Embracing the messy and situated practice of dance technology design

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Figure 1: Image from rehearsal of "The Game of Life" by *Le principe d'incertitude.*

ABSTRACT

Designing technology for dance presents a unique challenge to conventional design research and methods. It is subject to diverse and idiosyncratic approaches to the artistic practice that it is situated. We investigated this by joining a dance company to develop interactive technologies for a new performance. From our firsthand account, we show the design space to be messy and non-linear, demanding flexibility and negotiation between multiple stakeholders and constraints. Through interviews with performers and choreographers, we identified nine themes for incorporating technology into dance, revealing tensions and anxiety, but also evolution and improvised processes to weave complex layers into a finished work. We find design for dance productions to be resistant to formal interpretation, requiring designers to embrace the intertwining stages, steps, and methods of the artistic processes that generate them. We suggest that our findings can be of value in other HCI contexts requiring flexible design approaches.

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CCS CONCEPTS

• **Human-centered computing** → **Field studies**; • **Applied computing** → *Performing arts.*

KEYWORDS

interaction design, dance, performance, performance-led research, research through design

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1 INTRODUCTION

While the domains of design and artistic practice may share certain similarities, there are a number of things that set them apart. Both are inherently creative endeavors, yet design methods tend to be more carefully defined and structured than methods found in artistic practice. In many design fields, formalized processes are highly desirable, even necessary, to help ensure the safety and success of new products according to mutually agreed-upon criteria. On the other hand, artistic practice proceeds according to personal and collective artistic motivations, interests, and values. Accordingly, methods are wide-ranging and can be freely subverted, changed, reinvented, and explored [25, 29], and criteria for success may not be explicit [12]. In contemporary performance, the use of digital technology has become common practice [38]. This brings the domains of art and design together in a unique relationship, where technical systems are created — *designed* — to fulfill the aims of a creative work, where they must be depended on to function reliably and without failure. We can see this as design practice embedded *within* artistic practice, where opportunities to push technology in new and creative directions are met with challenges and constraints from both domains.

To examine this unique design space in detail, we present a project where bespoke interactive technologies were created for a contemporary dance piece. The piece is performed by three dancers and three musicians. The choreography and music proceed spontaneously as a structured game mediated through the designed interactive systems.

I (the first author, referenced in the first person singular hereafter) joined the production company of two choreographers, the third and fourth authors, to work on their new piece in the dual role of interaction/technology designer and embedded researcher. I documented my daily involvement in the production through field notes and ran conversational interviews with the creators and performers. From these perspectives, I have constructed a direct account of the preparation of the piece and the co-design of the interactive technologies that were developed. In particular, I focus on the design process itself as a situated activity within the larger artistic creation, with its own unique priorities, approaches, and challenges.

Together we, the authors, characterize our work as an example of performance-led research in the wild as defined by Benford et al. [2]. Through this lens, we examine our design research, situated in — and arising from — artistic practice, with an eye to characterize the unique demands, constraints, and opportunities that it entails within broader contexts of design and HCI practice.

Our findings are presented as a firsthand account of co-designing technologies that illustrates complex relationships of design within artistic practice, and a set of themes from conversational interviews that illustrate artists' and performers' relationships with artistic-technical creation "in the wild". Finally, we offer a critical reflection on how art and design intertwine, relating our own experiences to theory from HCI literature.

With this work, we propose three contributions following along the lines of Benford et al.'s three phases of performance-led research [2]. First, relating to practice, we offer practical knowledge and insights based on our own experiences of co-designing technologies within an artistic creation. We then provide an empirical study of creators' and performers' perspectives of working and performing with interactive technologies. Finally, we extend theories around performance-led research in HCI by reflecting on how artistic creation represents a complex and messy interaction design space with intertwining layers, responsibilities, and challenges that require flexibility and careful negotiation between stakeholders around intentions, processes, and priorities but also timelines and technical limitations.

2 RELATED WORKS

2.1 Research through (design) practice in HCI

The relationship between research and design has been the subject of much discussion in HCI. As a basic dichotomy, Fallman [16] proposed that design research can be structured in two ways: design-oriented research, in which research activities are carried out in the service of design work, and research-oriented design, where design activities are used as tools within research practice.

Similarly, Zimmerman et al. contrasted what *design research* means to different communities [47]. For designers, the term generally refers to "upfront" research done in the early stages of product development, while for design researchers, it refers to research with the intent of producing knowledge about design —- and more broadly HCI — practice. To address and expand upon the latter definition, Zimmerman, et al. proposed *research through design* (RtD) as a model for interaction design in HCI. The term is derived from Christopher Frayling's description of three distinct modes of art and design research: *into*, *for*, and *through* design [20]. While the first two conduct research to build knowledge around design (either about the activity of design itself or to advance the practice of design), RtD differs in that it proposes design as an active approach to doing research.

According to Zimmerman [46] et al., RtD is well-suited to address "wicked problems": defined by Horst Rittel in 1960 as "problems which are ill-formulated, where the information is confusing, where there are many clients and decision makers with conflicting values, and where the ramifications in the whole system are thoroughly confusing" [9, p. 15]. Wicked problems are likely to be found in artistic practice, where specific outcomes or criteria for success may not be predefined, and work may not be bound to established methods or guidelines. Rather than being at odds with more conventional forms of scientific research, the artistic practice provides a unique perspective that might otherwise be missed.

2.2 Arts-led research in HCI

Arts-led research is a well established theme in HCI, where artistic practice is applied as a form of interdisciplinary research toward the generation of scholarly knowledge and theory. As technology has become widely used in the arts, HCI methods have been applied to study and design interactions in different types of practices, for example in interactive digital art and installation design [14, 32], and music performance and technology [23, 24].

