and adapting to changing conditions, unpredictability is not only welcome, but *needed*.

If considered as a variable that can be applied to discrete musical parameters, unpredictability is also valuable as a *function*. When a musician can design controllable randomness into their coded systems it can extend the depth and range of musical output. Though it is not necessarily a *behavior* to *respond to* in performance, the incorporation of the randomness is *itself* a form of self-expression. How variables are coded, what they are applied to, the way they are used used over time–these are all creative decisions that reflect a musician's voice. Put another way, *coded expressions* can be *musical expression*.

10.4 Defining Risk: Computational Failure

10.4.1 Computational Failure is Different

Much like unpredictability, an understanding of computational failure emerged in large part through discussions of what sets it apart from acoustic failure. With a traditional instrument failure is described as a more "natural," organic process. This stems, in part, from the layers of transparency afforded by material objects: a violin may have complex systems of pegs and posts, but for the most part a violin's points of failure can be visually identified. The material components of a computer are, of course, visually obscured. Even if one could pry open the object at its seams, identifying a cold solder joint or burnt out resistor would be a challenge to most computer users. The presence of a second, invisible layer of software complicates matters further: a musician can know their software instrument inside and out and still experience failure when a calendar notification pings through the house speakers or an audio interface is suddenly not recognized.

There is a long list of obvious ways in which computers can fail, but this work is interested in what lies beyond software crashes, cracked screens, and dead batteries. In describing the differences between computational and acoustic failure, the most salient theme across participants was the presence of time. Participants identified fundamental differences in how failure and time relate to each other in acoustic versus computational processes.

Table 10.7: null/void Different Computational Failure Codes

4.1 COMPUTATIONAL FAILURE IS DIFFERENT

4.1.1 Failure in Time	4.1.2 Failure of the Self	4.1.3 Bounded Failure
Acoustic failure can be dealt with in real-time	Incompatibility between assumptions/expectations and reality can lead to feelings of personal failure	Computational failure disrupts the flow
Failure can be wrapped back into the process acoustic process	A fear of having done something "wrong" can persist after an experience	Failure in composition are interconnected elements (data transmission, power sources, sensor control, etc)
Fixing a computational failure halts the musical process	Failure can be assumed to be the result of self, or others	Failure feels more natural in acoustic process
Acoustic failure has a chance for recovery in performance	Failure can "hurt"	Computation has more layers and elements of failure than acoustic instruments
Computational failure inherently requires a lot of time to fix	Intelligence/Agency can be assumed of an external system	Computational failure is silence

10.4.2 Failure in Time

Most significant is the simple difference in the length of time required for diagnostics. Disregarding the amount of time it would take to address a mechanical failure (how long does it take to warm up a soldering iron?), even a single coding error can involve a lengthy scan of hundreds of lines of code. Identifying the source of a stack overflow can require traversal through a dozen nested bits of software.

In addition to the increased amount of time required to address computational failure, diagnostic and performative activities are far less likely to move forward in parallel. Time spent diagnosing and fixing a coding error can not be spent simultaneously in musical expression. While a performer may be capable of a quick re-patching or line edit without breaking their performative flow, the bar for manageable failure is set quite low. In contrast, acoustic failure is both easier to diagnose and remedy *and* less likely to bring the music-making process to a complete halt. Participant 1 provides a good description of the differences in their experiences with acoustic a computational failure when addressing one of the *null/void* reflection prompts:

> **P1:** There are many layers of failure with live-coding...With an acoustic instrument I'm at the point where I don't feel [like anything] is failure. Even if you make mistakes, you can turn it into a pattern. With live-coding I'm not at that level.
>
> **Interviewer:** It sounds to me like you're saying that with acoustic instruments you can move forward with failure more naturally, and with live-coding when a failure happens it's really hard to work it into what happens next.
>
> **P1:** Yes. Musically speaking, I think that's the case, and maybe an extreme example is your computer going into a blue screen. How do you [work] it into the proper performance? I wish I could capture the screen going into blue screen, or some really obvious error in live-coding, and then use that material directly as audio samples. Obviously, that's so demanding, I can not do that.

Computational failure is also more likely to be catastrophic with digital systems, killing the performance and providing no way to recover and carry on. Silence appears across participant data as the death rattle of a dying performance:

> **P4:** When you're playing with software and there's suddenly no sound, it's really scary because it's not supposed to do that. If the software is still open, visually, and running, and there's no sound all of a sudden, that seems like there's something with your computer that's broken. Which in a performance is catastrophic. At least with hardware you have the sense [that] if it's not working there's a chance that maybe I could wiggle something back into place. But if the software doesn't work, you're like, "This is probably something I do not have the time to recompile or rebuild."

The combination of high severity and a low compatibility with real-time expression makes computational failure particularly intimidating. Computer musicians have fewer choices in terms of safeguarding against or embracing risk elements, as their ability to carry on a performance uninterrupted is contingent upon their instrument functioning properly. In order to failure to be productive a performer must be able to adapt to it in real-time, and that is simply less possible with computational instruments.

10.4.3 Failure of the Self

A second definition of failure emerged from the *null/void* data, again connected to the unique nature of computational musical systems. Because these systems are not standardized in the way that acoustic instruments are, when asked to engage with something completely novel it can be difficult for musicians to develop a sense of authority and confidence. Computers are extremely young as far as the history of music-making goes, and also exist on a platform that evolves at a rate fast enough to make ubiquity impossible. It is not merely the longevity of traditional instruments that make them so pervasive, but the fact that their repertoire, performance practice, and pedagogy have not seen any major changes for several decades. As a result, when engaging with computational systems that feel *responsive* or *intelligent*, participants in the study often assumed the blame for perceived failures. When describing their initial impressions of using the interface, Participant 2 is quick to assign a lack of response from the device to their own actions:

> **P2:** I was a little bit stressed out at some point because I didn't know if the algorithmic composition engine that I chose as input to the [*null/void*] system was the right thing to reveal what its behavior was. Or maybe there was something wrong that I did. Maybe it was actually me doing something wrong.

Participants 1 and 3 echo these sentiments when experiencing minor technical failure of the interface:

> **P1:** The audio output from [the *null/void* interface] wasn't cutting off at the end...I'll try more and see if I'm doing something wrong.

> **P3:** I'm noticing the amp resource not moving and I was wondering if I'm understanding the resources correctly. I'm hoping that it's just my misunderstanding of the amp resource and that it's still working fine.

This sense of responsibility certainly stems (at least in some part) from an assumption that whomever designed the interface did so very well. Whether warranted or not, it would be socially offensive to immediately attribute any and all kinds of failure to the individual who built and deployed five of these *null/void* interfaces—surely the engineer conducted rigorous testing and used vast amounts of skill and knowledge to ensure a perfectly-functioning end product. A conflict between expectation and experience, or a struggle to "make sense" of system behavior that feels "wrong" can be a kind of failure that feel deeply personals.

10.4.4 Summary - Defining Risk: Computational Failure

While control, schema, and paradigm had the greatest impact on how failure was experienced and defined by *Torpere* participants, *null/void* musicians described failure in very different terms. It was less connected to personal, conceptual frameworks than computational ones; in particular, computation scaffolds risk in a space that is much more severe in its consequences, and much less manageable in real-time. Because of this, we will see that the effects of computational failure are similarly acute.

10.5 The Effects of Computational Failure

10.5.1 Failure is Negative

Table 10.9: null/void Negative Computational Failure Codes

4.2 COMPUTATIONAL FAILURE IS NEGATIVE	
4.2.1 There is No Time	4.2.2 There is no Recovering
Time spent being expressive and time spent de-bugging can not overlap	When a computer fails, the performance fails
The time it takes to fix an error is unacceptable to an audience	Computational failure is fatal to the musical process
Diagnosis is iterative, can take a prohibitive amount of time and effort	Failure kills computational performance

When a computer musician encounters failure in an expressive real-time activity, it is a much more procedural process than one might see in acoustic practices. Participants describe their process of observation, diagnosis, and repair in strategic terms. For example, when Participant 4 reflects on their use of the high-risk *null/void* interface, they describe navigating through an unpredictable space in stages:

> **P4:** I was playing with this granular synth, which I haven't played with in a while. Then, also I just forgot that [the *null/void* meters], like, "Oh yeah, they [behave] randomly." So, I was watching one resource and looking around and then the music stopped. I was like, "Okay, wait. Well, this isn't a failure of the [synth]." I looked and I was like, "Oh, this [*null/void*] resource ran out."

In stark contrast to the findings of the *Torpere* study, the effects of computational failure are not presented as beneficial in any way, shape, or form by *null/void* participants. The findings suggest that this may be due to a number of things, but can be grouped into two general categories: There is No Time, and There is no Recovering.

10.5.1.1 There is No Time

Computational failure inherently requires a great deal of time: a musician must first assess the failure and determine potential causes, and then systematically check each possibility until a sources is identified. While this process generally takes minutes, it is possible to require hours or even *days*. Because the process of diagnoses and repair involves a dissection of the instrument itself, time taken to address computational failure is often unable to overlap with time spent in musical expression.

While *Torpere* participants were able to fold failure into their musical improvisations and even operationalize it toward new creative potentials, the spectrum of failure in musical computation is simply more polarized: disruptive at the low end, and catastrophic at the high end, with little room between.

10.5.1.2 There is No Recovering

If the source of computational failure is not an easily corrected typo or mis-patched number box, the chances of real-time recovery are very low. This can be regularly observed at computer music conferences and festivals: a performer will experience catastrophic failure in the midst of a piece, the audience will wait in anxious silence—sometimes for several minutes—and eventually the musician will step forward to apologize and remove themselves from the stage. Ideally, they reappear at the end of the concert having successfully debugged their code and allowed an encore performance (to a very sympathetic audience), and sometimes they are reprogrammed for the following day. Unfortunately, oftentimes there is simply no performance to be had.

It is also not uncommon to spy two conference-goers anxiously huddled over a laptop, one scrambling to install the latest device drivers and 30-day trial versions of software so that the other can borrow a working instrument for their performance in 10 minutes. As anyone who has ever owned a printer knows, technology has a funny way of failing *just when you need it*—and quickly rebounding to full functionality as soon as you don't. It is these binary behaviors that make computational failure so unlikely to be experienced as positive creative elements of a performance; a percussionist can drum with one hand while picking up a dropped stick with the other, but live-coder can not restart their software and continue producing music at the same time.

10.5.2 Summary - The Effects of Computational Failure

Whether it occurs on a material, temporal, or digital register, computational failure is difficult to manage. At the worst, it kills a real-time performance (or prevents one from beginning at all), and at its best it disrupts the creative flow. While it is easy to point to any other creative practice and identify similar best- and worst-case scenarios, the nature of computation provides little in the ways of middle-ground. Where performers in non-computational practices can potentially wrap failure back into the expressive process, a computer musician is not often afforded that option; as P1 summarizes, "How do you [work] a blue screen [back] into the performance?"

10.6 Making a Metaphor Real

While the data from the *null/void* study is valuable to the development of a deeper understanding regarding risk and expression in computational musical practices, its most significant contribution extends beyond. Unpredictability and failure have been analyzed thus far in terms of definition and effect. However, this research is concerned with the proposition that physical and material risk create opportunities for musical expression. If this hypothesis can be confirmed, then it is worth considering the potential value that material and physical risk might bring to computer music practices. The *Torpere* study engaged the physical component of the hypotheses through computer performers' improvisations with a physically high-risk instrument. The material component of the hypothesis was not so easily engaged.

It is no stretch to say that attempting to make conceptual, virtual elements of computation feel tangible is an ambitious goal. The value of this particular research study was itself very high risk—if the metaphor for computational materiality was not effective for participants, the data would potentially have no meaning. It was only by deploying the interfaces to computer musicians that the metaphor could be tested. After 3-6 weeks, participants were able to provide an answer.

In their interviews, all four participants spoke transparently about the impact the *null/void* interface had on their experiences of musical expression; fortunately, the metaphor did not fall flat across the entire board. For one participant, the interface made digital musical resources feel *extremely* real, and for another it was not effective at all. For the remaining two the interface moved in and out of efficacy, at times feeling very connected to a conceptual tangibility and at times feeling entirely removed from the process altogether.

This wide range of perceptions present a more valuable set of findings than an entirely successful metaphor could. Through an analysis of the spectrum of success and failure we can identify potential criteria for successful and unsuccessful risk-metaphors for computational musical expression. The presence of both positive and negative perceptions of the *null/void* material metaphor also enables a deeper understanding of what value (if any) a successful metaphor brings to the computational musical experience.

10.6.1 Schema and Paradigms

Before presenting the results of the *null/void* study it is worth taking a moment to address a pattern of behavior that emerged *before* participants' actual improvisations. Though the study was not intentionally designed to engage with the role that schema and paradigm play in unpredictable engagements, strong themes emerged through thematic analysis (in *both* studies) that support a high degree of relevance to the research topic.

Table 10.11: null/void Paradigm and Schema Codes

3.PARADIGM AND SCHEMA

3.1 Expectations and Assumptions	3.2. Successful Schema and Paradigm	3.3 Unsuccessful Schema and Paradigm
Existing schema and paradigms define expectations and assumptions	Schema and paradigms feel synchronized	Disconnect between conceptual and practical senses of time is a conflict
Existing schema and paradigms define goals and objectives	Internal schema and external paradigm align in a way that feels natural	Disconnection between internal experience and external representation
Design and form factor define assumptions and expectations of behavior	Schema and paradigm allows you to gauge behavior of the unknown	Disconnection between conceptual and practical concepts prevents immersion
Design and form factor define immediate positive/negative impressions and interactions	The behavior of an unknown/novel paradigm "makes sense"	Disconnection between conceptual and practical concepts prevents creativity/expression
Name of device can influence assumptions and understandings of behavior		Schema and paradigm can produce a placebo effect
The visual form of a system and the paradigm it is assumed into are closely linked		Existing schema and paradigm can be very incorrect
		Schema/paradigm can be a limitation to engagement, exploration
		Conflict causes engagements to be negative: uncomfortable, disconnected

10.6.1.1 Expectations and Assumptions

The first question that participants in the *null/void* study were asked during interviews was, "Can you tell me about your first impressions and experience when using the interface for the first time?" Two of the four participants made statements regarding explicitly *not* utilizing the *null/void* documentation (which provided information regarding the setup and use of the system) included in the cultural probe package. The sample size of this study does not allow for concrete conclusions to be drawn from this difference in approach alone, but it worth noting that the two participants who self-reported foregoing the instruction guide also conveyed the following first impressions of the device:

> **P1:** So, first of all, when I looked at the device, it looked more like a synthesizer. Without reading much of the instructions at all, I felt it should make some kind of sound, it should actively contribute to the sound part of the composition. Without much understanding the purposes, the interface felt like it should generate some signal. The pitch, amp, and time controls should generate a monophonic melody.

> **P2:** Just by actually connecting everything together I started to conceptualize this as kind of like an interference layer. Like I'm going to be doing my performance thing and then [the interface] is going to be sending something back to me from what I'm doing. So, even before I turned on any sound or anything that was kind of how I thought about it...[When] I first turned it on, I thought that it was probably recording...[that] it might have space to fill up with incoming audio and it might have been a circular thing, and then [the interface] would reintroduce the sound. But I don't know if it was the kind of input that I was using, but I never actually heard extra sounds.

Participants 3 and 4 made no mention of the visual impression of the interface at all in their interviews, but Participants 1 and 2 drew immediate connections between the *null/void*'s form factor and its presumed function. Interestingly, they predicted opposite behaviors: P1 assumed the device would synthesize and produce its own sound, and P2 believed it would record and play back their own.

The attempt to understand the *null/void* interface through preexisting schemata (the interface "should actively contribute to the sound" for P1, and the interface as "interference level" that will "be sending something back" to P2) set an environment in which expectations and assumptions defined the expectations of participants. This had both positive and negative consequences.

10.6.1.2 Successful and Unsuccessful Schema/Paradigm

Of all of the participants, P1 experienced the most frustration in their improvisations with the *null/void* system. The majority of their notes, taken over the course of the study, convey dissatisfaction with interactions during their performances. Some examples include:

- It was pretty frustrating with the limited musicality and inability to modify the sound to workaround the depleting resources.
- It is more difficult to correct the musical direction when one resource is depleting faster...When I do change directions, there would be a big chunk of awkward silence rethinking and modifying the code. This obviously breaks the flow of performance.
- I was a bit frustrated by the pitch resource depleting faster regardless of the volume or [tonality] (as opposed to noisiness) of the sound.
- It hit the cap of expressiveness fairly quickly. I could explore more of the groove and flow aspects but this session wasn't flying.