Performance-led research can be seen as a specific type of arts-led research. What differentiates performance-led research is its focus on performative aspects like movement and embodiment, and interactions between performers and between performers and the audience. Case studies include Schiphorst's investigation of body-based somatic practices in HCI through the design of an interactive artwork [40], and Loke, Khut, and Kocaballi's work as artist-researchers exploring bodily-focused experiences through participatory live-art installations [31].

In dance specifically, we can see many examples including the design and evaluation of new technologies to support dance creativity [25], learning [35], and documentation [11], to name just a few. These contain approaches to support various challenges of dance practice and propose ways of designing for some of the wicked problems found in dance. However, they also highlight some of the limitations of using HCI methods in these contexts. As shown by Ciolfi et al. [18], developing research prototypes and assessing them via controlled experiments in the lab is not suitable for producing knowledge about artistic practices that tend to be more complex in real-world situations.

2.3 Performance-led research in the wild

A specific model of arts-led research and research through design is provided by Benford [2] et al.'s performance-led research in the wild. It defines three phases of research activity — practice, studies, and theories — and delineates the various ways each informs the other and the challenges during and across each of the phases.

The "in the wild" approach to performance-led research is critical in Benford et al.'s model. Rogers [36] describes it as occurring in situ, in "everyday" situations as opposed to controlled laboratory environments or neatly constructed experiments. This is consistent with the third wave of HCI research that prioritizes experience and emergent use arising from normal life and culture [7] supported by practice-based research approaches [22]. However, in the wild research applied to artistic performance goes beyond ordinary everyday situations and is entangled with wicked problems framed by the unique contexts where it occurs, such as communities of artists, audiences, and public exhibitions, which may lack predefined or straightforward solutions [2].

We find a few examples in the literature of performance-led research carried out in in the wild. Bisig and Palacio's work *Neural Narratives*, in which a dancer improvises with an intelligent "virtual body" onstage, was the result of a collaboration by the authors (researchers and designers) and a choreographer resulting in the artistic work and multiple research publications including [3] and [4]. Bluff and Johnston have presented their long-term collaboration between a physical performance company and interactive digital artists that spanned several years and five major works [6]. Eriksson et al. describe their reworking of a classic opera that incorporates drones performing onstage alongside a human performer. The work was carried out by an interdisciplinary team, and the research was presented from a first-person perspective [15]. The existence of these and other published accounts of in-situ performance-led research shows growing interest and validation for this type of in-the-wild arts-based research, which we build upon with our own work in Section 3.

2.4 Dance-led research in HCI

The topic of dance in HCI has been the subject of two recent meta-analyses of literature [28, 45] that provide a historical account, critique of the present state of the art, and opportunities for expanded engagement.

In the first review, Jürgens et al. [28] analyzed 42 HCI papers that mentioned "contemporary dance". From the corpus, they identify seven thematic categories of HCI engagement with contemporary dance including theory, practice, artistic works and processes, documentation, and archiving among others. Citing the concept of embodied interaction put forth by Dourish [13] and its possibilities for interaction design [30], along with a paradigm shift where contemporary dance practice often encompasses specialized and highly technical interdisciplinary activities, Jürgens et al. argue that contemporary dance practitioners become experts in embodied interaction, offering new and expanded opportunities for research [28].

Zhou et al. [45] conducted a separate systematic review of dance-related literature in HCI over the last twenty years, with an additional focus on the integration of technology into dance practice. Their analysis identified four different themes of technology in dance: physiological sensing, multisensory perception, movement quality analysis, and agent collaboration. While the categories provide a basic taxonomy of technologies, in practice these themes are frequently interwoven in vastly different and creative ways. For example, Niewiadomski et al. developed a system that uses both physiological and movement data as inputs for a machine learning model to identify expressive qualities of *Lightness* and *Fragility* in dance performance [33]. All four categories are recognized in Van Nort et al.'s *[radical] Signals from Life*, where dancers' muscular activity is recorded and used as input for an intelligent musical agent while audience movements are mapped to control signals for visuals, all of which culminate in a unique multisensory performance [42]. This mixing and matching technologies and approaches is found in our own work as well. Precisely, our paper describes such a complex layered "in the wild" design space.

Fdili Alaoui's research approach to her work *SKIN* is a notable example of practice-led research and design of multiple interactive technologies for dance [17]. The piece involves interactive video and audio elements triggered throughout the hour-long performance. *SKIN* took form as a co-creation with Fdili Alaoui (choreographer and HCI researcher), a choreographer/videographer, two dancers, a musician, and a developer. The piece was created during rehearsals that involved the entire team and included iterative choreographic development and technology prototyping and testing. While versions of the work made extensive use of multiple physiological- and movement-sensing components, ultimately the sensor-based

interactions were greatly simplified and some were removed entirely. Fdili Alaoui provided a written account of the creation in [17], in which she shared her first-person experience, accompanied by interviews with team members and audience attendees. The paper highlights tensions experienced between the artists and technology, where design choices were the product of not only creative ideas but also technical limitations and production constraints.

We see *SKIN* as an important reference on the research we present here, and a direct influence for the performance-led, in-situ approach we applied. But despite the similarity in approaches, there are notable differences between the research perspectives. The works have different stakeholders and roles, each with unique points of view. Fdili Alaoui, along with her partner, came up with the artistic concept for *SKIN* and can be considered the creative director, and her experience is told from this point of view. In our work, my perspective is that of a designer and developer working to bring the creative vision of the choreographers and composer to life. There are also unique artistic motivations for each work that helped to define different roles of technology in each piece, leading to different design strategies and outcomes.

3 "THE GAME OF LIFE": A FIRSTHAND ACCOUNT OF THE DESIGN

To explore the inner workings of interaction design embedded within artistic practice, I joined the third and fourth authors' dance company *Le principe d'incertitude*[1] for the production of a new work entitled "The Game of Life".

3.1 Design process

I followed a co-design approach, in which the design process was shared between multiple stakeholders on the team [39], including the choreographers, the composer, and the performers. During two residencies we collectively iterated through the ideation, prototyping, and testing of new interactive systems alongside, and intermingled with, the artistic creation that was in progress. I approached the production as a field study, to examine design processes in the wild. In parallel to the design work I was doing, I documented the daily process of technology development, testing, and rehearsals through design notes, sketches, photos, videos, and a research journal. From these materials, I have assembled a firsthand account of the collaborative design process of the interactive technologies that were developed for the piece, along with the unfolding artistic creation as the piece took shape.

3.2 About the piece

"The Game of Life" is a co-creation by choreographers Pierre Godard and Liz Santoro (the third and fourth authors) and composer Pierre-Yves Macé for three dancers (including Santoro) and three musicians — a violinist, flutist and percussionist. The name and high-level concept for the piece comes from John Horton Conway's well-known cellular automaton "Game of Life" [1, 21].[2]

A second, more direct reference for the piece comes from the biochemical process of protein production in living organisms. To summarize, proteins are made up of several amino acids chained together. Amino acids are coded by DNA, and DNA is formed by arrangements of four nucleobases (or simply "bases") — A (adenine), C (cytosine), G (guanine), and T (thymine) — in groups of three, called "codons". Codons are notated by the letters of their bases (for example ACG, CTT, and GGG). There are a total of 64 possible codons ($4^3 = 64$); 61 code for one of the 20 amino acids that occur in protein production, while the remaining three are stop codons which designate the end of a coding sequence [41, 43].[3]

The choreography of "The Game of Life" simulates the formulation of DNA strands by chaining codons together. The codons are enacted through movement and music as shown in Table 1: each base (A, C, G, and T) is distinctly represented by directional movements in the choreography and a one-beat rhythmic pattern in the music. In turn, each of the 64 codons is represented by a module consisting of three movements and rhythms (in musical terms, a 3/4 measure with the three beats representing the first, second, and third base, respectively). In performance, this module is looped until a new codon is specified.

Table 1: Codon-based movements and rhythms in "The Game of Life"

Base	Dance movement	Musical rhythm
A	forward/backwards	a triplet
C	left/right	two eighth notes
G	up/down	quarter note
T	rotation	three syncopated 16th notes

3.2.1 Rules of the game. Reflecting the generative automation in Conway's original work, a fundamental concept for the piece was that the choreography and music would not be fixed but unfold spontaneously as a rule-based game played by the performers on-stage. Through the two residencies, the structure of the gameplay was explored and finalized, as were the technologies that would provide the interactive structure. The basic rules that emerged were as follows:

- The piece is executed by the dancers and musicians performing all 64 codons without repetition.
- Each codon is looped until one of the performers calls out the next codon to move to.
- The order in which the codons are performed is determined by a hierarchy of transformations from one to the next (mimicking actual biochemical processes). The first transformation that doesn't result in a previously performed codon is the next move. Transformations one and two are deterministic, while three and four are stochastic and rule-based:
  (1) First shift: bases rotate position by one (e.g., ACG to GAC)
  (2) Second shift: bases rotate again (e.g., GAC to CGA)
  (3) Mutation: a new codon is formed by changing the third base (e.g., CGA to CGC, CGG, or CGT)
  (4) Impasse: if none of the previous three transformations are available, performers can call out a new codon. If it has

[1] https://lpdi.org/

[2] An interactive example and explanation of Conway's "Game of Life" can be found at: https://playgameoflife.com/

[3] An complete overview of the biochemical processes involved can be found on Wikipedia's page for *genetic code*: https://wikipedia.org/wiki/Genetic_code