There was a clear struggle between P1's objectives and the inherent behavior of the interface. While P1 was not the only participant to describe struggling with the nature of the interface (P3 also reported similar experiences in their session notes), they were the sole musician to convey those conflicts throughout the entirety of their participation in the study. In the case of P3, an initial struggle to accept the natural behavior of the interface prompted immediate shifts in conceptualization and approach. In the notes from their first improvisation, we can see this rapid adaptation:

- The amp resources completely depleted first, much quicker than I expected. I played a lot of notes that had short decay time. I completely overlooked how fast the amp resource was depleting. I [will] sustain the note as long as possible and modulate and pitch bend during the next take in order to conserve the amp resource.

By their third improvisation, P3 reports the result of this new approach:

– I think I was trying too hard to figure out a way to save up the amp resources and disregarding how I can play the current system better. I need to focus on playing something musical while saving up the amp resource. It got less and less engaging to play as I modified the [software] system. Take 2 should have focused on longer release time and pitch-bend.

The next time they make a journal entry, the behavior of the interface has become more integrated in their creative process:

– I have a better understanding of how the amp resources deplete. It made me play sparingly and play shorter notes. During those short notes, I tried to modulate and pitch-bend to try to make them sound more interesting. While playing, the amp resource still depleted faster than I expected so it really made me feel more and more conscious about playing sparingly and making each note count.

P3 is quick to adapt to the emergent behavior of the *null/void* system with each subsequent engagement, while P1 was much less willing to let go of their desired interaction modality. One might assume, based on these findings, that the metaphor of limited computational materials was not effective for P1, but as we will see in the next section, this was not the case. This suggests two things:

1. The design and form factor of a novel musical instrument/interface matter: The lack of standardized pedagogy and repertoire in computational music, and the absence of standardized/universal paradigms for interaction may lead to a musician connecting the “unknown” to whatever is conceptually “closest” (e.g. synthesizer or effects unit)
2. Existing schema can define the expectations and assumptions of a musician engaging with a novel instrument/interface and be very difficult to overcome

To give an example of the second point we can revisit P2, who conceptualized the *null/void* interface as a recording/playback device. When prompted to expand on their perceptions, P2 explicitly identifies the complicated nature of interpretation:

> **Interviewer:** It sounds like your experience was that you thought the system was adding or removing some kind of active effect on your sound. Would you say that’s true?
>
> **P2:** My limitation, as somebody who’s been using–people have all these expectations about what the system’s behavior is based on their experience, and maybe that’s just my limitation. I was doing this layer of processing, and I’m not able to get over this idea of: The input has to come from somewhere, and

> that somewhere is my sound, and so the only thing that this thing can do is either play my sound or play a different version of it. Or *not* play my sound. [laughs]
>
> **Interviewer:** So, would you say it felt kind of binary?
>
> **P2:** Well, it's called "*null/void*." And so I was like, "Oh, is that kind of a thing that's switching between two modes? And there's the "null" mode, which *does* have my sound in some way. And then there's the "void" mode which is just silent."

Even the name of the interface can have a significant impact on how a musician conceptualizes and interprets their experiences when using unfamiliar systems. The influence of these combined assumptions was powerful for P2 in particular, to the point that a kind of placebo effect was described:

> **P2:** Sometimes I was imagining things happening and then I saw something happen in my software and I realized, "Oh, that was probably just me." [laughs] I realized that probably 5 percent of what I was hearing might have just been me imagining stuff because I was trying to figure out what [*null/void*] was doing.

10.6.1.3 Summary - Schema and Paradigm

Participants in the *null/void* study were asked to use the interface within their own practice, and it is possible that this contributed to the comparatively low presence of preexisting paradigms, which was highly observable in the *Torpere* study. Schemata, however, had a significant effect on some participants' engagements in the study. Schemata can be productive in that they offer a lens through which to understand unfamiliar behavior, but can also serve to hinder a musician's ability to understand novel behavior on its own terms.

This is valuable to consider as we return to the topic of metaphorical risk. In the next sections the ways in which the *null/void* material metaphor was successful and unsuccessful for the different participants in the study will be examined.

10.6.2 Metaphorical Failure

Table 10.13: null/void Metaphorical Failure Codes

6.2 METAPHORICAL FAILURE

6.2.1 Form and Function	6.2.2 Internal and External Conflict
The physicality of the interface can kill the metaphor	It can be a struggle to accept a metaphor at all
Physical and digital spaces can not be imposed on one another	If a metaphor is not accepted, there is no movement from conceptual to embodied
If a metaphor fails, the device takes on the function of an informational system: information versus representation	If a metaphor is not accepted, there is no movement from theoretical to practical
	Time must align with internal and external experiences

10.6.2.1 Form and Function

Participant 4 provides a case study that exemplifies a total failure of the *null/void* metaphor. As described in the Exploration section of this chapter, P4 was very deliberate in their approach to the study, driven much more by a desire to learn and understand the system's behavior than actually interact with it. For P4, the interface was nothing more than an informational system that provided metrics for limited musical properties, and while it did play a role in directing their musical creativity it was only to a small degree and entirely unidirectional.

There is no limit to the number of factors that could have influenced P4's experience with the *null/void* system and no way to know with one hundred percent certainty why the system did not make their computational resources feel more "real." However, there are certain criteria that can be considered with some authority, as they are presented by the participant themself. When discussing the potential reasons *why* the metaphor fell flat, P4 identifies two possibilities, one mental, and the other physical. First, P4 reflects on their own disposition:

Interviewer: I get the impression that the interface didn't really impact your

> creative process, or your creative decision-making while you were making music.
>
> **P4:** I think, no. No, not for me. Maybe that's my mindset coming to it as, "I'm kind of curious to see how this responds." Being a maker and having an idea of what was happening, but also being really curious to see how the interface works. I think if I was more of a performer I would have been like, "Is this going to make me change?" I think the instrument choice that I made, coupled with almost playing a game with it in some ways...maybe it didn't affect my performance as much as it might with somebody else.

Simply put, P4 is a curious individual. Their curiosity drove them to focus on the interface as a *practical* object rather than a representational one. This interest in the physical rather than conceptual state of the interface leads to the second reason offered by P4 regarding why the *null/void* metaphor did not affect them, one that may have been imposed by accident:

> **P4:** I think I was thinking of it more like a hardware thing, and I was also playing hardware. Maybe if I was playing an Ableton session, or playing a Max patch, I'd think a bit differently. Plugging hardware into hardware–maybe I connected those two things [conceptually] together all at once.

The seemingly innocuous act of connecting the *null/void* interface to a hardware instrument may have bound the objects to a paradigm in which disembodied computational data simply was not present. The *null/void* interfaces were intentionally designed to be as physical and tangible as possible, obscuring all digital components. The rationale for this was reasonable: to create a sense of materiality in an immaterial space, it should be done using materials rather than software. In the case of P4, however, the form factor had an opposite effect: the materiality did not transfer conceptually, but rather anchored the physical object to the lived space, severing any connection to digital materiality that might have been present.

10.6.2.2 Internal and External Conflict

In order for a metaphor to be successfully integrated into engagements with the *null/void* system, the behavior of the *represented* material resources had to align with internal perceptions of music that is produced over time. When the connection between internal and external conceptualizations of resource behavior fails, so too does the metaphor. Participant 1 used the *null/void* device in two stages: first with an electric guitar, and then with a live-coding system. Although the study was not intentionally designed to be used outside of computational musical instrument use, P1's perspective regarding the difference between metaphorical resources for physical and digital instruments is significant. We can observe that, when using a guitar with the *null/void* system, there is a significant disconnect between the use of pitch, amplitude, and time elements, and the visual representation of that process:

> **P1:** I felt like there's a little bit of a fundamental difficulty when I'm looking at the resource meter decreasing and I'm trying to calculate how much time I have [left]. What the trajectory for this real-time composition I should create. I'm creating very short phrases and there's definitely some resource decreasing I can see. Maybe I'm consciously trying to map this speed between the two and it feels unnatural or uncomfortable–they should nicely synchronize together. Maybe I'm [taking] the wrong approach here, but that's a constant discomfort I've felt.
>
> **Interviewer:** So, it was uncomfortable because the visual representation of the resources didn't line up with what you felt like you were using?
>
> **P1:** Yeah, you can say it like that.

This incompatibility was present in both low- and high-risk modes:

> **P1:** I was feeling–not always thinking, but feeling–like there's some tempo to this depleting behavior, and it fluctuates. But it's not exactly synchronized to how I'm feeling–with the tempo of the improvisation, or the small repeating patterns, motifs, or a bigger structure I'm trying to create. The speeds felt different and a little uncomfortable.

10.6.3 Metaphorical Success

Table 10.15: null/void Metaphorical Success Codes

6.1 METAPHORICAL SUCCESS

6.1.1 Internal and External Harmony	6.1.2 Feels Really Real
Sense of synchronized behavior between musician and interface	An instrument's behavior must feel connected to the resources in order to be productive
Behavior of an external metaphorical representation feels internally real or natural	Resources feel more real with computational instruments
Resource compatibility determines how much the device will impact creativity	When resources feel real there is a deep level of acceptance

Participant 3 provides a case study for the other extreme: a highly successful metaphor. P3 offers two distinct ways of understanding the successful application of a material metaphor to computational resources: describing a high level of integration between the representation of resources and the concept of them, and revealing how that acceptance emerges in real-time musical expression. When describing their experience using different interface resource settings P3 uses language that draws no distinction between the visual *display* of resources via the *null/void* interface's meters and the conceptual resources themselves. For P3, the *null/void* contained all the pitches, amplitude changes, and units of time that were available (or not):

> **Interviewer:** Did having [*null/void*] counting your resources down make it feel like it was more limited or real?
>
> **P3:** I think I it did, yeah. That's why I wasn't battling with it a lot throughout the study. In the beginning, having the pitch at max and minimum didn't make too much of a difference because I just played in a way that depleted the resources way too fast regardless of the setting. But later on it did affect me. [When] I have all of the resources at maximum it was boring to me. Compared to having all the resources at the minimum setting, all at maximum just feels like I have infinite resources. When the time resource is at max it feels like I can just do whatever without any consequences–but, in the end it was boring to play. I would rather do the setting at all minimum and do a minute-long improvisation. That's more exciting to do. I think being on the edge a little bit did make it more engaging.

Participant 3 appears willing to dive into the metaphor as deeply as possible, and the result is an expressive musical engagement in which P3 not only accepts the limitations placed on their musical resources but also finds exciting potential in higher-risk spaces. The strength of the metaphor has both positive and negative effects (boredom and excitement), but there is no doubt that P3's musical expression is changed by the interface.

As with failure, the reason(s) behind the success of a metaphor can not be fully known. However, the data from Participant 3 (the strongest success case) can be used as a metric with which to identify commonalities across other participants. In terms of thematic analysis, Participant 3 presented the most codes regarding successful engagements with resources as materially "real." When collating codes across participants it became clear that P1, P2, and P4 would all ultimately contribute codes to Theme 4.1: Metaphorical Success. However, examining the codes shared—and perhaps more importantly, the codes *not* shared—with P3 allowed the most salient information regarding materiality as metaphor to emerge. Generally speaking, two criteria contributed to the success of the *null/void* metaphor, represented in Subthemes 4.1.1: Internal and External Harmony and 4.1.2: Feels Really Real.

10.6.3.1 Internal and External Harmony

As we have seen in the previous Internal and External Conflict section, the connection between an external *representation* of resources and an internal *conceptualization* of them must feel natural and direct. For P1, using a guitar with the *null/void* resulted in a situation where the metaphor clearly did not actualize. However, they describes a very different experience when using the interface with their live-coding system:

> **P1:** With the acoustic guitar it was like one-to-one. You play a note, you might see the pitch resource decreasing a little bit–I couldn't really synchronize to this resource and the performance, I didn't really feel musical progression in terms of that decreasing resource with the acoustic instrument. With digital instruments and live-coding, it was, in a way, very direct. It was connected. The resource was directly contributing to the musical flow in a way, because I

> had a sense of actually using up the limited resources. The computer is using up this limited resource.

P1's comments suggest that resources—time, in particular—are experienced differently based on what musical instrument is being used. Further, the use of a computational instrument appears more compatible with the conceptual resources presented through the interface. Although the guitar and resource meters are both physical, tangible, visible objects, *null/void* synchronizes with a computational instrument in a way that "feels" more natural.

10.6.3.2 Feels Really Real

When speaking of their experiences in the study participants generally offered a wide variety of examples of metaphorical success and failure. When describing engagements in which their musical resources felt real or tangibly represented through the *null/void* interface, their language was often focused on describing the *behavior* of interconnected musical systems. In particular, resources felt "real" when the *null/void behaved* in a way that felt *natural*.

It is difficult to know what, exactly, "natural" behavior is in a metaphorical representation of digital resources, but participant did offer some insight. The metrics with which they evaluated *null/void* behavior were often contextualized in the difference between computational and acoustic instruments. Participant 4 describes a conceptual disconnect between the limited resources represented by the *null/void* system (only three) and the vastness of computational resources:

> **P4:** Only having the three parameters–They're three extremely prominent parameters, but maybe on some software instruments that could be limiting in itself? What about one for texture? Or, what about one for tone color?

Participant 1 illuminates the differences between strong and weak compatibilities when using *null/void* with acoustic and computational instruments:

> **P1:** It made more sense with the pitch and amp resources being used for live-coding. It felt more natural. The time resource was more of an annoyance and not really contributing to the live-coding process, but that was a good, positive impact. Whereas [with the] acoustic instrument, I think the pitch and the amp resources weren't directly related to my improv and musical decision-makings. They just happen...I see things decreasing, but they didn't give me any urgency or anything.

These sentiments suggest that metaphorical resources feel "real" they are conceptually compatible with an instrument's behavior: when used with a guitar, the *null/void* system seems to be measuring the acoustic vibrations of the strings and reflecting that activity to the musician visually. When used with a computer, *null/void* is interpreting zeros and ones, removing them from an internal stockpile, and conveying what's happening inside to the performer.

10.6.4 Summary - Making a Metaphor Real

A valuable lesson can be taken from these successful and unsuccessful case studies: *materiality* and *materials* are different things. Designing a physical object as a container for an intangible concept does not imbue one thing with the state of another. This research presents digital and material resources in opposition to each other, leaving little room for nuance. In reality, it may not be productive to define computational musical resources as less "real" than acoustic ones. They may in fact be very "real," but *felt* in a different way. The presumption that computation can be made to feel more tangible through a material object may be intrinsically flawed.

When the *null/void* fails to enact a materiality metaphor onto the computational musical process, the connection between a musician's instrument and their musical resources is uni-directional. In the visualization below we can see how the interaction dynamics of P1 and P4 extend outward from the instrument toward the *null/void* interface and/or digital resources. In the case of P1 (in their guitar improvisations), the music produced through their instrument triggers the behavior of the interface, and the interface displays conceptual resources as visual response. There is a sense of connection between the *null/void* and musical resources, but those resources do not connect back to the musician's instrument. *null/void* presents a metric representation of time, pitch, and amplitude that feels slightly autonomous, but P1's *felt* experience of using musical material does not resonate with what is represented on the device.

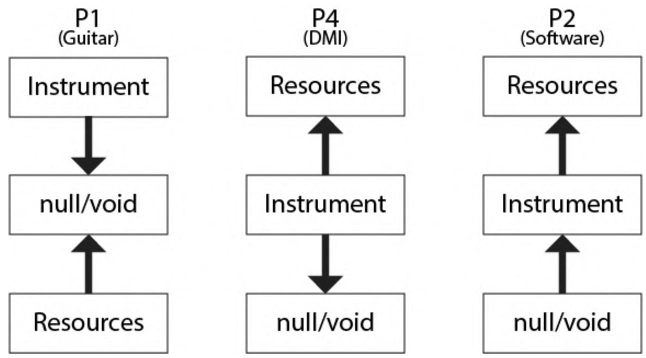


Figure 10.1: Interaction dynamics: P1, P4, P2

In the case of P4 the musical dynamics of improvisation are similarly anchored to the instrument (in this case, a DMI). Their musical content flows outward toward the *null/void* device and conceptual resources–however, the *null/void* interface exists merely as a visual reaction to musical articulation and there is no organic connection between what is observed on the interface and the resources P4 is using. P4 does not *interact* with the *null/void* system, they *control* it. The interface ultimately has no impact on P4's perception of available musical material; they and their instrument maintain sole agency in the engagement.

Participant 2, who uses the interface with musical software, has a unique interaction dynamic. In their experience both the *null/void* and metaphorical computational resources are disconnected; however, the behavior of the interface itself has a great deal of agency and autonomy and impacts P2's musical expressivity significantly. Although there is no evidence that P2 made any musical decisions at all based on the materiality metaphor, *null/void*'s sense of "otherness" prompted deep levels of reflection and engagement within their musical improvisation.

These instances of low-level (or near absence) metaphorical materiality contrast significantly from the experiences of P1 (in live-coding) and P3 (software instrument).