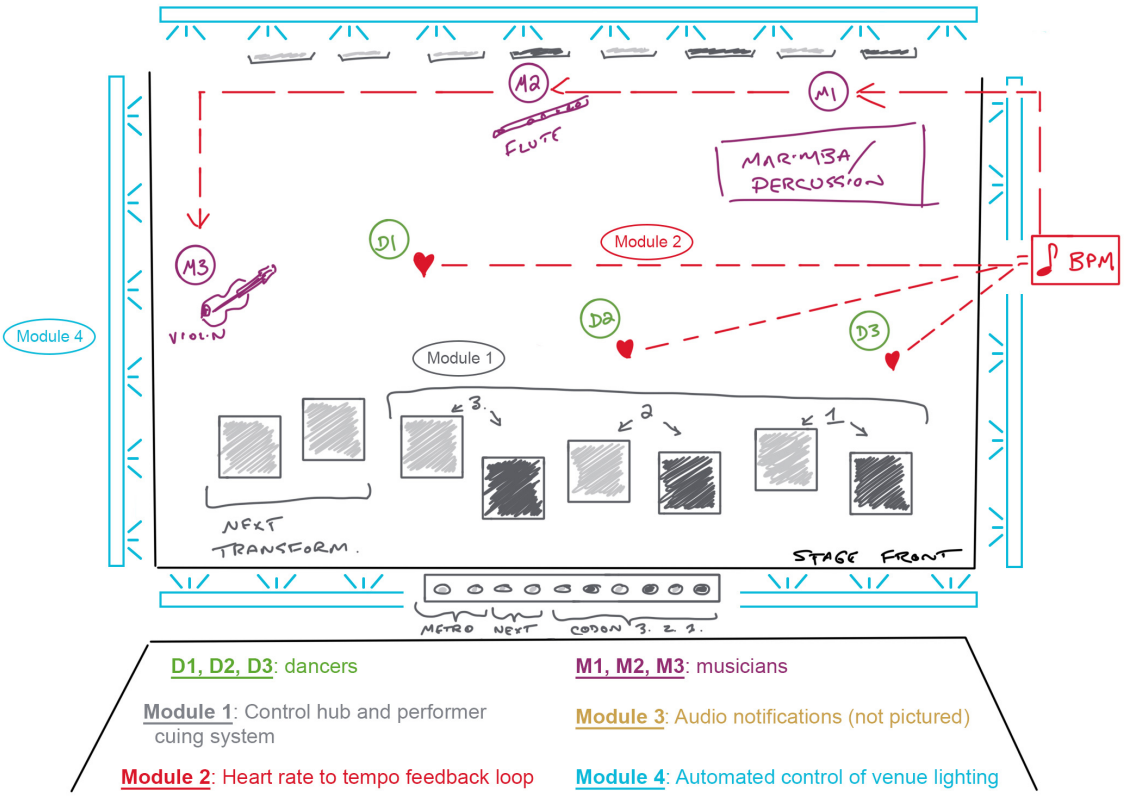

Figure 2: A sketch showing an overhead view of the stage showing the four interactive modules integrated into the piece.

already been performed, a new random codon is provided for the performers instead.

Additional rules specify which performer(s) are in charge of calling the next codon, as well as the active state (living or dead, as with the cells of Conway's piece) of each performer.

3.3 The technologies

The creators envisioned extensive use of digital technology to provide the game structure and interactivity throughout the piece. Ultimately we developed and integrated four different interactive modules. To help clarify our account of the design that follows in Section 3.4, we first provide an overview of the modules in their completed forms, as sketched in Figure 2.

3.3.1 Module 1: Central control hub and performer cueing system. This main interactive module (Fig. 3) serves as both the control center for the gameplay and a communication system for the onstage performers. An interface and underlying architecture allow an operator (typically Godard) to track the available and used codons, signal the next available moves available to the performers, and perform a variety of secondary tasks both in rehearsal and performance. As a communication system, the interface connects to three banks of lights at various locations on the stage: squares projected on the floor, panels suspended at the back of the stage, and a light bar at the front of the stage visible only to the performers (the floor and suspended lights are visible in Fig. 1). The six rightmost lights indicate the current codon to the performers (expressed in binary code, with 2 bits for each base), while the two remaining lights indicate the next available transformation as described in Section 3.2.1.

Module 1 also featured a data logging function that recorded the steps of the gameplay during a run-through. An excerpt of the log is shown in Fig. 4, which shows, for each of the 64 game "moves", information about which codon was performed and elapsed time between moves. The original data log had been planned to collect some quantitative research data about the interactions, but a more immediate use was found in rehearsal, where it could be consulted to show how the run-through had proceeded, if or where delays or wrong moves had been encountered, and to better understand and talk through certain sequences.

3.3.2 Module 2: Heart rate to tempo feedback loop. The second module is a physiological sensing system that dynamically modulates the tempo of the performance according to changes in the dancers' heart rates (HR). The system uses a third-party smartphone application and streaming platform[4] to relay HR data from commercial fitness sensors worn by the dancers and to the interaction software. The user interface (Fig. 5) provides controls to apply different types of filters and transforms to the incoming data

[4]Pulsoid (https://pulsoid.net/)

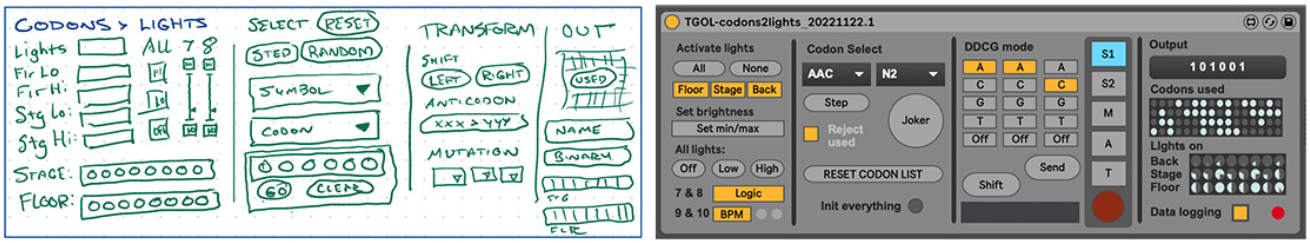

Figure 3: Module 1: Central control hub and performer cueing system. (Left: early sketch. Right: Finished user interface.)

#	app_time	c_id	c_sym	c_XXX	c_binary	elapsed_sec	tempo
7	11272292	19	L3	CTA	0 1 0 0 1 0	43.500	87.200
8	11315769	37	T1	ACT	1 0 0 1 0 0	23.400	80.000
9	11339203	38	T2	ACC	1 0 0 1 0 1	36.200	81.500
10	11375419	26	H2	CAC	0 1 1 0 0 1	30.200	90.500

Figure 4: Excerpt from the data log of Module 1, showing moves 7 - 10 of a rehearsal run-through. From left to right, the columns indicate: move number, timestamp (milliseconds), codon {ID, symbol, bases and binary code (which was shown on the stage lights)}, elapsed time of move (seconds), tempo at start of move (BPM).

which is mapped to the master tempo in the audio software (Ableton Live[5]). The pulse of the tempo is received by the performers via audible "click track" embedded in the music as well as visually on the light bar at the front of the stage (the two leftmost lights marked as 'metro' in Fig. 2).

3.3.3 Module 3: Audio notifications. This is a submodule of the central control system that sends cues to a separate computer that controls the live audio. Along with the musicians onstage, the musical composition includes several tracks of synthesized audio, sampling, and live processing of the onstage instruments. These elements are sequenced according to the gameplay, so for each move, a series of corresponding MIDI messages are sent to the audio computer to trigger the appropriate actions.