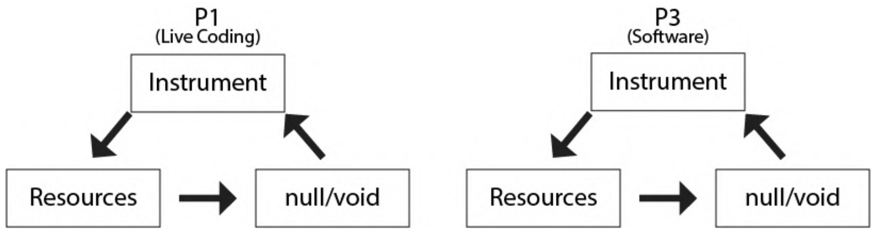


Figure 10.2: Interaction dynamics: P1, P3

When the *null/void* metaphor is successful, the connection between instrument, interface, and resources is complete and omni-directional. The instrument acts upon the *same* resources as are visually represented through the *null/void*. Because they feel "real," the behavior of the *null/void* has a direct impact on which resources the musician chooses to use as they improvise over time–and that decision-making process in turn feels as though it is authentically being enacted on an extant bank of resources.

10.7 The Effects of Material Risk in Computational Musical Practices

10.7.1 High-Risk Materiality

This study was developed in order to investigate the hypothesis that material risk states enable higher levels of musical expression and support that theory through the application of a metaphor for limited material resources onto computational musical expression. In analyzing the findings from this research, there are two questions that must be answered:

1. Was the *null/void* interface effective in making digital musical resources feel more "real" to improvising computer musicians?
2. Did the high-risk behavior of the *null/void* resources provide increased opportunities for improvisers to feel musically expressive?

The first question has been addressed in previous sections of this work: for Participants 1 and 3, the *null/void* interface made digital resources feel *very* material. For Participant 2 the unpredictable behavior of the interface itself was compelling and led to novel feelings of expressivity—but the resources themselves did not move from conceptual to embodied.

Lastly, P4 reported no sense of connection to material resources at all and found the interface to be interesting only insofar as the fact that it could intentionally be made to behave in one way or another. Ultimately the answer to Question 1 is a resounding: "Sometimes."

In order to answer the second question we must consider the experiences of Participants 1 and 3 more closely and examine the ways in which their low- and high-risk experiences differed. Additionally, we can utilize the experiences of P2 and P4 as a kind of baseline for experiences with low- and high-risk mode that were *not* strongly influenced by *null/void*'s metaphor. If material risk creates more opportunities for musical expression in computer music, the data from P1 and P3 should provide evidence that supports that claim.

10.7.1.1 The Fact Versus the Feeling

Much like what was observed in discussions of FEW in the *Torpere* study, *null/void* participants were inclined to give clear, objective opinions regarding their improvisational experiences—and then proceed to describe the exact opposite in their reflections. *Every null/void* participant claimed that the low-risk and high-risk *null/void* improvisations were not significantly different, though some participants put it more bluntly than others. Data from Participants 2 and 4 demonstrate no significant differentiation between low- and high-risk improvisations, and both participants were inclined to use one mode over another (P2 = HR, P4 = LR):

> **Interviewer:** Did you have a chance to use [the interface] in the two separate modes?
>
> **P2:** With the LR, I kind of convinced myself that my sound wasn't working with it because I was just hearing throughput. For the remainder of my experiment I switched it to HR because I assumed that was [active] mode, where I would hear more of the system's behavior, and then I just stuck with that.
>
> **Interviewer:** Did you see that [the system] would unpredictably add or remove your resources in the meters in the high-risk mode?
>
> **P2:** Yeah, it would jump up. The thing that I saw the most was that I would see a jump up and then I would see it would slowly go down.

> **P4:** I wish that I had spent more time toggling between the two [modes]. I don't think I did high-risk mode while using this pitch-based synthesizer. What I tended to do more was [use] more low-risk mode, but change the parameter settings for the [resource] banks. So I'd be like, "This time I'm going to have the largest amount of time parameter, but I'm going to minimize the pitch and the amplitude," and then I would just do different settings of those three. I do wonder what it would have been like if I had swapped more to high-risk and have [the interface] make those changes randomly for me.

P2 and P4 seem generally uninterested in the difference between modes and their statements convey a clear lack of metaphorical efficacy. Beyond those particular responses to direct questions neither participant brings the topic of low- versus high-risk *null/void* behavior back into the conversation. From this it is reasonable to conclude 3 things:

1. The low-risk and high-risk *null/void* modes are not necessarily perceived differently by musicians during an improvisation
2. The *null/void* interface may be more valuable in terms of its *behavior* rather than its *metaphor*
3. Lacking any metaphor for materiality, low- and high-risk behaviors may seem meaningless.

P1 and P3—the two participants who experienced the materiality metaphor most successfully—were also, surprisingly, *more* vocal regarding experiencing no significant difference between modes:

> **Interviewer:** Do you feel that your experience was different at all based on the low-risk and high-risk modes?
>
> **P3:** It wasn't that big of a difference. I think when I had the high-risk setting I was looking at the interface a lot more. So I guess it was a tiny bit more distracting than the low-risk. But in terms of how it affected my playing, I don't think it did greatly. I did see the meters going down randomly and also going up. There were some times I had a false sense of, like, "Oh, I have a lot more pitch resource than I remembered," but then I'd look back and it's almost gone. So, there were a few moments like that, but it wasn't that major difference between the two.
>
> **Interviewer:** I'm surprised that using it in the high-risk mode, where it randomly gives you more or less...I'm surprised that that experience wasn't more different or distinct from using it in the low-risk mode. You were paying a lot of attention to how the resources were being depleted and how you were using

each one, so, I would imagine that having random spikes or drops in those resources would have had more effect on you. But it seems like there wasn't that much difference between the low- and high-risk.

P3: Yeah. It surprised me too, because I thought...While I was trying it, the high-risk setting, it was scaring me to use it. And then once I did use it I was surprised to see it not affect me too much.

Interviewer: Do you feel like there were any similarities or differences in your experience with low-risk and high-risk modes?

P1: Not much, I have to say. [Both the low-risk and high-risk modes] didn't add too much of an emotional or aesthetic difference. The resource depletion, and also this kind of randomness, happens a little too slow compared to how I think or perform. Though, I feel like I can get around these slow behaviors a little bit by adjusting my playing style.

If we were to stop here, the answer to the question, "Did the high-risk behavior of the *null/void* resources provide increased opportunities for improvisers to feel musically expressive?" would be a clear-cut and well-supported, "No." However, as previously mentioned, the *lived* experiences of Participants 1 and 3 during their improvisations differ quite a bit from what they objectively report. At multiple points of the interview, Participant 1 describes the impact of high-risk mode as (mostly) positive, having a direct effect on their expressive engagements:

P1: I appreciated the high-risk mode. The nice unpredictability–I was happy when resources go down suddenly, and I'm like, "Okay, I'm going to change the style, try to change the style," and I do that, and then the resource goes back up, "Okay, it's safe, now, to do more different things." Resources going up definitely had a nice impact. When it went down a big chunk I think it also has a bit of a positive effect...slow decay isn't really noticeable sometimes, but it forces you to change the mood a little bit when the change is bigger. The HR factor seemed to have somewhat favorable effects on [my] performance. When a resource (pitch, for example) suddenly decreased, it had me thinking [about] how to focus on the other resource to balance out and maximize the duration of the performance.

We can see a clear evolution between Participant 1's earlier improvisations with *null/void* and later ones. Initially, they are very clear about low- and high-risk modes having very little difference in terms of impact on their expressivity. However, as discussions go on and P1 moves from guitar to live-coding, there are very clear instances of high-risk mode having a positive impact.

Participant 3 provided a great deal of information regarding their use of both *null/void* modes. While Participant 1 showed a significant transformation from earlier to later improvisations in high-risk mode, P3 reported only minor variations from their original sentiment. An analysis of their session notes provides insight into their engagements with low- and high-risk modes over several weeks. When P3 describes their first experience with high-risk mode, they do not report being significantly affected:

> **P3:** [High-risk mode] didn't feel that drastically different from the LR setting. Seeing the amp meter go up did make me feel like I could play more notes and this take is 40 seconds shorter [than the previous LR improvisation]. Amp depleted first, so the random addition of resources may have led me to falsely think that I can play more notes. I did see the pitch meter going down faster than before, so I did play differently for a short period of the time, until I saw the amp resource gradually decreasing and my focus shifted again.

P3 is clear that if high-risk mode had any effect at all it was minor, and potentially more bothersome than interesting. However, in the same journal entry they express a more confident claim that high-risk mode prompted more mental effort and compositional planning. While not exactly a positive experience, P3 reports a sense of excitement regarding exploring high-risk mode more:

> **P3:** The unpredictability of the [HR] system did affect my playing. It kept me wondering how the resources will deplete and add and how I should adjust my playing. It was a bit more distracting but I'm actually excited to use the HR setting more.

In the second week's session notes P3 describes a lack of risk when improvising with the low-risk interface, but experiences a benefit from the metaphor in general:

> **P3:** Right now, there isn't too much of a 'risk' or 'failure' (other than feeling bored or not satisfied with the take). Nothing feels too much at stake unless I take this interface to a live performance and had to do a 20 minute set. I think treating the interface as something that is challenging the way I improvise is still engaging enough for me, personally.

The next session is done in high-risk mode, and P3 reflects the following:

> **P3:** Compared to yesterday's session (with the LR setting), the length and the general impression of the improv were similar. I did see the meter move around in a more unpredictable manner, but in this instance it didn't affect my playing that much...I think being conscious of the resources and the structure/sections is actually important to keep myself engaged. Even with higher amount of resources, the limitation was still guiding me to be aware of preserving them which helped me play in a way that actually is ultimately more engaging? Limitation and risk are a guide?

Lastly, in their third and final week of the study P3 compares their low-risk and high-risk improvisations:

> **[Low Risk] P3:** Pitch depleted first. 1:30 long. Nothing much new to say. Seeing the pitch meter depleting fast didn't really affect my playing.
>
> **[High Risk] P3:** The time resource was moving in an unpredictable way. I saw that there were plenty of time left by the time I got to the wall of sound section, so I extended that part a bit and slowly decreased the intensity in order to have a natural ending before the timer ran out (and I still had plenty of pitch resource left). The time resource decreased a lot all of a sudden when I was playing the ending section. So, I kind of rushed through the 6th section. The unintended last note wasn't that bad, though. And since I was kind of afraid that the pitch resource was going to all of a sudden decrease, I was playing a bit more conservatively (less reverb, shorter notes, a bit more space). The HR setting did keep me alert and made me look at the meters closely more frequently. I didn't think it was too distracting. If anything, it was acting as a guide (the interface acted even more of a guide compared to the LR setting. An active guide).

By the end of the study P3 has shifted from experiencing low-risk and high-risk modes as *no different*, *slightly different in a passive way*, and finally *slightly different in an active way*. While the findings from P3 do not convey P1's level of support for a connection between risk and expressivity, the fact that the *null/void* system eventually came to feel like an "active guide" is not insignificant. In fact, as we will shortly see, this point of data will contribute to one of the most interesting themes to emerge from the study: Engaging with the Other.

10.7.2 Positive Musical Impact

Table 10.17: null/void Positive Metaphor Codes

7.1 POSITIVE MUSICAL IMPACT

7.1.1 The Benefit of Limitations	7.1.2 Creativity and Expression	7.1.3 Realizations and Reflections	7.1.4 Engaging with the Other
Building limitations into computational systems produces expressive behavior	Pushed improvisation in new directions, produced creative opportunities	Enables unexpected elements/qualities to emerge	Having somebody who's "watching you" leads to being more cognizant actions
Unlimited nature of computation can lead to self-indulgence	Realizations from use of device can produce methods for self-imposed creative shifts	Prompts realizations about reliance, overuse, safety/comfort	An other has the ability to impact how you feel about yourself and the things around you
Limitations contribute to the development of a deep understanding of the depth and range of a process/instrument	Device can prompt both conceptual and structural changes to interface/instrument	Reveals the edges of creative musical spaces	Metaphor as other can be a teacher, guide
A lack of limitations can be overwhelming	Device as a way to gain a sense of objectivity about expressive process	Prompt s realizations about the self, self-reflection	Agency of the other prompts creative change
All instruments need limitations and constraints in order to be expressive	Device added productive constraints to DMI	Device prompts self-observation	Unpredictability of resources being under an other's control alleviates some of the pressure of being judged
Music without limitations/constraints is boring, pretentious	Prompts considerations about musical materials and musicality in general	Prompts deep listening, critical thought	
Incorporating and/or designing limitations into software systems is valuable	Prompts positive small-scale change (live-coding)	Positively quantifies musicality in computer music	
		Positive: interface as guide	

Despite being unable to fully support the hypothesis that material risk can increase expressivity in computer music, the data from the *null/void* study offers significant support for the notion that unpredictability can offer something to computational creativity that even randomness can not. Participants describe the interfaces as prompting significant shifts in their exploratory, performative, and improvisational processes. The most prevalent themes are presented below, representing codes that described increases in critical thinking, self-reflection, and creative decision-making, among others.

10.7.2.1 The Benefit of Limitations

Many participants explicitly reported an appreciation of the *null/void*'s effect of limiting their computational resources. This sentiment was often expressed within discussions of acoustic instruments, which have natural affordances and constraints. The ability of the interface to apply constraints to the open-ended nature of a computational system felt productive to the expressive process and made musical decisions feel more meaningful:

> **P1:** Digital musical instruments, or software, tend to be too open-ended–they [don't] have much of a structure to get [things] going as an actual musical activity. They are so open-ended you can just do whatever, so I think [the *null/void* interface] makes quite a bit of sense to have.

> **P4:** [Considering] an endlessly flexible piece of software and the baked-in walls and rigidity of other [physical] tools is an important balance to strike. I guess with [*null/void*], keeping an eye on it, I was thinking there were limitations, because it would just literally cut off sound at a certain point. So yeah, I think this is a really interesting way to put some natural–or even random, in some cases–limitations on an unlimited system.

Beyond identifying the positive role that limitations can play on computational musical expression, participants also reflected on compelling creative states that emerged specifically through the material limitations of the *null/void* interface. When Participant 3 feels as though there are consequences to their creative decisions, they feel as if they are improvising "on the edge," where those decisions carry higher levels of risk. Being musically expressive in this liminal space is higher-pressure, but also more creatively fulfilling. The sense of limitation on computational materials results in a conscious effort to make intentional, meaningful musical choices:

> **P3:** I was trying to make each note count rather than just noodling it, since I have very limited amount of notes that I can play. Instead of just playing mindlessly I tried to make each note very distinct.

Making computational resources feel truly limited—-tangible and finite, bound to a material condition—-can scaffold a space for considering new modes of musical expression. It can apply positive constraints to musical resources that are not tethered to physical materials, and allow musicians to express themselves in a space of deep affordances rather than wide variability.

10.7.2.2 Creativity and Expression

The *null/void* interfaces were successful in applying limitations and constraints onto some participants' concept of computational materials, but also influenced the performative trajectory of their improvisations over time. Participant 1 explains that the interface introduced a sense of urgency, which added momentum to their improvisation:

> **P1:** At a general level, there was a sense of pushing forward and urgency when I'm using the device and live-coding. The depletion of resources, that actually reflects the progress of music with live-coding.

In addition to feeling that their improvisation was intensified by the interface, P1 describes feeling prompted to make more creative decisions:

> **P1:** Something unexpected [would happen when] I noticed the resource was low. I did not feel negative about that situation, [it was] more like a driving force to do something else, and I feel good about it, actually. Rather than having the full resource–that's too open-ended, I can do anything and it doesn't constrain my performance at all kind. So yeah, I think in this use case I think I feel good about the resource decreasing in some ways. In [the *null/void*'s] response I feel positive and I can have some creative opportunity here...Paying attention to the resource meters, I tried making small local changes and adjustments more often, and that was nice. Rather than staying in one musical pattern and state forever, I wanted to adjust things a lot more in response to the resources.

We can see meaningful overlap between material limitation and musical expression. The sense that an instrument has unique musical depth and range stems not from endless flexibility and openness but rather from a belief that it has natural boundaries–characteristics and capabilities that are unique and that set it apart from other instruments. Improvising with a sense of instrumental limitation had positive effects on participants' levels of engagement and creativity and made the musical decision-making process feel more intentional and meaningful.

10.7.2.3 Realizations and Reflections

The *null/void* system also had a productive function in provoking self-reflexive behavior among participants. Each musician conceptualized the interface differently, but all engaged in contemplative activities because of its presence. Some participants described having experiences that were were highly introspective, even going so far as to say that they "learned" something about themselves as a product of using the interface. P3 describes a process of self-realization through challenging confrontations with the device:

> **P3:** I looked at it as a guide–it was good guidance for me to really reflect on how I improvise. The interface started to make me reflect about how I play and about my musical style. It allowed me to see limitations in my playing and performance system that I tend to make. It was changing how I was playing. I think it could be frustrating at times, but at the same time it's challenging me to play differently.

Participant 2 describes an entirely different introspective process that emerged from using the *null/void* system, one more focused on critical listening and deep analysis. It is particularly valuable to consider P2's statement in the context they provide, which addresses the effect that long-term use of an instrument can have on the musical process:

> **P2:** [The device] was really productive and helpful in redirecting my listening process in a valuable way. It kind of pushed me into this observant listening mode–I've been using [my software instrument] in one form or another for 16 years now, so I am no longer in listening mode with it, because I just know exactly what it's going to do. [*null/void*] forced me to go into listening mode.

The introduction of an external object into the creative music-making process seems to allow musicians to step back from the experience and examine their modes of expression with a sense of objectivity. For P2 and P3, the presence of the *null/void* interface challenged them to examine their own process with a critical ear and take the time to meditate on their own practices.

10.7.2.4 Engaging with The Other

Lastly, one of the most intriguing themes to emerge through data analysis was the positive impact that the *null/void* system had as an "other" in musical improvisations. We have seen, in previous sections of this work, that agency and autonomy are crucial elements of musical creativity. They can contribute to higher or lower levels of interaction, the success or failure of *null/void*'s metaphor for material limitations, and the degree of expressivity a musician feels during musical improvisation.

When participants effectively experienced *null/void*'s metaphor in improvisation the interface seems to have taken on a surprising degree of autonomy and agency. In reflections on their experiences the interface is almost anthropomorphized, described as an "other" capable of speaking to, teaching, and observing them.

Participant 1 describes the interface in ways that almost imbue it with a social component–*null/void* could act aloof or show them kindness:

> **P1:** I decided the pitch resource wasn't being reasonable to me, I think, so I just focused on the time resource here.
>
> **P1:** I think [high-risk mode] frees you from the sense of being bound to this resource. It's telling you, "It's not your fault. It's going to decrease a bit, or [a lot], but it just happens." It's not your direct fault, it just happens.

In the first example P1 struggles with the behavior of the *null/void*'s pitch resources during an improvisation and concludes that interface is being unreasonable to them. It is a fairly universal experience to occasionally treat inhuman objects as as sentient beings–kick back at the table you stubbed your toe on or call your cellphone an jerk when it drops your call. However, in the second quote we can see a more fully-formed "other" described; the high-risk interface reassures P2 that they are not solely responsible for what happens during the improvisation, that P2 shouldn't worry that they are entirely at "fault" for what happens.

Participant 3 speaks at times of the interface taking a role of teacher or guide, almost as if the device has knowledge to impart:

> **P3:** It made me realize a lot of different things and guided me to play in a different way. It was teaching me a lot about how I tend to improvise.

Participant 4 described the potential uses of the interface in mildly voyeuristic terms, capable of over-the-shoulder observation while you perform:

> **P4:** [The interface] could act like somebody who's watching you, deciding when your sound stops. Asking how cognizant you were being of resources– of the time you were using, of your changes in amplitude, your changes of pitch.

The intelligence and agency that P4 describes the interface having is echoed in Participant 2's description of the device's role during their improvisations:

> **P2:** There was something very intelligent happening in the way that it was actually looking for changes in my output and then responding to that.

Whether described as a teacher, guide, observer, collaborator, or other conscious being, all of the participants in this study described moments of interaction with the interface that involved some degree of agency. P1 and P3 seemed to experience the most "human" dynamics with the system, describing it as speaking to them or providing outside knowledge. This may indicate a correlation between the success of a metaphor and the perceived agency and intelligence of the system it is being deployed through, but unfortunately there is not enough data to know this with certainty.

10.7.3 Negative Musical Impact

Table 10.19: null/void Negative Metaphor Codes

7.2 NEGATIVE MUSICAL IMPACT	
7.2.1 Disruption	7.2.2 Metaphorical Uselessness
Creates higher need for structure and planning	More useful for formal performance situations
Engagements can become focused on understanding/figuring out metaphor	Limited and unpredictable resources are less useful the more you feel you know what you want to do
Removes sense of control and autonomy, limits freedom and experimentation	More useful for social contexts
The need to understand/figure out behavior can disrupt musical expression	Not necessarily useful in computational setting
Resources can conflict with personal musical goal/objectives	Can be incompatible based on natural playing style
Resources prompt a desire to preserve and conserve at all costs	Does not necessarily feel any different
Can cause a weighing of cost-value of musical elements	Does not necessarily cause creative changes
High-cost resources can be a disruption to creative flow	Resources can be forgotten or ignored
Limited resources are especially challenging to deal with in the long-term	

A successful metaphor is not inherently positive. In fact, the more "real" a metaphor is, the more polarizing its effects it will be. When the *null/void* played a negative role in musicians' improvisations it was usually due to a feeling of being personally restrained by the interface, unable to pursue paths of interest due to the level of risk involved. Participant 3—the musician for whom the metaphor was most successful—describes feeling as though they were forced to weigh their creative desires against the cost of hypothetical resources:

> **P3:** I did constantly feel that I was making decisions more based on preserving the resources rather than what would sound the best in that situation...There were points that I was playing just to kill time; it wasn't engaging all the way through. I wanted to have variety throughout the improvisation, but I was constantly afraid that I would end up playing something 'risky' that was going to destroy the pitch resource. I felt like I was playing in a very reserved and safe manner.

Particpant 1 describes a similar conflict between the pressure to manage resources and their personal musical desires:

> **P1:** You want to use up three different resources, otherwise you are wasting two others. It's better, if I can, to decrease the use of the primary resource, but it's pretty difficult here, so instead I try utilizing all the resources as much as I can. Also, pitch resources were depleted [in a way that] I didn't really expect, so I think it was kind of a failure. It cut [the sound off] in the middle of my plan, my musical structure.

In these examples the logistics of balancing and managing resources was at conflict with expressive paths. This introduced a frustrating barrier between creative expression and strategic decision-making and suggests that a musician's mental bandwidth can be overwhelmed by the demands of problem-solving. Absent a sense of creative fulfillment, the musical process becomes one of struggle rather than expression and a musician can feel trapped in an inexpressive process, potentially even resenting the inability to make decisions freely.

Because the allure of following an interesting and engaging musical path is so powerful, it has the potential to pull a musician out of the metaphor. If the value of the music is greater than its cost, the interface can be rejected:

> **P3:** Despite seeing the meter go down rapidly, I still couldn't resist playing more notes. I was consciously playing shorter notes and less notes each sections, but I started playing what felt good to my ears near the end, which drastically depleted the resources.

Participant 1 presents a similar feeling of being creatively hindered by the interface. When reflecting on one particularly frustrating improvisation they describe the system as simultaneously "natural" and prohibitive:

> **P1:** It was more stress than being inspired. It did feel natural, the usage of resources and the way I decided to play some sounds, but I think I could get more experimental without the device, that's for sure. The [resource] constraint was a lot; I couldn't try to do drastically new stuff with the device. I think that was a big negative limitation there.

The third condition was so disruptive to both P1 and P3's musical expressivity that P3 describes it as painful:

> **P3:** When the resources ran out [*null/void*] just cuts off the sound, and I think that...it *hurts*. [laughs] I want a resolution to any of the improvisations that I do. Even if it's just to phase out the sound, that would be totally fine.

These findings suggest that a strong metaphor can be a double-edged sword. A sense of limitations regarding musical resources can prompt new creative paths, but also reduce a musician's sense of freedom and flexibility. Further, it can apply pressure to make decisions that feel unnatural or against the grain of personal expressivity. The same constraints that at times give a computational instrument more depth and richness simultaneously eliminates some of the flexibility and openness of experimentation.

10.7.4 Criteria for Efficacy

10.7.4.1 Autonomy, Realness, and Scale

While the *null/void* device was capable of having a positive impact on a musical improvisation through its sheer presence, a successful material metaphor produced the most dramatic effects for musicians. From analyzing the data we can identify a set of criteria for building an effective interface for materiality in computational music. Though not exhaustive, the data suggests that an interface such as the *null/void* is most effective when:

1. It feels autonomous: The interface's behavior conveys a sense of agency and intelligence; it feels like an "other" capable of meaningful interaction
2. Its metaphor feels real: There is a sense of shared time and space between the performer and interface, and the internal and external conceptualization of computational resources is synchronous
3. There is a balance between the limitations imposed onto a musician's computational resources and their sense of personal creative freedom

We are able to additionally identify areas in which the *null/void* device was particularly ill-suited to the creative process. By examining the contexts in which participants felt the most negative about the interface, we can conclude that it may not productive in the following musical situations:

1. Prompting large-scale change: Particularly in live-coding, the interface can suggest or prompt musical changes that are not logistically possible in computer improvisation, either due to the amount of time required, or the speed at which a computer musician would need to respond

2. Engaging in long-term improvisations: the pressure to plan and structure an improvisation around the resources available is compatible with short musical improvisations, but increasingly problematic as the duration of a performance increases

3. Solo performance: The metaphor for limited material resources might feel so high-risk as to be damaging in a solo (public) improvisations

The process of planning and structuring musical material before improvisations and performance emerged several times as a challenging element of using the *null/void* system. Some musicians felt as thought the presence of depleting materials not only forced them to do additional work of pre-planning the structure of a piece, but was also frustrating to feel forced to deviate from their planned form of an improvisation:

> **P1:** When I think I have limited resource of materials, one thing I have to get my head around is even before starting playing or improvising is whether I should have some sort of mental picture of what I'm going to do and see if I can carry it out nicely or not. This isn't like a zero/one thing, like I have the complete picture of what am I going to do and execute. Sometimes I start anyway and I pretty quickly formulate a bit of a picture, the trajectory or materials I should be using, and then I start using them. On the other hand, if I don't have any plan then I don't have anything mapped before heading to the available resource, and I just start playing and start constructing or creating new materials. In that case I do feel positive about [the interface].
>
> **Interviewer:** It seems kind of like you're saying that the more you know what you want to do, the less helpful the interface is.
>
> **P1:** Yeah, you could say that.

In their notes from improvisational sessions, Participant 3 describes this struggle as well. One case in particular is criticized particularly harshly:

> **P3:** Wow, what a failure. With the limited resources (and also a noise-focused instrument), it's extremely difficult to think and plan out a structure. I have to admit that the limitation can be frustrating and almost discouraging, but it is also satisfying when I have a decent take that I was satisfied with.

Much like P1, P3 also experienced the flip side of the challenge, expressing a sense of accomplishment after a particularly engaging improvisation:

> **P3:** That almost worked! It helped to write out the sections prior to playing. I didn't have as much pitch resource as I thought by the end, so section 5 was shorter than I anticipated. But I was able to play something according to plan by diving up the pitch and amp resources. A shorter improvisation where I'm being generous with the resources and playing sporadically can be more engaging (a risky performance in this context) than trying to preserve the resources and attempting to have a structured improvisation that is over 5 minutes.

While it is clear that in private improvisations participants are able to identify and employ behavioral modifications to overcome the stress of planing and preparing their improvisations, it is also clear that in a context of a live performance this strategy would likely fall apart. Participants 1, 2 and 3 all mention the interface in a live performance context as functioning beyond the threshold of exciting, challenging risk and into a space of paralyzing fear. As P3 summarizes:

> **P3:** I was imagining [using the interface] in a live setting–it would be scary. I would be super scared to use it. In a live setting, you want to play for at least more than 10 minutes–I would be super, extra conscious about [performing] with it in a live setting. I can definitely imagine that...Yeah. It's hard to imagine, but I know that it would be super, super scary. I feel certain about that fear. And I'm not 100 percent sure if I would put myself in such a scary situation even if I did have that opportunity. [laughs]

Overall, the *null/void* study shows that having limited computational resources for musical improvisation has the potential to increase of decrease expressivity based on situational context, musical objectives, and expectations and assumptions about the behavior of an interface. A final theme that emerged from the data shows that musicians see potential future applications for a system such as *null/void*, suggesting that even if a material metaphor is not productive to improvisation, it has value to other musical activities.

10.7.5 Potential Futures

10.7.5.1 Collaboration, Composition, Teaching, and Learning

Interestingly, despite expressing fear regarding using the *null/void* in a live performance, participants imagined potential in live collaborations:

> **P1:** [It would] definitely be useful in more formal setting, like live performance or collaboration. Having shared resource–or like a chess match, you have the timer for both of the players. That setting itself is more high-risk, and that makes more sense I think. In live performance you wouldn't be practicing or experimenting with your first notes, you have to get started and get going.

> **P4:** You could do a whole study of pieces with different instruments each time, with more complicated systems and situations and stuff like that. That'd be really fascinating.
>
> **Interviewer:** I would be really interested to see what would happen if I put [an interface] between two people. Maybe there's some weird social politeness that would occur...
>
> **P4:** Yeah, totally. "I'll let the other person go. You play a billion pitches, I'll just do all the amplitude stuff." Yeah. I think that's really cool–I think using these as a performance interface or in the signal chain in a collaborative performance would be pretty tight.

These opinions indicate that a metaphor for limited computational resources may have more interesting and impactful applications in situations involving two or more performers improvising together. Managing and distributing responsibility across multiple individuals provokes consideration around the social dynamics of co-creativity, and "gamifies" the sharing of a stage space.

The previously mentioned conflict between resource management and planning the structure of an improvisation emerged again in participants' opinions regarding potential productive uses of the interface. Participant 4 re-contextualizes what was identified to be a challenging element of a performance process as productive to situation free from the pressures of time:

> **P4:** If I were using [the interface] more and more, and I was trying to perform into it as a composing tool as opposed to just a performance reaction, I think it would be really valuable. I have a goal and I want to see if I'm changing pitch or amp too much, I can look at [the interface] and it will tell me specifically. I think it would be a really cool performance practice or composition partner. Particularly if you say, "I'm going to go into a piece where it's very little pitch stretched out across a lot of time." If you're composing while performing into [the interface], you could actually quantify that. You could be like, "No, within two minutes I changed pitch too often and I've got the data to show me."

Participant 1 similarly points to the productive function that the interface can have on not only representing computational material, but prompt broader considerations of the nature of computer music practices, stating, “This digital musical instrument, I feel it’s a really nice way to quantify some things about musicality.”

Finally, participants reflected on the value that the *null/void* interface could bring to learning about computational musical performance. Participant 4 addresses one of the unique issues facing the computer music community as a whole, a sentiment that any contemporary practitioner can relate to:

> **P4:** I’m thinking about how I could teach this [*null/void* metaphor] in the future. I think it would be interesting to use with students. Like, “You’re entering into this realm of music where there’s endless possibilities...but you shouldn’t aim for that.” [laughs] “Your music is going to sound real dull and it’s going to sound real boring and–you’re going to come off real pretentious. You need to treat [computer music] as this weird bubble of infinite possibilities that you purposely put some kind of self-limitations into” I think when you’re doing something with software, you’ve got to have some kind of limitations as a way to curb your endless desire for sound-making.

Using an interface that reflects how a performer uses musical parameters over time presents an opportunity for learning, not only about how to be a considerate and conscientious computer musician, but also how to think critically about the nature of musical creativity. An interface such as *null/void* can assist in the development of musical skills, particularly in terms of understanding and appreciating the value of fundamental musical qualities. Meaningful musical expression requires an ability to recognize that just because you *can* doesn’t mean you *should*: expression is as much about what a musician chooses *not* to do as it is about what they choose *to* do. As Participant 1 explains, practicing making meaningful decisions about the music you are producing is important to becoming a better musician:

> **P1:** It’s nice that we all have performance experience, especially for live-coding. Many things like the flow of time, the timing resource itself, or aligning to the inner degrees of resources. All those things really matter in live performance, so I think that it’s a nice model, or nice tool to use for practicing that.

10.8 Conclusion

The data from the *null/void* study contributes to the research question in three key ways. First, the findings show that a physical/acoustic instrument's natural material limitations are important elements of musical expression. Second, many computer musicians feel that digital instruments could benefit from some constraints that curb some of the open-ended nature of computational musical expression. Finally, the study strongly suggests that imposing a metaphor for limited computational resources can have a positive impact on a computer musician's improvisational process, prompting novel modes of musical expression, self-reflection and critical thought regarding personal approaches to music-making, and the development of new skills and knowledge.

As a boundary object, the *null/void* system was designed to *provoke* questions as much as answer them. The objective of this research was not to suggest that computer music is inherently less expressive because it lacks physicality and materiality, but rather investigate whether introducing such risk factors could create expanded expressive opportunities for musicians. As such, the contributions of this study are neither prescriptive or empirical. They are, however, authoritative, having emerged directly from the perspectives and experiences of practicing musicians themselves.

Taken together, the findings from the *Torpere* and *null/void* studies present insight into the relationship between risk and musical expressivity and suggest that the incorporation of physical and material unpredictability and failure can have positive effects on computational musical practices. In the next chapter the significance of these findings will be discussed, both in terms of value to the community and implications for future instrument design.