3.3.4 Module 4: Automated control of theatre lighting. The final interactive module (Fig. 5) was a late addition. After automating many of the other systems (audio, onstage lighting, and performer cueing), we created one more module that controlled all of the venue lighting based on the gameplay. Simply explained, venue lights are grouped into banks, which are mapped to parameters of the game, including the individual bases (A, C, G, and T) and their positions, as well as special game situations (for instance, when the performers arrive at an *impasse*). During performance, the lighting would change dynamically based on the progression of the game.

[5]https://www.ableton.com/en/live/

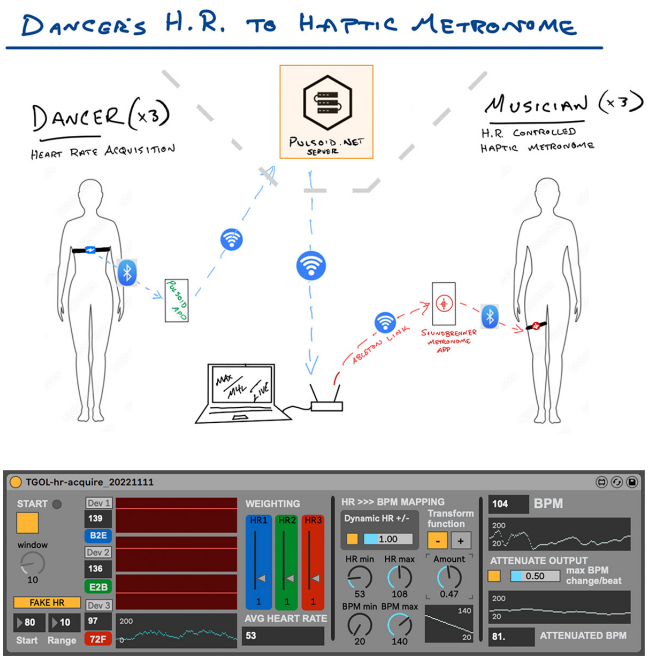

Figure 5: Module 2: Heart rate to the tempo feedback loop. (Top: a sketch of the signal flow showing an initial version that used a haptic metronome instead of audiovisual cues. Bottom: The finished user interface.)

3.4 Design story

This section provides my own firsthand account of the design process that was carried out in the two months leading up to the first performances of the piece. When I joined the production team, preparation was already well underway: the basic choreography and music had been developed and the high-level concept for the piece was in place. However, the interactive elements and structure of how the piece would be performed were all yet to be determined. These elements would come together in the final weeks across three discrete time periods. : a two-week "pre-residency" preparation block, followed by two two-week residencies separated by a week-long break. The second residency culminated in the public premiere of the new piece. Given that the design activities were a subset of activities within an artistic process that was in a state of active creation, the design goals and structure were not fixed but

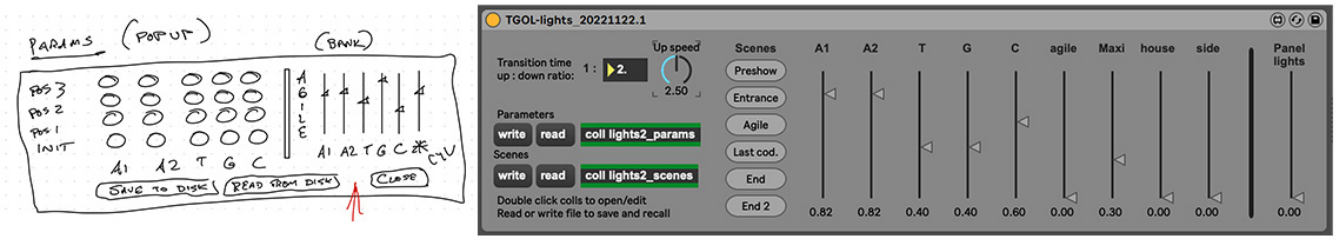

Figure 6: Module 4: Automated control of venue lighting. (Left: An early sketch. Right: The finished user interface.)

evolved according to the needs, progress, and constraints of the larger creation. A timeline of the design of the interactive systems is shown in Figure 7 to accompany my account.

Weeks to premiere:		W7	W6	W5	W4	W3	W2	W1	Premiere
		Pre-residency		1st residency			2nd residency		
Module 1	Control hub				1	2	3	4 5	6
Module 2	HR - tempo loop	1	2	3	4			5	6
Module 2a	Audience EDA loop		1	2	3	(discontinued)			
Module 3	Audio notifications						1	2,3 4	5, 6
Module 4	Venue lighting							1,2 3,4	5, 6

Figure 7: Timeline of the technology through six development stages: 1) ideation, 2) proof-of-concept, 3) first functional prototype, 4) major design iterations, 5) fine-tuning, and 6) finished module.

3.4.1 Pre-residency: Initial research and tests. In the two weeks before the first residency I met multiple times with the third author. During these meetings, we discussed the conceptual themes and intentions of the piece, sketched out ideas for interactive elements, and proposed the technical systems, hardware, and software that we would use.

Given the tight timeline, we established certain working constraints. First, there would be no bespoke hardware development: any devices we used would be off-the-shelf and commercially available. Second, software programming would be limited to higher-level interaction design and not concern itself with more low-level processes (such as complex network communications or writing firmware). We agreed that all software would be programmed with Max, a visual programming language for music and interactive media[6], and specifically Max for Live[7] to permit interoperability with the audio production running on Ableton Live.

In this initial two-week period, we focused on the preliminary design of two feedback loops that would employ physiological sensing to control certain parameters of the live performance. The first loop is meant to capture dancers' heart rates to modulate the performance tempo (Module 2 as described in Sec. 3.3.2). I ran an initial test, equipping the fourth author with a wearable HR device, and developed a working prototype to test with the performers at the first residency.

The second feedback loop (Module 2a in Fig. 7) was meant to modulate the behavior of the performers (for instance, by indicating the next codon that they would perform or the pace at which they would move from one codon to the next) based on physiological input from audience members. In particular, we were interested to experiment with a commercial electrodermal activity (EDA) sensor[8] and open source software[9] to send and receive sensor data over a network, that can provide a measure of cognitive arousal or stress by measuring the changes in electrical conductance of the skin [34]. With our initial design concept in place, we ordered the sensor hardware to conduct preliminary tests at the upcoming residency.

3.4.2 Residency 1: Prototyping interactions. The first two-week residency was held six weeks before the premiere. Notably, this marked the first time that the entire team was physically present together.

Several elements of the creation occurred simultaneously over the two weeks. Musicians and dancers rehearsed daily, first learning and practicing the 64 dance and music modules (that corresponded to the 64 codons), then developing transitions from one to another. The lighting and stage design was being constructed, and the sound design (including supporting live electronics and audio processing) continued to be developed and refined by the composer and sound engineer.

My work on the design of the technology consisted of meetings (most often with Godard or Macé) to define and review the interactive elements, and independent development time to provide working prototypes that could be tested during afternoon rehearsals. While the scenography design and rehearsals followed a predetermined schedule, the design of the technology was mostly freeform. Priority was placed on whatever items or tasks would support the creators and ongoing rehearsals, which, in addition to the performers learning and practicing the choreography and music, were also exploring and formulating how the piece would actually be put together. Development and ad-hoc meetings occurred throughout the day and into the night, and testing of systems (which would include working with the performers or use of the stage lighting) was done on a limited basis whenever possible.

In the first week of the residency, I built the first full prototype of the second module (HR to tempo loop) and conducted initial tests with the performers. While the system was functional, we found that the initial mapping algorithms caused "unnatural" tempo modulations resulting in awkward or even impossible transitions for the performers. Throughout the rest of the two residencies, I

[6]https://cycling74.com/products/max
[7]https://www.ableton.com/en/live/max-for-live/
[8]https://moodmetric.com/services/moodmetric-smart-ring/
[9]https://www.forger.fi/fsensync/

would continue to iterate on the design and mappings to smooth the transitions to where they would fit naturally with the piece.

Another issue we faced concerned the delivery of the tempo pulse to the musicians. Our initial designs planned to use haptic metronomes [26] worn by the musicians that would deliver the tempo information through the sense of touch. However, after testing two different commercial devices we were not satisfied with either. On the first, the powerful vibrotactile actuators that delivered the metronome pulse were too loud and distracting for the performers. The second relied on a Bluetooth connection for wireless operation that would periodically lose sync, causing dropouts and inconsistent output that was impossible for the performers to follow. After several tests, we decided not to use haptic metronomes at all and instead moved to the audiovisual click track that is described in the final specification (Section 3.3.2).

During this time, I also developed a prototype module for the second feedback loop (Module 2a) that captured EDA data from our newly acquired sensor device. To test its viability, I ran a simple experiment where I would wear the device and record the sensor data for a few hours while taking note of my own activities and levels of stress or excitement. Afterward, I visually reviewed the sensor data to see if I could correlate it with my own activities and perceived emotional states, as well as with the device application's "stress score" derived from an unknown, closed-source algorithm. I found that the raw sensor data was noisy and, despite applying some basic filtering, was unable to devise a model that would suit the piece. Without sufficient time and resources to fully explore other signal processing algorithms, we ultimately decided to remove it from the piece.

Towards the end of the residency, as the scenography and lighting came together, I created the first prototype of first module, the central hub and interface for the onstage lighting that would provide the performance cues. While rudimentary, it was able to be used in the rehearsals to explore ways in which the performance could be sequenced.

3.4.3 Residency 2: Putting it all together. One week after the conclusion of the first residency, with just over two weeks to the premiere, the team gathered for the second residency. Upon my arrival, there was a critical technical issue to address: communication between the interaction and lighting software was intermittently stalling, freezing the onstage lighting cues, and interrupting rehearsal runthroughs. Given the rapid pace of software development and minimal time to test the systems, it was difficult to isolate where the issue came from and my first work item was, therefore, to troubleshoot all of the hardware and software systems. The issue at hand was ultimately resolved. However, the issue highlighted concerns about the technical reliability, which remained through to the performances.

The first week of the residency focused on major design iterations for module 1 as the creators approached the finished concept for the gameplay. I frequently met with Godard and Macé to discuss the newest changes to the structure, which I would then integrate into a new update of the module to try in the afternoon rehearsal.

Module 2 also continued to be developed. In addition to discussing and trying new algorithms for the HR to tempo mapping, I also got feedback from the performers in the evenings, as we were housed together in a nearby residence. We discussed tempo changes in music at length, and they demonstrated in detail the acceptable rate of change that their performance could accommodate, as well as how the transitions between moving and fixed tempos needed to be attenuated. These informal and more relaxed conversations helped me to better understand their needs and concerns, which I used to iteratively improve the mapping algorithms in the software.

The final week of the final residency found the team — and the design process — in an intense and focused atmosphere. As evident in the timeline of Fig. 7, a great deal of design work transpired in the last handful of days.

Development of module 3 began in the final week and continued up to the last hours before the first performance. What began as a relatively straightforward task to transmit each move of the gameplay to the audio software progressively became more complicated as additional elements of the sound design were finalized. The finished protocol included 21 different messages that could be sent for each move depending on context.