CHAPTER 11

CONTRIBUTIONS OF THIS WORK

The work presented in this dissertation endeavors to answer three questions:

1. RQ1: How is risk incorporated into computational musical practices?
2. RQ2: Does a higher physical and/or material risk state lead to higher levels of expressivity perceived by a performing computer musician?
3. RQ3: What value might applying these risk qualities to new computational musical instruments have for musicians?

As stated previously, this research makes no presumption that concrete, abstractable answers to these questions can be garnered—or that such information even exists. Rather, it offers a critical examination of the nature of computational musical technology and the means by which human expression is facilitated in a digital space. When musicians are disconnected from the physicality and materiality of their instrument it creates room for questions: is there something gained or lost when an instrument becomes disembodied? Is there a quality of risk inherent to physical and material objects that could bring value to a computational practice?

The *Torpere* and *null/void* studies offer significant insights into all three research questions through the perspectives of practicing computer musicians themselves. Chapter 7 detailed the importance of research and analysis methodologies that empower practitioners to speak on their own behalves, preserving the language and perspectives of each individual both separately and together. Thematic analysis has enabled an identification of salient themes across a set of data that is both diverse and complex. The findings maintain the unique experiences of each musician *and* offers a framework of principles and priorities that will benefit the computer music community at large.

Some of the most compelling contributions of this research emerge from the nuances of explicit and latent information; we not only have data that contributes answers to our research questions on a conceptual level, but also an experiential one. The ways in which computer musicians define risk and explain their methods of incorporating it into their practices are sometimes at odds with reflections on their lived experiences. Examining this data together provides a more complete picture of how risk and expressivity are related and allows for the extrapolation of information that can be used to design better, more expressive computer instruments in the future.

11.1 RQ1: How is risk incorporated into computational musical practices?

Physical and material unpredictability and failure were examined in depth across many practices in Chapters 3 and 4. The value of these particular forms of risk were demonstrated through case studies with a focus on classical and jazz music. There is clear evidence that risk can provide opportunities for idiosyncratic problem-solving and creative decision-making that contribute to musical expression—so much so that many virtuosic musicians purposefully engage in high-risk situations in order to push their own skills and talents.

The *Torpere* and *null/void* studies presented in Chapters 9 and 10 demonstrate how risk is considered in computational musical practices. In discussions with participants, definitions of unpredictability and failure were developed that diverged from acoustic music traditions in several ways. First, it is much more *designed* and *controlled*. The incorporation of unpredictability is most often done with intention and pre-planning, coded into an environment with clear boundaries and control parameters. These implementations range from low-level randomness to highly complex system behavior; a process to apply or a responsive interaction. In most cases, computer musicians drew a line between positive and negative risk through a qualification of *predictable unpredictability*: behavior that gives a performer something to respond to while remaining within the boundaries of assumptions and expectations.

Second, computational risk is more *binary*: it is either designed (productive) or catastrophic, and there is little room between the two. Unpredictability that has *not* been designed into the behavior of an instrument is simply considered to be undesirable behavior. Because a computer musician is likely to have developed their own instrument over days, months, or most likely years, they have comprehensive knowledge of what is possible. Unpredictability as designed randomness is useful because it is expected behavior; unpredictability that was not designed is most often an indication that something has gone wrong. If a computer musician designs their instrument to generate five random notes to build a melody, and it instead plays a burst of white noise, it does so either because the musician has made an error in coding/programming, or the computer is experiencing a malfunction.

Lastly, risk in computation involves a *temporal conflict*: if something unpredictable happens–or failure is encountered–a computer musician must engage in parallel diagnostic and performative tasks. Unlike acoustic instruments, these dual processes are (in most cases) incompatible: in order to produce music a computational system must run without issue, and fixing a system that is not functioning properly involves altering the instrument itself. Where a musician using a physical instrument might be able to wrap an unpredictable behavior back into the creative process in real-time, computational instruments demand separate spaces for adaptation and use.

For these reasons computational unpredictability is more tightly associated with failure, and its *threshold for productive versus unproductive use is extremely low*. While many *Torpere* participants discussed their experiences with physical and material failure as positive prompts for creativity, not a single *null/void* participant expressed such a sentiment. Failure in computational instruments differs from physical instruments in both severity and demand–not only is a computational failure more likely to cause a full collapse of a musical experience, but it also demands a prohibitive amount of time to resolve. In most cases, diagnosing and fixing a low-level computational failure or error shifts attention away from expression and toward a search for something that needs to be fixed. If no fix can be found, the failure, again, is likely to kill a musical expression.

In the illustration below, we can visualize this forking path of risk and expression in computational music. In comparing the branches which result in failure and the ones that lead to expression we can see a strong difference in probability. Risk that is designed is very likely to be productive to musical expression–the line is direct. Risk that is not designed must be adapted to. If a musician is able to adapt, this can be considered a *positive failure* that enabled (or even enhanced) musical expressivity for the performer.

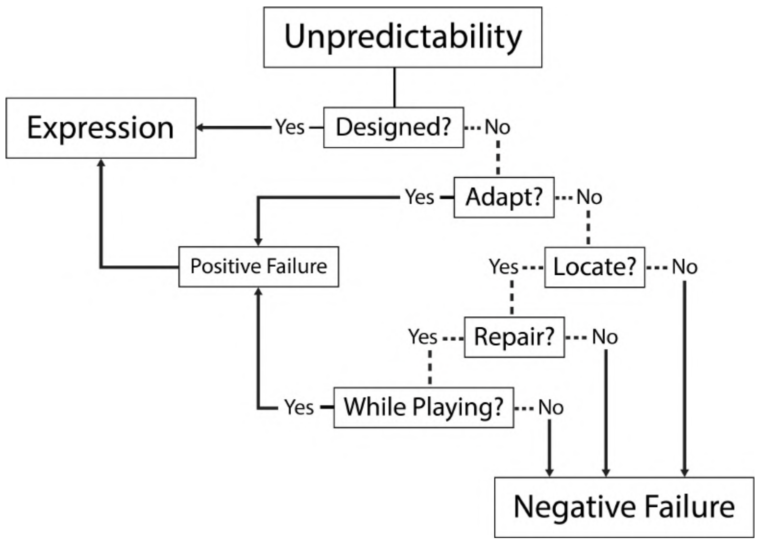


Figure 11.1: Unpredictability, Failure, and Expression in Computer Instruments

If the instrument's unpredictable behavior can *not* be adapted to, then a process begins in which a musician must identify the source of the issue, correct whatever is causing the behavior, and maintain their current mode of musical expression at the same time. If there is a breakdown at any point in that process, the path through multiple points of failure leads away from expression entirely.

There exists potential for risk to be a positive and productive element of musical expression–however, the criteria for that outcome are relatively low with physical instruments and prohibitively high with computational ones. This will have significant consequences for RQ3, which will be discussed shortly.

11.2 RQ2: Does a higher physical and/or material risk state lead to higher levels of expressivity perceived by a performing computer musician?

When presented with a high-risk physical instrument, participants in the *Torpere* study experienced both positive and negative impacts on their levels of musical expression, ranging from paralyzing disruption to engagement at a surreal level. The value of physical unpredictability was defined in large part by a musician's existing schema and paradigm—in particular, how willing they were to deviate from one or both.

The more willing a musician was to deviate from their existing mental models, the more likely they were to experience heightened levels of expression in general. Interestingly, the sheer novelty of the low-risk *Torpere* itself was sometimes "risky" enough that a musician felt compelled to explore the space beyond their comfort zone. For one participant the low-risk instrument on its own felt very high-risk, and they experienced a sense of self-expression that bordered on transcendent. However, the addition of high-risk physical behavior pushed some participants past their boundaries of musicality altogether. Participants who struggled to leave the familiarity and controllability of an existing paradigm were not only less prone to experience an increase in their levels of expressivity in general, but were actually likely to experience a *negative* impact when using the high-risk instrument.

This incompatibility between a musician's personal criteria for musical expression and the risk introduced by the *Torpere* led, in the most negative cases, to *forced paradigm looping*. In this state, musicians repeated a cycle of attempting to force paradigmatic control onto elements of physical risk, failing, and repeating the process–this almost unilaterally resulted in a complete abandonment of their expressive musical activities.

For musicians who were not tightly bound to an existing schemata, and who were willing to accept the affordances and constraints of the *Torpere* as an entirely new paradigm, the high-risk *Torpere* was extremely productive in producing higher levels of musical expression. Some participants reported having "profound" experiences through their high-risk engagements, and even conceptualized the instrument as having its own agency and sentience. This is a particularly significant finding, as it resonates with the most positive experiences reported by the *null/void* participants.

Forced paradigm looping appeared in the *null/void* study as well, though nowhere near the degree of that observed with *Torpere* participants. In most cases, a musician's inability or unwillingness to accept the *null/void* metaphor led to them experiencing little or no impact on their musical process at all. In the worst case, an incompatibility between the external behavior of computational resources and the internal experiences of the participant pushed them into a cycle of playing music, depleting their resources too quickly, getting frustrated, and repeating the process. Rather than deviate from their "default" approach to musical improvisation, these participants were inclined to arrive at judgements of the device: it was unfair or unreasonable to them, and their experience was generally dominated by frustration.

In cases that *null/void* participants either fully embraced and internalized the metaphor, or else modified their behavior to be more compatible with the interface's behavior, both low- and high-risk modes were productive to the expressive process. Though it often took more time (just hours for one, several days for another, and over a week for a third), most participants experienced positive changes to their expressive musical engagements brought on by the interface, most often through engagements with self-reflection. In addition, although each musician reported experiencing minor (or no) difference between low- and high-risk modes, half of participants reflected on experiencing notable positive differences when using the higher-risk interface either in their interviews or study journals.

Though the metaphor for material resources was not successful with every participant, when it *was* effective it was effective to a high degree. The imposition of materiality and limitation on computational resources prompted increased self-reflection, meaningful decision-making, and, at times, an exploration of entirely new modes of musical expressivity. In both studies, the presence of physical and material behavior contributed to a sense of *interaction* rather than *reaction*, a *bidirectional* relationship between two systems with agency and autonomy rather than *unidirectional* user/interface dynamic.

Some of the most exciting results from these studies emerged through the conceptual shifts participants were willing to make. It is no small feat for a musician to let go of their existing patterns of understanding and interact with risky new musical instruments. To contextualize high-risk situations through existing mental models is natural—expected, even. Beginning interactions with the unknown through the application of existing skills and knowledge is the first step to identifying the language of a new expressive instrument. When a musician hit the boundaries of those schemata and paradigms, their willingness to step into a space filled with the potential for failure and unpredictability took courage–and there was no guarantee that taking that risk would pay off. However, in choosing to embrace the uncertain, some musicians scaffolded entirely new paradigms, and their instruments gained a level of depth and richness. In some cases musicians experienced modes of expression that were novel: interactions with an "other," or reflections and reconceptualizations regarding their own musicianship.

If we are asking the question, "Does material and physical risk increase musicians' experiences of expressivity?" then the answer we are able to offer based on the findings of this work is, "Sometimes." However, if the question is, "*Can* material and physical risk increase musicians' experiences of expressivity?" we can reply with a definitive: **Absolutely.**

11.3 RQ3: What value might applying these risk qualities to new computational musical instruments have for musicians?

Developing and deploying high-risk boundary objects in order to carry out this research was valuable, and contributes to important discussions regarding musical expression in CMPs. We must ask, though, what the implications of this information are to the future of the practice. It is important to recognize that instantiating physical and material risk through electrified strings or a digital-resource interface is not realistic as a generalizable suggestion, and the findings presented in this work are distinct from the instruments themselves.

With that said, this work has identified several insights into the value that physical and material risk can bring to contemporary and future practices. Presented below are the three most significant:

11.3.1 Limit the Limitless

There are many qualities that set computational and physical instruments apart, but the most fundamental difference is likely in their inherent affordances and constraints. This is not a matter of great dispute in the community, and is in fact one of the most commonly addressed research topics in the field [46][47][146][147][116][85][148]. However, the focus of these discussions is most often on how to make computer *interactions* more tangible and physical, rather than the computational resources themselves.

All of the musicians who took part in the *Torpere* and *null/void* studies discussed the limitless and open-ended nature of computation as both valuable *and* problematic. Although the freedom and flexibility to do anything and everything through computation is one of the most powerful developments that music—and any other creative activity—has seen, there is a trade-off. For centuries, musical expression has emerged from a shared understanding of the universal affordances and constraints of a physical instrument: how does *that particular cellist* use the same lengths of string, resonating wooden body, and band of horsehair in a way that is unlike thousands of others?[1] What are they able to say at the edges of what is possible with wood, string, and hair?

It is hard to know how what musical expression looks, sounds, and feels like when materiality disappears. The use of material and physical risk can grow the computer music field by allowing musicians to demonstrate their skills through the same elements of risk that are available on acoustic instruments. How does *that particular computer musician* express

[1] There are, of course, hundreds of thousands of variables involved in the material composition of a cello, but the sounds that emerge from one will always be a bound to its material properties and understood through a lens of centuries of repertoire and pedagogy

themself in their use of limited resources? What decisions do *they* make at the boundaries of instrumental constraints that are unique to them? The implementation of constraints has been standard practice for decades, but an approach to making computational resources feel truly limited—tangible and finite, bound to a material condition—might scaffold a space in which we can consider new answers to these questions.

11.3.2 Change the Shape of Failure

If the nature of computational failure draws boundaries around expression, then creating opportunities to "safely" engage with it could open the door to a significant shift in praxis. Providing a way to experience and respond to physical and material risk has the potential to bridge the divide between what *Torpere* participants were able to do (use risk as an expressive element of an unfolding musical experience) and what *null/void* participants could not (wrap failure into the expressive process).

When P1 in the *null/void* study described the inability for failure and unpredictability to be positive elements in computer music ("I wish I could capture the screen going into blue screen, or some really obvious error [in live coding], and then use that material directly as audio") it gets to the heart of this research. One of the most exciting outcomes from these studies is evidence that a metaphor for material and physical risk could bring this exact opportunity to practitioners; as P1 goes on to say, "The *null/void* device gives a really nice performance-simulating effect. Failure really affects the [acoustic] improvisation process, and the same [could be possible] with live-coding on stage. It has a really good effect."

Redefining computational failure could result in deeper reconceptualization of its value to computational musical practices. Freeing failure from its correlation to fatal error suggests a music-making process that allows a musician to draw upon more than controlled randomness as a way to express themselves through response. In addition to expressing oneself through the intentionality of an instrument's design and reacting to the conditions of the environment, expression could emerge through highly idiosyncratic responses to the risk of an instrument itself—what its core components are, how a limited number of resources are distributed over time. Failure could reveal a mode of expression that is built upon what a musician is willing to stake in the face of fragile conditions.

If we want to embrace what makes computer music so unique, it is not enough to design boundaries around a limitless environment. It is also not enough to devise modes of human-computer interaction that leverage human behavior to constrain a disembodied system. If we want to make computer music truly, uniquely, expressive, it requires an engagement with risk at a computational level. If we can develop a way to fail *productively* rather than catastrophically, and utilize the fundamental materials of computation in a way that is organically constrained, then expression can emerge through risk in an entirely new paradigm.

11.3.3 Engagements with the Other

The *Torpere* and *null/void* studies have shown that unpredictability and failure are deeply human. Not only do we experience both through our internal and external interactions with the world around us, we also recognize the behavior in others. Our behavior as human creatures is not always (or even often) the direct result of a single event; it emerges through the filter of a lifetime of experience. To have a discussion, teach someone a skill, fall in love—all of our human interactions are a risk taken with the knowledge that we can never be truly certain of the outcome, and that one possible outcome is always failure.

Musical expression accepts these risks as well, and that risk gives value to a musician's voice. It is why we broadly agree that to cue a playlist and press "start" is not musical expression, but writing and compiling lines of code is: in one case the musician's creative decision-making is reflected in pre-planned curation, and in the other it emerges over time. A live-coder changes the music that is produced in real-time through interactions with the instrument itself, and in doing so conveys agency and intentionality [2] – the fact that we, as

[2] We will not engage with a discussion regarding whether or not the "shuffle" feature of a playback system conveys agency at this time.

an audience, can not know for certain what will come next (and whether or not it will be *failure*) contributes to expressivity.