Just a few days before the premiere, the idea for module 4 (venue lighting automation) was introduced. Given the automation of the other lighting and audio controls, we wanted to connect the rest of the stage and house lights to the control hub as well rather than operating them as a separate, unconnected system. After a quick ideation session, I created a working prototype one day before the performance. It was tested and fine-tuned in the last two rehearsals and added to the show.

3.4.4 Testing, contingencies, and a premiere. The final two days leading up to the performance saw the last dress rehearsals of the full piece. On the technical side, I continued to make small updates and improvements to the software and did my best to troubleshoot and test all of the software I had created. Because of the high degree of automation that we had designed, a technical failure would stop the live show in its tracks, and this concern was very much at the forefront of our minds. The third author and I planned contingencies for things that could potentially go wrong, like having additional manual controls to override certain automated processes. As an additional fail-safe, we decided that for the live show, the interaction modules would run on two redundant computers so that if anything did happen to the primary system, we could quickly switch and the show would continue.

The premiere performance was held at the end of the second residency, and a second show was performed later in the week. From a technical and artistic standpoint, everything worked as planned, and judging from the positive audience response, the shows were a success. Looking forward, additional dates are scheduled in the coming year.

4 IT'S A TEAM EFFORT: INTERVIEWS

In addition to my own firsthand account, I wanted to capture the thoughts and impressions of the performers and creators on the design and creation of both the piece and the technology through interviews. I interviewed all of the performers and the third and fourth authors in the final days before the premiere. These interviews provide additional context and insight into the atmosphere of the rehearsals and elucidate the various points of view around

the roles of art and technology, as well as design and creation, happening together.

4.1 Data collection

The focused nature and close quarters of the residencies, along with my involved role in the production, demanded special consideration for the interviews. A typical approach in qualitative HCI research might call for semi-structured interviews [5] and efforts to limit interviewer bias by trying to keep the interviewer neutral in their questioning [37]. However, in the context of this project, my embedded role in the organization meant that the experience of the residencies was shared by the team. Not only did we work together every day, but we also took our meals together. Additionally, during the second residency, most of us also shared a residence together. While this gave me intimate access to the inner workings of the production, I was also far from an unbiased observer. Therefore, I chose to conduct informal conversational interviews [44] with the performers and choreographers. The open-ended format permitted the interviewees to speak freely about whatever they chose to focus on and allowed us to engage in open dialogue. I believe that this approach allowed for greater empathy during the interviews than other methods would have, yielding the most authentic understanding of the team members' points of view.

The interviews were kept to around 10 minutes, save for those with Godard and Santoro that ran around 20 minutes each. Interviews were fit in between rehearsals, meals, or other scheduled events. Each interview was audio recorded and later transcribed. The roles of the interviewees, along with the alphanumeric IDs that are referenced in the following section (except for the co-authors), are shown in Table 2.

Table 2: Roles of interviewees.

Name or ID	Role
Godard *(co-author)*	co-creator and choreographer
Santoro *(co-author)*	co-creator, choreographer, and dancer
D1	dancer
D2	dancer
M1	musician (marimba, percussion)
M2	musician (violin)
M3	musician (flute)

4.2 Analysis

We conducted a thematic analysis of the transcribed interviews following guidelines put forth by Braun and Clark in [8], which allow for a bottom-up approach to understanding the data. The analysis steps were as follows. The second author and I independently read and annotated the transcripts, ascribing codes to any quotes that we found relevant to our topic. We then met to compare our quotes and codes. Those that we had both identified were kept, and any identified by only one of us were discussed and mutually decided upon whether to keep or discard. We then reviewed all of the codes we kept and, through an iterative process of grouping and discussion, arrived at nine overarching themes across two categories. In a final step, I compared all of our original codes against our nine themes, reassigning or removing any that did not fit. This helped to clarify the themes and verify that they were true to the content of the interviews.

The first thematic category presents *(A) the realities of a constrained and messy process*, focusing on tensions and interplay of the technology design and the evolving creation processes. The second explores the shift towards *(B) trusting technology to become an invisible scaffolding for an embodied performance* that occurred as the technology became integrated into the artistic work over time.

4.2.1 A. The realities of a constrained and messy process. Our findings reveal that the design and creation process is highly constrained and fraught with difficulty while at the same time dynamic, highly experimental, and often non-linear and messy.

A1. Working with imposed time constraints. Exhaustion and fear, but also excitement, were recurring sentiments in the interviews and throughout the residencies themselves due to the tight window of time to complete the creation and present the piece. Godard shared his mixed emotions about his experience, saying, "*It's been kind of an intense process because we didn't have too much rehearsal time [...] so I feel a mix of confident and scared and exhausted.*"

The time constraints were felt in the pace of creative development and the limits it imposed for exploration and refinement, as described by Santoro:

> "*Every time you make those steps forward, you suddenly open up a door to make a lot more things possible... But then it's just like, oh, gosh, do we really not have two weeks to integrate that? We really only have two days, you know, so it's overwhelming, but at the same time quite exciting.*"

Godard and I also talked about the rapid pace of the development, which I described as "hacker mode", where new and untested technology was constantly being deployed in the rehearsals. Both of our concerns about the technology were increased given the compressed time frame. The performers felt that the time pressures were highly stressful, but some also pointed out that the urgency and pressure made for an extremely productive and dynamic work environment, which was viewed positively.

A2. A high degree of difficulty. Everyone generally agreed that the piece was difficult. For the performers, the cognitive task of memorizing, recalling, and chaining together 64 different modules of choreography and music during the performance was a formidable task. Adding to it was the additional layer of the lighting/cueing system to which they had to pay close attention. With just one final day of rehearsals left, M3 found that "*it [referring to the performance] still requires concentration and [there are many] things to improve.*" The cognitive demands of the piece presented challenges for the performers to remain connected with each other. M1 recalled a difficult moment in rehearsal where "*The dancers were dancing but I could not concentrate on what they were doing.*".