The more agency a system (human or otherwise) has, the more human it *feels*, and this extends beyond the experiences of an audience. This work has shown that an increased sense of agency on the part of a performer is desirable, but beyond that it demonstrates that a perception of agency on the part of computational instruments can deepen a musical engagement. When a computational system exhibits *behavior that feels human*, a reciprocal relationship can emerge that transcends human-computer interaction. In their engagements with the high-risk instruments in both studies, musicians describe an "other" contributing to the expressive engagement: For *Torpere* P5, the high-risk instrument was an "added voice;" for P7 it was a force directing them try things that they "know [they] would have never thought of to do," "put [their] mind in a different place," and "changed how ideas triggered in [their] mind." *null/void* participants conveyed engagement with a similar "other:" at times "unreasonable" or unfair [P1], at times "intelligent," [P2] a "teacher," "guide," [P3] "observer," or "partner." [P4]

The contribution here is not that computer systems that feel more intelligent, responsive, and interactive contribute to more expressive musical engagements. That is something that has been known from the earliest days of computational music and been proven over many decades in musical contexts and far beyond. Today, computer instruments are capable of deep learning, reproducing human gesture, being controlled by brain waves, sensing emotion—there is no lack of work being produced in the interest of making computers more human. However, what this work contributes to this ongoing discourse is the suggestion that there is potential to evoke a sense of agency and autonomy *beyond designing computers to have human behavior*. Through the application of a high-risk relationship between a computer's behavior and the resources it represents, its *humanness* can emerge from a shared space in which we are *all confronting unpredictability and failure together*.

11.4 Implications for Design

11.4.1 Physical, Conceptual, Purposeful

The design of the *Torpere* and *null/void* artifacts were suitable for engaging with the research questions presented through this work; however, they themselves would not have much practical use in the field. While it would not be productive to outline specific techniques for design and fabrication based on this research's instruments—nor would it be possible to present prescriptive instructions for future instrument design—a framework of design considerations can be offered based on the knowledge gained through this research.

In the creation of novel DMIs that serve to engage with physical and material risk, the following practical and theoretical considerations should be made:

1. **Physical Design**

   (a) **Form Factor:** The success of an instrument or interface hinges on its design–that is as true of doors and toothbrushes as it is of computer systems. When creating an object with the intention of applying a metaphor for physical and material risk to a musical environment, thought must be given to the visual elements of the "resource" container itself. In the case of the *null/void* interface, vintage audio hardware served as inspiration; the rationale being that its analog features and solidity of the metal enclosure would reinforce the conceptualization of computational resources as tangible. However, as a direct result of this, half of the *null/void* participants made *immediate* and *persistent* assumptions regarding its function: because it looked like a piece of vintage audio gear, it should behave like one. This is particularly problematic if the equipment that is brought to mind is a synthesizer or effects unit, but your interface/instrument neither produces nor modifies incoming audio.

   In the *null/void* study the consequences of design were deep internalizations of "right" and "wrong" behavior *both on the part of the interface and the musician themselves*, and produced extended periods of struggle. Musicians were quick to believe that they were doing something wrong to prevent the interface from working properly, or that the interface itself was faulty. An association with existing equipment can be so strong that a novel instrument/interface's actual function can remain misunderstood or even unidentified entirely throughout the duration of an engagement. Several design iterations could be carried out to accommodate for this issue: perhaps a software representation would be less likely to clash with the metaphor, or the analog meters could be replaced with screens that represent material resources through pixels turning on and off.

The takeaway is: constructing an effective metaphor for invisible commodities must account for the flexibility of and variability of imagination; what computational resources "look" like has no grounding, and one must draw upon the perspectives of practicing musicians themselves in order to craft an appropriate metaphor.

2. **Conceptual Design**

   (a) **Appropriateness of Scale:** Because computer musicians are often composers, performers, coders, luthiers, and many other things all at once, designing an instrument or interface for musical activity can be challenging. While a DMI is relatively flexible in its use (most often a musician can compose for the instrument they perform with and vice versa), a high-risk instrument is less adaptable to a broad range of activities. It is important to consider depth over breadth and give critical thought to what the system is *specifically* intended for: Composition? Performance? Improvisation? Is it trying to be valuable to all three? Different modes of creativity have different criteria for engagement; what is high-risk in performance may not necessarily be high-risk in composition. One must consider who, *specifically*, the system should be most accessible to, and scaffold support for compatibility in those particular contexts.

   (b) **Consideration of Schema and Paradigm:** As evidenced by the *Torpere* study, the schemata and paradigms carried by every musician inform the use of novel instruments and interfaces from start to finish. Depending on the musician's willingness to deviate from one or both of these elements, their starting and ending points may be rigid or flexible, but that, too, is defined in many ways by the schema itself. Coupled with the associations a musician will draw between novel and existing systems, and the context within which the system is deployed, even a low-risk instrument or interface has the potential to fail if perceived as incompatible with a musician's personal values and priorities. In the case of a high-risk instrument/interface, schemata and paradigms are *absolutely crucial* to consider. If the design process has considered the scale and form factor guidelines as outlined above, the system will be better equipped to contend with this challenge–however, one must still be cognizant of different musicians' thresholds for minimum levels of control, the ability to succeed in musical objectives, and conflict between expectations and reality.

   (c) **Desired Outcomes:** The studies presented in this work show that high-risk instruments have the potential to be extremely productive to musical expression, but can also benefit musicians in a multitude of other ways. Many participants from the *Torpere* and *null/void* studies reflected on engagements that resulted in discovery, self-reflection, critical listening, learning, play, and many other positive experiences. Further, musicians shared clear opinions about potential future applications for the boundary objects, including use in educational settings, collaborations, and compositional activities. The suggestion given here, then, is to consider as many variations on the following questions as possible: What is the desired outcome of engagements with a novel interface/instrument?

Is the best case scenario that someone learns something about themself? About music? Should they feel challenged? As if they are playing a game? Should they feel as though the system is judging them? Supporting them? Revealing/obscuring/changing something? Is it intended to change a social dynamic? Between audience and performer? Performer and Collaborator? Performer and computer?

This is merely a starting point, and these questions are provided simply to assist a designer in the development of a high-risk instrument that will be successful in prompting positive expressive outcomes. Creating a high-risk interface/instrument with a meaningful purpose requires the inclusion of productive constraints. That is what will allow rich affordances to emerge.

3. **Purposeful Design**

   (a) **Metaphorical Clarity:** The final guidelines presented in this work concern the high-risk metaphor itself. Assuming there is a platform to deploy it on and a context in which it will be meaningfully used, the metaphor itself must be both *relevant* and *relatable*. It must speak to an issue that the community cares about–that they themselves have invested in–and say something new. In order to accomplish those things a balance must be struck between complexity and approachability: a metaphor must be attached to something of value, and it must be understandable to those it is put in front of. It is easier to build something complex around an idea than it is to represent it through profound simplicity, but in order to make an abstract concept seem embodied it must feel unified and singular. A metaphor should gain meaning from what runs through it, not endeavor to demonstrate its own value. There was nothing within the *null/void*'s resource banks–not pitch, amplitude, or time. What *was* inside were computers, microcontrollers, and digital audio interfaces. A slew of digital technology to make a computer feel more material. Not one participant asked about the contents of the interfaces–perhaps they simply had no interest, perhaps they unscrewed the chassis and peeked inside as soon as the box arrived. More likely, though, musicians found it more interesting to play their own music through the *metaphor* than the *equipment*. The simplicity of three voltmeters, not the computation driving them, is what makes the metaphor for risk, computation, and expression feel real.

   (b) **Authentic Behavior:** In addition to clarity, a metaphor must be conveyed through behavior that feels "right" and "natural." High-risk instruments must react in ways that feel synchronous to a musician's internal and external perceptions. It should be clear that this is not related to the physics of electricity flowing through circuit boards or neurons, but rather the compatibility between how a musician conceptualizes a pitch and how the system reflects that concept back. To design a high-risk metaphor one must ask questions that go beyond *What are a musician's computational resources?* to *What do computer musicians feel that their resources are?* How would they draw a pile of them?

How do they feel time passing, and does it feel different based on other factors? How are musicians' musical resources *used*? Is pitch used differently than amplitude? Do changes feel bigger, or more meaningful in one than the other?

Asking these questions is the only way to build something that will truly feel high-risk. If the behavior of the interface does not resonate with the musician's lived experiences, the metaphor falls apart.

(c) **Productive Goals:** Lastly, in designing a high-risk instruments, we should endeavor to create something that does *good*. If asking a musician to confront high-risk failure, it should be in the spirit of redefining failure to be something new–not catastrophic, but useful. Not fatal to a performance, but recoverable and productive. If asking them to relinquish control and familiarity in the face of unpredictability, it should be to endorse self-reflection, creative decision-making, and expressive agency. The design objective should always ultimately serve to positively contribute to the community.

One final note: The name of an interface/instrument matters. Choose it with care.

It should be clear at this point that the actual *metaphor* of a high-risk system is, in many ways, less important than its method of implementation. Without an appropriate system of deployment and rigorous conceptual consideration, a metaphor of any kind will struggle to be realized: the wheels of concept, design, and context must turn together. Beyond that, the metaphor must stand on its own legs, and its success or failure will depend on the cares of the community.

In doing this work, I hope to contribute to an understanding of expression in CMPs outside of the boundaries of usability and task replication, where the experiences of practitioners are valued and validated. Regardless of schema, paradigm, instrument, or skill level, every musician can benefit from an expressive space where failure and unpredictability are positive rather than catastrophic, and considering material and physical risk is one way to do that.

11.5 Final Remarks

This research is, itself, high-risk. Asking a musician to perform in front of a stranger with a video camera is one thing—asking them to do it with an instrument that has electricity running through it is another. Setting out to research how risk and expression are related is, in some ways, destined for failure from the start. Expression is no *one thing*, it arises from a multitude of invisible points strewn across fleeting moments in time and space. Risk is not unpredictability and failure, those are simply two words to describe its possible outcome.

What I have come to understand through this research is that engaging with risk is an important part of human expression—musical and otherwise—but *expression* is risky as well. The musicians who agreed to participate in the *Torpere* and *null/void* studies took a risk before even sitting down, and they chose to do so because acting in the face of unpredictability and the potential for failure would contribute something to the community.

While I believe that this research provides compelling evidence for the proposition that computational musical expression can be made richer and deeper through physical and material risk states, the real contributions lie in its representation of the community itself. For all of the diversity of perspective, experience, background, and aesthetics, one thing is certain: computer musicians are willing to engage with material and physical risk to explore the potential for higher levels of expression—but they are also willing to do it simply because you asked, and they want to support you.

Appendices

APPENDIX A

TORPERE FULL CODEBOOK

Topic	Theme	Subtheme	Codes
1. Risk: Unpredictability	1.1.3 Unpredictability is Valuable	1.1.1 Unpredictability Pushes Beyond the Known/Familiar	Unpredictability is a positive and productive element for exploratory processes: it can prompt shifts, reconsiderations, and new directions
			Unpredictability can present creative challenges and push you past the boundaries of convention and comfort, which can be constraining
			Stability, familiarity, control, and comfort can be boring and reduce/limit exploration and creativity
			Unpredictability can be a prompt for novel physical interactions
		1.1.2 Unpredictability is New/Revealing	Unpredictability can reveal emergent control/interactions of an instrument
			Unfamiliar and uncontrollable elements of an instrument can become new dimensions of a musical experience
			Unpredictability can reveal emergent affordances of an instrument
			Unpredictability can prompt a search for the extremes of an instrument, promotes an exploration of the range and depth of an instrument's affordances
		1.1.3 Unpredictability is Human	Unpredictability is an organic, human element
			Unpredictability can offer a sense of otherness, autonomy, interactivity, and create a force to respond to: creates a reciprocal relationship
			Humanness involves error and unpredictability
	1.2 Unpredictability is Negative	1.2.1 Unpredictability Kills Creativity	Unpredictability is inherently negative: causes anxiety, fear, pressure, discomfort, stress
			Unpredictability is overwhelming, disruptive, and causes creative disconnection
			Overload of unfamiliarity and unpredictability prevents ability to shift between creative modes (composing, improvising)
			Inability to identify repeatable or reproducible elements leads to a hard boundary on creativity and exploration
			Familiarity is a prerequisite for exploration, composition, and creativity
			Dealing with unpredictability is a skill and can be foreign and uncomfortable
		1.2.2 Unpredictability Kills Performance	Performance inherently requires familiarity, control, and stability
			Predictability and familiarity are necessary to make skill and mastery visible to audience
			Unpredictability prioritizes process over product: "Learning to express something" versus "expressing something", "Trying to make sound" versus "using sound for something"
		1.2.3 Unpredictability is Uncontrollable	Unpredictability becomes something to attempt to control, and that process is frustrating (and often impossible)
			Physical risk and unpredictability imposes hard limits on possible objectives, which is the crux of musical engagements
			Unpredictability leads to lack of control, which prevents intentionality, and unintentionally can not be meaningful
			The emergent affordances facilitated by unpredictability lack meaning and value without control
2. Constraints and Affordances	2.1 Constraints and Affordances are Productive	2.1.1 C&A Drive Exploration	Constraints and affordances can prompt an exploration of the depth, range, and extremes of a physical instrument
			Exploration inherently focused on exploring and discovering physical affordances and constraints
			Instrument affordances drive and define aesthetics
			The nature of the tools/instruments used inherently impact creative experiences
		2.1.2 C&A Are Uniquely Interesting	The appeal of a new instrument lies in its unique affordances and constraints: Positive engagements involve a desire to understand and use an instrument on its own terms
			An instrument can be considered as an autonomous agent that can bring value to an experience via its unique characteristics
			Accepting native affordances allows you to explore the instrument's depth and complexity
			All instruments exist on a spectrum of "self" to "other," and can be integrated, extensions, or autonomous
		2.1.3 Emergent C&A	Emergent affordances of a new instrument can direct and shift creative engagements
			Reaching the boarders of skill and ability through constraints and affordances result in emergent prompts for novel creativity
	2.2 Constraints and Affordances are Barriers	2.2.1 C&A are Impositions	Conflict between C&A and goals/objectives can dominate an experience (trying to brute-force control)
			Unfamiliar C&A can lead to an obsession regarding the how and why
		2.2.2 C&A Lead to Abandonment	Affordances and constraints of a new instrument can be an undesirable imposition/limitation on objectives/goals and lead to frustration and abandonment
			Attempting to ignore native affordances leads to frustration and annoyance
		2.2.3 C&A Conflict with Skill	Existing skills define how useful affordances can be
			Reaching the boarders of skill and ability through constraints and affordances result in negative return to familiar, abandonment of engagements
3. Risk: Error, Failure, Wrong	3.1 FEW are Negative	3.1.1 FEW are Objectives	"Error/wrong" is objectively discernable
			"Wrong" is defined by assumptions and expectations of existing framework among performers and audience, can be objectively identified and evaluated by those metrics
			In collaborations "right" and "wrong" can be defined by others' responses and reactions
			Not knowing "right" and "wrong" led to confusion and disconnection
			Personal objective are inherently "right" and/or "correct"
			Error can not be intentional, and intentionality is required for "good" musical creativity
		3.1.2 FEW is Incompatibility/Conflict	"Bad" is an incompatibility between expectation and reality, objective and result
			"Failure" is an unobtained objective/goal
			"Failure" is the inability to develop control
			Error/wrong and sounding "bad" are inseparable
		3.1.3 FEW Ruin Everything	Mistake/Error results in inability to continue performing
			Exploration is incompatible with error/wrong
			FEW is something that must be fixed
			Performative "mistakes" "ruin" things
			The fear of FEW limits the range and pacing of musical creativity
	3.2 FEW Are Valuable	3.2.1 FEW Prompts Creativity	Low-level error/mistake can be prompt for new exploration and motivator
			Intentionality can make mistakes/error positive creative elements
			Skill and mastery of a framework/rules/practice allows for mistake/wrong to be creatively valid and "wrong" in a good way
			Error and wrong can be productive to the creative process and creatively valid
			Mistakes are an opportunity to "find something else"
			Mistakes can reveal something interesting
			Low-level error/wrong can be incorporated into the process
		3.2.2 FEW are Human	There are no "mistakes" that you can "fix" in improvisation, because it's a real-time human activity
			Physical FEW is social (incompatibility between skill/experience levels among performers), aural, more internal
			"Mistake" in improvisation is more a subjective feeling (not "feeling" good) than it is an objective element
			FEW is inherently human: humanness is a "deviation from perfect"
		3.1.3 Failing at Failing	Something interesting is inherently not a failure
			Musical expression outside of a rigid framework allows for a wider definition of "wrong"
			Improvisation allows for error and wrong
			Low-level error/wrong can be reconsidered as not-error/wrong
			FEW is fluid, a spectrum, and based on context
			Self-confidence determines how wrong is defined and understood
			Mistakes can be intentional, and intentional is good
4. Creativity	4.1 Creativity and Cognition	4.1.1 Plans and Methods	All musical activities are a process of making an idea a reality
			Creativity inherently begins with remembering and relating
			A positive creative experience requires knowledge and understanding of the how/why
			Personal musical creativity is always toward an end product, never for "improvement or exploration"
			All activities are inherently a form of thinking
			Emotional investment and plans/objectives can conflict
		4.1.2 Setting Creativity Free	Suspending thought can promote creativity and exploration
			Creativity happens without planning
			Creativity comes from an unconscious/subconscious place and is not directed or controlled
			Thinking can limit and constrain creativity and exploration
			Engagement and exploration lowers level of active thinking
			Flow conditions emerge from a suspension of active thought
			Deep creative engagements can lead to a warped sense of time (lengthened or suspended altogether)
	4.2 Creativity is Physical		Physicality and materiality are natural vehicles for musical exploration and creativity
			Physical unpredictability and discomfort change creative directions and interaction modes, sometimes positively and sometimes negatively
			Physical instruments/engagements are top-down: This is more comfortable, but less interesting than "bottom-up." Limited in terms of creativity and expression due to existing conventions
			Physicality and materiality are tactile and inherently more creative than computation
			Subconscious and conscious awareness of physicality are fluid, allowing for creativity on multiple registers
			Physical, material objects are "authentic," "real," and have "proper" uses and functions, which are productive constraints
			Physical interactions allow for natural emergent properties to be discovered and developed creatively
			Physicality is inherently more unpredictable, and is therefore a more risky and creative process than computation
	4.3 Computational Creativity		Computation is more stable and predictable than physical/material musical systems; Computation is not inherently unpredictable.
			Computation requires more thinking and cognition than tactile creativity
			Computation lacks the natural expressivity of the body; is rule-based and "human" elements of gesture, unpredictability, and expression must be designed in in order to improvise/create musically
			Computational instruments/engagements are bottom-up: This is less comfortable, but more interesting. Bottom-up processes are less constrained by existing conventions
			Computation is not inherently musical
			Computation is a top-down creative system: it imposes structure onto a musical experience, forces a certain kind of engagement, and is not "real" or "authentic"
			The safety of digital systems (save/recall) reduces creativity
	4.4 Creative Tools		Physical and computational systems inherently involve different iteration/ideation processes
			Working with digital and physical systems together requires both physical and cognitive bandwidth

Topic	Theme	Subtheme	Codes
5. Schema and Paradigm	5.1 S&P are Required		Performance and exploration requires an existing foundation of skill and knowledge, which is defined by schema/paradigms
			The safety and stability of paradigms/schema are necessary for creativity and exploration
			The safety and stability of paradigms/schema are necessary for positive engagements with unknown systems
			Interactions with the unknown inherently begin with relating to a known paradigm/schema: The unknown/unpredictable must inherently be understood through a known paradigm
			Schema/Paradigms define what positive and negative interactions/music are
			Schema/Paradigms shape and direct musical engagements
	5.2 S&P Scaffold Creativity		Previous experiences with an instrument provide materials for expansion and development
			Known schema can provide a space to begin exploring new techniques
			Schema/Paradigms provide transferrable elements of control across multiple systems
			Unfamiliarity and unpredictability are only positive when they are contained within a known schema/paradigm
			Relating novel experiences to existing schema results in positive new experiences
			Previous experience reduces hesitation when confronting the unknown and unpredictable
	5.3 S&P are Limitations		Paradigms/Schema limit exploration
			Paradigms/Schema pull a performer back to familiarity
			Paradigm and objectives can be rigid and restrictive, limiting creativity and exploration
			Attempting to force paradigms/schema can be an obsession that constrains and limits the entire creative experience
			Inability to successfully apply/force a paradigm can lead to novel engagements/objectives
			Failure to impose existing schema/paradigms on the unknown results in frustration, brute-force, discomfort, and abandonment
			Existing schema/paradigms are inherently uninteresting
			Pushing past the limitations of an existing paradigm prompts physical and conceptual adaptation
			Suspension of objective and forcing paradigm can open up space for creativity
			Rigid frameworks do not allow for "good" mistakes, they demand perfection
6. Goals and Objectives	6.1 Goals and Objectives are Inherent	6.1.1 G&O Define Creative Processes	All musical engagements and interactions are inherently defined and directed by an objective/goal
			Compositional objectives/goals are rigid and precise, and impose definitions of value onto musical elements
			Objectives and goals define the entirety of an engagement
			Exploration is guided by goals/objectives, and is only valuable if it helps to accomplish them
			Exploration has inherent goals: familiarization, control, and stability
			Exploration has inherent goals: Searching for the interesting and novel
			A positive musical experience is qualified by successfully achieving objectives and goals
		6.1.2 G&O are Judgeable	The expectations of an audience or ensemble matter, and they define objectives and goals
			It's impossible to apply objective metrics of "good/bad" and "right/wrong" onto the unpredictable, and those metrics are required for performance
		6.1.3 G&O are Fluid	The affordances of an instrument can enable, conflict with, redefine, or enhance objectives/goals
			Creative processes are inherently a balance between achieving a known objective and engaging with the unknown
	6.2 Creativity is Free from Goals and Objectives	6.2.1 Lack of G&O is Good	Deep exploration can cause one to forget goals/objectives
			An inability to obtain goals/objectives can lead to a space of pure exploration with no objective at all
			Preexisting plans and objectives can be forgotten in the course of deep engagement
			Failing in a creative objective leads to positive shift in creativity
			Musical elements that can not be judged by objective metrics allow for authority and self-determination
		6.2.2 O&G Cause Problems	When objective/goal is rigid and narrow, navigating through the unknown to reach that goal is unpleasant
			Inability to obtain goals/objectives results in a return to the familiar
			Schema/paradigm and objectives can hinder and limit exploration
			Rigid focus on goals and objectives can prevent creativity
			In order to realize personal objectives, engagements happen at a "safe" level
7. Creative Modes	7.1 Exploration	7.1.1 Bounded Exploration	Exploration is focused on and driven by what is personally interesting/compelling
			Exploration requires safety, comfort, and familiarity
			Exploration is less valuable than composition
			Exploration and composition are incompatible
			Exploration is driven by objectives, exists to serve those needs
			Exploration within performance is only positive if it doesn't compromise the end goal
			Exploration prevents performance
			Low familiarity with an instrument allows for exploration, but not performance or composition
		7.1.2 Exploration as a Process	Exploration is a continual process of searching, finding, developing, repeat
			Exploration is a learning process: making the unknown known, curating content, following curiosity
			Exploration develops into composition, or is a process of curating compositional elements
			Improvisation and exploration are inherently linked
			Exploration can produce control states
			Exploration is a familiarization process
			Exploratory improvisations with new people is positive because others bring in new and unexpected ideas
			Exploration is a process of continually searching for new interesting spaces
		7.1.3 Exploration Unbound	Exploration driven by desire to know the range and depth of instrument's affordances
			Exploration accepts the affordances and constraints of the unknown
			Exploration is an open space with which to safely engage with unpredictability
			Exploration reveals emergent points of interest, both in terms of music, instrument, and interaction
			Exploration happens outside of metrics/frameworks for "good/bad," "right/wrong"
			Exploration happens at the edge of discomfort, boundary of the known and unknown
			Deep exploration can cause a loss of sense of objective, time
	7.2 Performance	7.2.1 Bounded Performance	Performance requires more thought and planning than exploration
			Performance requires visible skill and mastery
			Visible technique and form are criteria for "good" performance
			Performance inherently requires control, comfort, familiarization and composition
		7.2.2 Performance Objectives	Performance has an end goal of meeting expectations of audience, which raises pressure and cognition
			Ideal performances involve organic development of material, creating and sitting in interesting "spaces" before moving on to new material
			Performance process shaped by exploring "just enough" to move on
			Improvisation in performance involves not only exploring, but also an awareness/consideration of the audience
			Objectives are based on social context
	7.3 Composition	7.3.1 Composition, Bound	Low familiarity with an instrument allows for exploration, but not performance or composition
			Exploration and composition are inherently incompatible
			Composition is highly temporal and actively constrained/defined by time
			Compositional mindset can define entirety of an engagement (in a negative way)
			Improvisation is more compatible with exploration than composition
			Composition involves utilizing the unique characteristics of an instrument's materiality
			Compositional structure can be developed through creating different musical spaces
		7.3.2 The Composition of Composition	Composition requires the identification and control of repeatable musical elements
			Composition as highly structural requirements (layers, repeating, contrast, etc.) and organized
			Composition inherently requires full control, exactness, precision
			Compositions are formal and require cohesion, logic, and objective metrics/frameworks, and are judged by others as "good/bad"
			Composition requires plans and objectives, a lot of thinking
8. Control	8.1 Control is a Requirement	8.1.1 Control is Skill and Knowledge Made Visible	Positive creative engagements require skill and knowledge to be actuated through control
			Virtuosity, skill, and mastery are impossible without control
			Control is an observable, judgable element of performance
		8.1.2 Control is Required for Creative Expression	Control is required for comfort, and comfort is required for creativity and expression
			Control is required for stability, and stability is required for creativity and expression
			Control is a prerequisite for creativity
			Control is required for an objective, and an objective is what creativity serves
			Lack of control results in return to familiar
			Control is required for the unknown and unpredictable to be positive
		8.1.3 Control or Bust	Imposing control drives the entire process
			Control is more important than aesthetics
			Inability to obtain control leads to random interactions, Random interactions as lacking value/meaning
			Lack of control results in chaos, and chaos is an undesirable element of musical creativity
			Lack of control leads to frustration and abandonment
			A lack of control and precision is inherently negative
			Control that lacks nuance is uninteresting
	8.2 Control is a Constraint	8.2.1 Control Hinders Creativity	Searching for control can limit exploration and creativity
			Searching for control can place the performer in conflict with the natural affordances of a novel instrument
			Ease and controllability trump innovation and interest
			Desire for control outweighs creative exploration
			Control imposes objectives onto musical explorations

APPENDIX B

NULL/VOID FULL CODEBOOK

Topic	Theme	Subtheme	Codes
1. Creative Modes	1.1 Exploration		Exploration is a learning process
			Exploration is required to develop knowledge of the unknown
			Exploration is killed by stress and pressure
			Exploration involves a sense of openness and lack of limitations
			Exploration is not "safe"
			Familiarity enables "play" in exploration
	1.2 Performance	1.2.1 Bounded Performance	Performances require limitations and constraints
			Performance isn't compatible with exploring and "wasting" musical material
			Performance is management of resources over time
			Performers are beholden to an audience
			Performance is high-pressure
			Performance happens in and is bound to time
		1.2.2 Performative Functions	Performance is communication/storytelling
			Performance is scaffolded on expressive arcs
			Performance conveys intentionality
			Performance connects internal and external states
	1.3 Improvisation	1.3.1 Improvisation Bounded	Improvisation requires an understanding of musical systems
			Improvisation is inherently new/unfamiliar
			Improvisation requires constraints and limitations
			Improvisation inherently requires freedom to "waste" resources
		1.3.2 Improvisation in Performance	Improvisation in live coding requires "preparing the environment"
			Improvisation requires planning and structure for musical content
			Improvisation involves "arrival" at a natural ending
			Improvisational performance process has a natural arc
			Improvisation requires "warm up" and practice
		1.3.3 Improvisation as Exploration	Improvisational exploration is an iterative process of playing, evaluating, acting
			Improvisation inherently begins in a process of wasting resources
			Improvisation can be mindless/meaningless
			Improvisation involves an identification and curation of possibilities
2. The Effects of Unpredictability	1.1.3 Unpredictability is Valuable	2.1.1 Expression as Response to Unpredictability	Expression is a response to the unknown
			Expression is the response of one agent to another
			Expression is adaptation
			Expression is a response to behavior
			Part of being a performer is engaging with unpredictable behavior
			Unpredictability is valuable because it gives them "something to respond to"
		2.1.2 Unpredictability is a Prompt	Unpredictability prompts expressive changes, prevents repetition
			High risk states are "on the edge" of creative boundaries, prompt engagements with unknown
			Unpredictability has value in both aesthetic and behavioral capacities
			Expression in high risk states is more compelling
			High familiarity of a musical system results in a move away from exploration and critical listening
	2.2 Unpredictability is Negative		In order to concentrate on human expressivity, a certain level of stability and dependability is required
			Too much unpredictability can monopolize expressive bandwidth
			There are hard boundaries on unpredictability: a little bit can be good, but a lot is certainly bad
			Unpredictability is scary
			Unpredictable unpredictability is not positive
			Unpredictability can kill performance
3. Paradigm and Schema	3.1 Expectations and Assumptions		Existing schema and paradigms define expectations and assumptions
			Existing schema and paradigms define goals and objectives
			Design and form factor define assumptions and expectations of behavior
			Design and form factor define immediate positive/negative impressions and interactions
			Name of device can influence assumptions and understandings of behavior
			The visual form of a system and the paradigm it is assumed into are closely linked
	3.2. Successful Schema and Paradigm		Schema and paradigms feel "synchronized"
			Internal schema and external paradigm align in a way that feels "natural"
			Schema and paradigm allows you to gauge behavior of the unknown
			The behavior of an unknown/novel paradigm "makes sense"
	3.3 Unsuccessful Schema and Paradigm		Disconnect between conceptual and practical senses of time is a conflict
			Disconnection between internal experience and external representation
			Disconnection between conceptual and practical concepts prevents immersion
			Disconnection between conceptual and practical concepts prevents creativity/expression
			Schema and paradigm can produce a placebo effect
			Existing s&p can be very incorrect
			Schema and paradigm can be a limitation to engagement and exploration
			Conclict cause engagements to be negative: uncomfortable, disconnected, unnatural

Topic	Theme	Subtheme	Codes
4. Defining Risk: Computational Failure	4.1 Computational Failure is Different	4.1.1 Failure in Time	Acoustic failure can be dealt with in real-time
			Failure can be wrapped back into the process acoustic process
			Fixing a computational failure halts the musical process
			Acoustic failure has a “chance” for recovery in performance
			Computational failure inherently requires a lot of time to “fix”
		4.1.2 Failure of the Self	Incompatibility between assumptions/expectations and reality can lead to feelings of personal failure
			A fear of having done something “wrong” can persist after an experience
			Failure can be assumed to be the result of self, or others
			Failure can “hurt"
			Intelligence/Agency can be assumed of an external system
		4.1.3 Bounded Failure	Computational failure “disrupts the flow"
			Failure in composition are “interconnected” elements (data transmission, power sources, sensor control, etc)
			Failure feels more “natural” in acoustic process
			Computation has more layers and elements of failure than acoustic instruments
			Computational failure is silence
	4.2 Failure is Negative	4.2.1 There is No Time	Time spent being expressive and time spent de-bugging can not overlap
			The time it takes to “fix” an error is unacceptable to an audience
			Diagnosis is iterative, can take a prohibitive amount of time and effort
		4.2.2 There is no Recovering	When a computer fails, the performance fails
			Computational failure is fatal to the musical process
			Failure kills computational performance
5. Defining Risk: Computational Unpredictability	5.1 The Nature of the Machine	5.1.1 Computation is What you Make it	In acoustic, future is created; in computation, future is certain
			Computation inherently lack a natural structure with which to start musical activity
			Computation requires more preparation of an environment than acoustic
			You can not do something "truly unexpected" in coding
			Computation is inherently predictable/logical
			Computer systems are inherently open-ended
			In computation, the system defines the note. In acoustic, the note builds the system.
			Computation involves more thinking and planning than acoustic
			Live coding “can’t” involve taking very big musical “risks”
		5.1.2 Computer Beings	Agency is intelligence
			Agency is autonomy
			Agency feels meaningful
			Behavior of a musical system can seem like a “response” to actions
			Otherness can involve senses of time, intentionality, and intelligence
			A musical system can feel like an “other”
			The presence of an “other” has a huge impact on musical expression
			Computers are in a gray area between extension and autonomy
	5.2 Unpredictability is not Randomness	5.2.1 Design and Control	Randomness is unpredictability that is designed
			Unexpected randomness and unpredictability are inherently negative
			Unpredictability is something that has an inherent lack of control
			Randomness without control is disruptive
			Predictable unpredictability can be positive
		5.2.2 Internal/External	Randomness is a decision made internally
			Unpredictability is an outer state
			Unpredictability requires mental bandwidth
			Randomness and Unpredictability cause fear and anxiety
		5.2.3 Creative Randomness	Randomness can be overused and/or over-relied upon
			Randomness is doing things “without thinking”
			Randomness can be a creative choice
			Randomness frees you from thinking
			Randomness can introduce interesting results
6. Making a Metaphor Real	6.1 Metaphorical Success	6.1.1 Internal and External Harmony	Sense of synchronized behavior between musician and interface
			Behavior of an external metaphorical representation feels internally “real” or “natural”
			Resource compatibility determines how much the device will impact creativity
		6.1.2 Feels Really Real	An instrument’s behavior must “feel” connected to the resources in order to be productive
			Resources feel more “real” with computational instruments
			When resources feel “real” there is a deep level of acceptance
	6.2 Metaphorical Failure	6.2.1 Form and Function	The physicality of the interface can kill the metaphor
			Physical and digital spaces can not be imposed on one another
			If a metaphor fails, the device takes on the function of an informational system: information versus representation
		6.2.2 Internal and External Conflict	It can be a struggle to accept a metaphor at all
			If a metaphor is not accepted, there is no movement from conceptual to embodied
			If a metaphor is not accepted, there is no movement from theoretical to practical
			Time must align with internal and external experiences

Topic	Theme	Subtheme	Codes
7. Effects of Metaphorical Risk	7.1 Positive Musical Impact	7.1.1 The Benefit of Limitations	Building limitations into computational systems produces expressive behavior
			Unlimited nature of computation can lead to self-indulgence
			Limitations contribute to the development of a deep understanding of the depth and range of a process/instrument
			A lack of limitations can be overwhelming
			All instruments need limitations and constraints in order to be expressive
			Music without limitations/constraints is boring, pretentious
			Incorporating and/or designing limitations into software systems is valuable
		7.1.2 Creativity and Expression	Pushed improvisation in new directions, produced creative opportunities
			Realizations from use of device can produce methods for self-imposed creative shifts
			Device can prompt both conceptual and structural changes to interface/instrument
			Device as a way to gain a sense of objectivity about expressive process
			Device added productive constraints to DMI
			Prompts considerations about musical materials and musicality in general
			Prompts positive small-scale change (live coding)
		7.1.3 Realizations and Reflections	Enables unexpected elements/qualities to emerge
			Prompts realizations about reliance, overuse, safety/comfort
			Reveals the edges of creative musical spaces
			Prompt s realizations about the self, self-reflection
			Device prompts self-observation
			Prompts deep listening, critical thought
			Positively “quantifies” musicality in computer music
			Positive: interface as guide (“it was a good guidance for me to really reflect on how I improvise”)
		7.1.4 Engaging with the Other	Having “somebody who’s watching you” leads to being more cognizant actions
			An other has the ability to impact how you feel about yourself and the things around you
			Metaphor as other can be a teacher, guide
			Agency of the other prompts creative change
			Unpredictability of resources being under an “other’s” control alleviates some of the pressure of being “judged”
	7.2 Negative Musical Impact	7.2.1 Disruption	Creates higher need for structure and planning.
			Engagements can become intensely focused on understanding/figuring out metaphor behavior
			Removes sense of control and autonomy, limits freedom and experimentation
			The need to understand/figure out behavior can disrupt musical expression
			Resources can conflict with personal musical goal/objectives
			Resources prompt a desire to preserve and conserve at all costs
			Can cause a weighing of cost-value of musical elements
			High-cost resources can be a disruption to creative flow
			Limited resources are especially challenging to deal with in the long-term
		7.2.2 Metaphorical Uselessness	More useful for formal performance situations
			Limited and unpredictable resources are less useful the more you feel you “know” what you want to do
			More useful for social contexts
			Not necessarily useful in computational setting
			Can be incompatible based on natural playing style
			Does not necessarily feel any different
			Does not necessarily cause creative changes
			Resources can be “forgotten” or ignored
	7.3 Potential Futures		Device would be valuable as a “composition partner”
			Device would be valuable as a “performance practice partner”
			Device can “gamify” resources
			Device could be particularly useful in social/collaborative settings
			Device as useful as a tool to create a model for developing and practicing musical skills
			Interface provides a way to teach and learn about musical improvisation

APPENDIX C

TORPERE PRE-TESTING QUESTIONNAIRE

Name: **Date:**

Torpere Pilot Study: Pre-Testing Questionnaire

1. **How do you approach a new musical improvisation?**

    1. “Big picture” planning about a piece’s form, or smaller musical elements?
    2. Concrete “direction” in mind, or let the piece unfold by itself?

2. **How you feel when improvising with an instrument you are unfamiliar with?**

    1. Challenges cause frustration and stress, or excitement and creative opportunities?
    2. Does familiarity ever impose limits on what you feel you can do?

3. **When improvising, are there certain events or outcomes which result in feelings of satisfaction, expressivity, or creative fulfillment?**
    1. If so, can you describe what causes these feelings?

4. **When improvising, are there certain events or outcomes which result in feelings of dissatisfaction, frustration, or creative failures?**
    1. If so, can you describe what causes these feelings?

5. **When improvising, how much control do you desire over the behavior of your instrument/system?**

    1. Do you enjoy the challenges of unpredictable behaviors, or is this something you safeguard against?
    2. Do you ever purposefully build elements of randomness, chance, or unpredictability into your performance systems/instruments?

6. **If you experience something going “wrong” in a performance (an error occurs, the result of your action is not what you expected, etc.), how does this make you feel?**

7. **What are some key terms you would use to describe an expressive improvisatory performance?**

8. **What are some key terms you would use to describe an inexpressive improvisatory performance?**

Transition into practice session
- Explain the tools available (including the amp), and the difference between bows
- Encourage participant to do whatever they like with the instrument and tools.

APPENDIX D

NULL/VOID PRE-TESTING QUESTIONNAIRE

Null/Void Study: Pre-Testing Questionnaire

1. **Can you tell me a little bit about your background as a musician?**
   1. How long? What kind of instruments?
   2. When did you start using computers musically?
   3. Why did you start using computational technology in your practice?

2. **How do you approach using computational technology musically?**
   1. Do you consider your computer a musical instrument? Creative tool? Another voice? Framework? Etc.

3. **How do you think about the musical capabilities of computational technology?**
   1. Do you use constraints or limitations for pieces or performances?
   2. What does computational technology offer that traditional/analog instruments don't?

4. **How do you approach a new musical improvisation?**
   1. "Big picture" planning about a piece's form, or smaller musical elements?
   2. Concrete "direction" in mind, or let the piece unfold by itself?

5. **How you feel when improvising with an instrument you are unfamiliar with?**
   1. Challenges cause frustration and stress, or excitement and creative opportunities?
   2. Does familiarity ever impose limits on what you feel you can do?

6. **When improvising, how much control do you desire over the behavior of your instrument/system?**
   1. Do you enjoy the challenges of unpredictable behaviors, or is this something you safeguard against?
   2. Do you ever purposefully build elements of randomness, chance, or unpredictability into your performance systems/instruments?

7. **When improvising, are there certain events or outcomes which result in feelings of satisfaction, expressivity, or creative fulfillment? Or the opposite?**
   1. If so, can you describe what causes these feelings?

8. **If you experience something going "wrong" in a performance (an error occurs, the result of your action is not what you expected, etc.), how does this make you feel?**

9. **What are some key terms you would use to describe an expressive improvisatory performance?**

APPENDIX E

NULL/VOID POST-TESTING QUESTIONNAIRE

<u>Null/Void Study: Post-Testing Questionnaire</u>

1. **Can you tell me a little bit about your <u>first</u> experience with the interface?**

2. **Did your thoughts/feelings about the interface change <u>as time went on?</u>**

3. **Did you use the interface in <u>both Low-Risk and High-Risk modes?</u>**
    1. How would you describe the differences in your experience when using these different modes?
    2. Did you experience any positive effects when using the High-Risk mode?
    3. Did you experience any negative effects when using the High-Risk mode?

4. **Did experiencing <u>limitations on your resources</u> have any impact on your experience?**
    1. Which resource limitation was the most negative? Which was the most positive?
    2. Did the resource limitations cause you to think about your practice differently?
    3. Did you learn anything interesting through the imposition of these limitations?

5. **Did you feel that having limitations on your resources made them feel more <u>"real" or "tangible?"</u>**
    1. Why, or why not?
    2. If yes, do you feel as though that had a positive or negative effect on your experience?

6. **In general, do you feel the interface <u>changed your creative process</u> at all? (Pos/Neg?)**
    1. Compositional?
    2. Performative?

7. **Did you use any of the <u>reflection and/or action prompts</u>?**
    1. Which did you find most interesting? Why?
    2. Did you learn or experience anything that surprised you?

8. **What are some words that you would use to describe your feelings about your overall experience with the interface?**
    1. Disruptive? Challenging? Fun? Provocative? Etc.

9. **Do you imagine a device like this being useful in any kind of scenario?**
    1. What kind of scenario? Brainstorming? Collaboration? Performance? Etc.
    2. Why do you think the device would be useful in this/these scenario(s)?

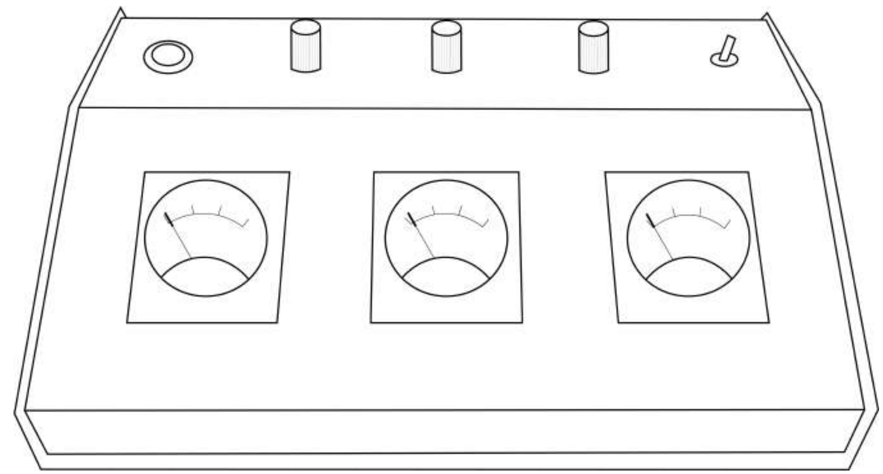
10. **What would you say was the <u>most negative</u> aspect of using this interface?**

11. **What would you say was the <u>most positive</u> aspect of using this interface?**

APPENDIX F

NULL/VOID USER GUIDE

ENCLOSED:
- **Null/Void Audio Interface**
  - Stereo TS-to-RCA Cables (x2)
  - USB-C Power Supply
  - User Guide
- **Documentation Materials**
  - Whiteboard and Dry-Erase Markers
  - Magnets
  - Note Cards
  - Journal
- **Repository Information**
  - Name and unique password



NULL/VOID
User Guide

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null/void interface

SETUP AND USAGE GUIDE

USING THE NULL/VOID INTERFACE

Step 1: Set up your performance system/instrument as usual. Then, connect your 1/4” audio output to the RCA audio inputs on the back of the null/void interface using the included cables.

Step 2: Power the null/void interface using the USB-C power supply (included). You will see the meters do a “swipe.” This is for calibration purposes.

Step 3: After roughly 30 seconds, you will hear a startup sound and see the meters do a second swipe. When the swipe is finished, the system is ready.

Step 4: Using the three knobs, set your resource banks for pitch, amplitude, and time parameters.

MIN TIME: When the time knob is at minimum position (turned all the way counter-clockwise), your clock will be set to roughly 4 minutes.

MAX TIME: When the time knob is at maximum position (turned all the way clockwise), your clock will be set to roughly 20 minutes.

PITCH/AMPLITUDE: In the minimum position, you will have few pitches and dynamic changes, and they will deplete quickly. In the maximum position, you will have a larger resource bank, which will deplete more slowly over time.

Step 5: When you are finished setting your resource banks, use the LR/HR toggle to select your mode.

LR: Pitch and amplitude resources will deplete based solely on audio input. Time resources will deplete linearly.

HR: Resources may be added and subtracted to your resource banks unpredictably, in addition to depleting over time based on audio input.

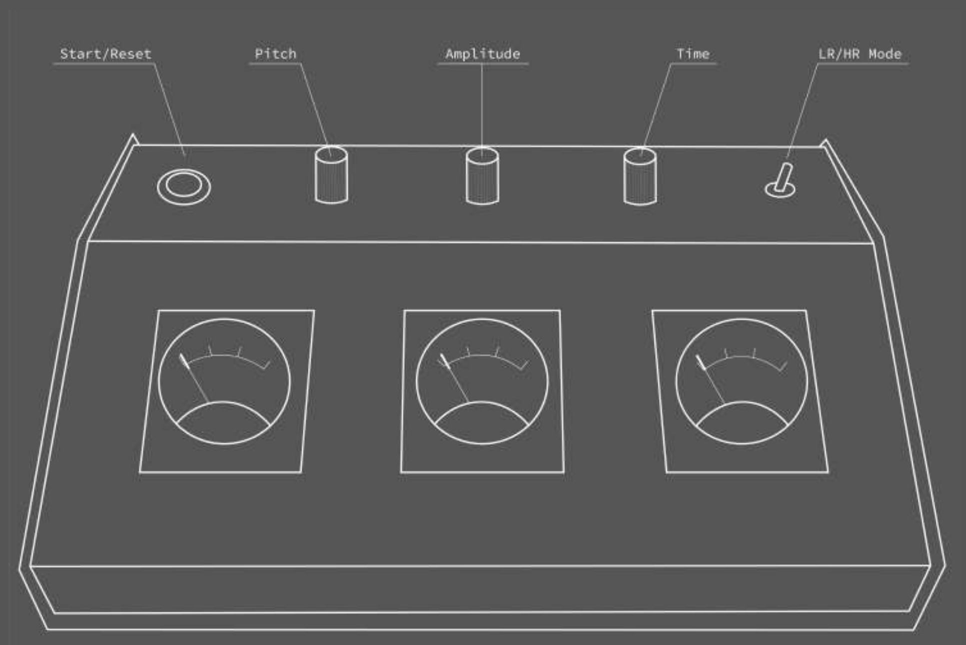
Step 6: To begin, press the start button to the left of the knobs.

Successful Start: You will see the meters jump to the top of their range. Resources will be shown on the meters over time. When any resource bank runs out, your audio will be cut off.

Step 7: If you need to reset the system, press and hold the start button for 5 seconds.

Successful Reset You can release the reset button during the meter swipe.

Interface ID: ____________________



null/void study

DOCUMENTATION AND DATA COLLECTION

USING THE CULTURAL PROBE PACKAGE

Whiteboard, markers, magnets: Useful for creating diagrams of signal paths, networks of resources, brainstorming ideas, jotting down notes, sketching, and more. You can draw on the whiteboard and the magnets, and erase as needed.

Example: On the magnets, draw a person, laptop, and audio interface. Place on your whiteboard and draw lines to connect each element’s input and output. Add circles or X’s at the points along the signal path where you believe the most risk for failure is present.

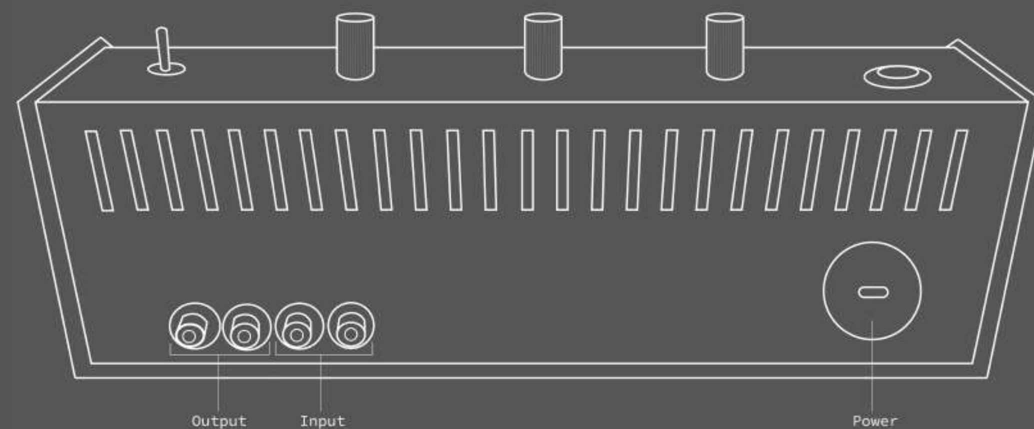
Example: Draw a network diagram of your audio system. Write “+” and “-” signs on your magnets, and place them along the lines of your network where you feel positive or negative emotions during your performance. Compare these networks when performing without the interface, as well as when using the LR/HR modes. Do you see any similarities or differences? Does anything interesting stick out to you?

Notecards: Some notecards will have “thought” and “action” prompts. These are optional, and intended to provoke exploration and creativity. If you use any of the prompts during your sessions, note down your experiences/observations on the back of the cards.

Example: After using the null/void interface in low-risk and high-risk modes, create a list of 10 key words you would use to describe each performance (e.g. challenging, exciting, frustrating, thought-provoking, engaging, distracting). Do you see any overlap in your terms? Are there significant differences in the language you used to describe each experience, either positive or negative?

Journal: You can use this booklet to record your thoughts over the weeks you spend participating in the study. Feel free to write long-form entries, make short notes, draw sketches, create lists of parameter settings or words/phrases that come to mind, create/notate compositions, etc.

Online Repository: You will have a password-protected folder to upload documentation. You can put voice memos, videos, digital images, text documents, recordings of compositions or improvisations—really, anything that you might create during the course of the study.



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