Mistakes were frequently mentioned, and while frustrations at making them were expressed, they were also seen as an important and useful part of the rehearsing process. According to D2, recovering from a mistake represented "*a great moment to see how*

we manage to pass to something else, [to understand] how we do it." Throughout the interviews, the theme of difficulty and mistakes illustrated the challenges of working with the new interactive systems that we were designing, which required the performers to work in unusual and unfamiliar ways, and divided their attention between the technology and the artistic performance.

A3. A messy, non-linear process. Godard and Santoro spoke at length about the open, sometimes chaotic and unpredictable development of the piece. A major turn in the creation came just before the final week of rehearsals, which Santoro described: "*We were sitting here all day until like two in the morning [...] re-making the setup of the piece. You know, we changed the whole game, the game setup and rules and everything.*"

The progress of the creation was aided by responsive technical development that formed a sort of feedback loop. Ideas for the interactive systems came out of rehearsal that I would integrate into a new update. The new technology would then be deployed back into rehearsal which could facilitate new creative development. For example Santoro described the evolution of the onstage cueing system: "*Being able to catapult an idea of like, 'Oh, you know, is there a way we can use that to communicate?' And then being able to [try a new software update] in a way where it's not only possible, but then it ends up re-feeding back into how we're working.*"

A collaborative atmosphere pervaded the residencies where multiple interrelated elements and processes were being created simultaneously by a small team, with individuals working across and between them. This was noticed by M3: "*Each one has their work, but it's linked.*" Given the interdependence of systems and personnel, much of the work (and especially the technical development) didn't proceed along an orderly design method with scheduled steps and stages. Instead, it proceeded according to the needs at hand and the availability to integrate technology into other areas: design of the onstage cueing system (Module 1) proceeded as the stage design and lighting were installed, while the iterations of the audio notification system (Module 3) evolved as the composer and sound engineer were actively creating the interactive musical score, which itself was evolving as the gameplay was invented during rehearsals.

A4. Integrating many layers into one piece. An important part of the development process, and a unique characteristic of the work itself, was the interleaving of systems, technologies, and mediums together, as described by M1:

> "*One of the things that I like the most in the piece is this kind of integration of the [different] ways of expression: lights, all the lights, rhythm, music, body, and also what is taking place in the bodies of the dancers with the heart rates. And for me, it's a kind of utopia of integration of all these mediums.*"

Bringing these layers together into a coherent performance was a constant concern for all through the second residency. M3 described the evolution of the creation for the performers: "*The first week [...] was the period of research, trying different possibilities. And since the second week, it has become stable [and] there is a clear form for everyone to follow.*".

In addition to simply bringing the layers together, it was important not to lose sight of the overall artistic intent of the work. Godard worried about "*how to make the piece be a piece, and not just a study or an idea,*", and Santoro described how the work would transform into "*an inhabited piece that can start to be thought of being brought to the stage.*" Despite the time pressures and complexity of the elements being developed and brought together, this overarching focus on creating an artwork integrating all layers and mediums together was shared and embraced by the entire team.

A5. Revealing tensions. The last theme in the first grouping was that of tensions that arose during the residencies, especially as the piece became more automated and structured by technological integrations. In particular, the need to balance the technological layers with the embodied elements of performance was a struggle at times.

One example came with the use of module 1's data logging feature (described in Sec. 3.3.1) to review rehearsal run-throughs. Its use was met with mixed feelings, as described by D1:

> **D1:** "*The log is a beautiful thing. [both laughing] That's kind of one nerdy step because it's almost like performance policing.*"
> **First author:** "*It is funny. It does feel like almost a little invasive or something to the process. It's like, 'Okay, here's how you actually did.'*"
> **D1:** "*Yeah, this is undeniable. And I would sort of plead 'No, but for that moment there, you know, there were also other deeply human aspects that were going on [and] it took me a while to realize it was me. I was supposed to be looking for that [next codon].*"

On the one hand, the use of quantitative data — "performance policing" — could be seen to be at odds with the human and embodied demands of performing and represented a new, unfamiliar way that technology was imposed on the dancers' and musicians' performance practice. But at the same time, this additional layer of rehearsal analysis and review allowed for (and even required) greater attention to technical details and, as voiced by D1, perhaps more accountability in performance.

4.2.2 B. Trusting technology to become an invisible scaffolding for an embodied performance. The second category of themes encompasses the outlooks and implications of creating and performing a piece that relies heavily on technology. This includes pragmatic concerns about the technology being operational and reliable and reflection on the evolution of the technical elements as a structural framework for the piece that would serve and support the performers.

B1. Fears and anxiety around technology Depending on the point of view, there were varying degrees of concern about the reliability of the technology. The performers, who, for the most part, were not involved with or updated on the technical development of the interactive systems, were generally untroubled. They trusted that it was working well and were more preoccupied with their own progress of assimilating the interactive elements into their own performances.

For those of us involved with the technical production, concerns for technical problems — even failure — were ever-present. Previous

works by Godard and Santoro had employed technology in limited ways. *Stereo*[10] (2019) used commercial software for screen sharing to bring visuals to the stage, and in *Relative Collider*[11] (2014) a real-time computer program determined dancers' movements based on patterns found in text. For each piece, a software failure could have interrupted the show. However, "The Game of Life" represented a significant leap in technical scale and complexity, with multiple interconnected systems custom-built for the production. We focused on being prepared and minimizing the risks of technical failure. For Godard, this meant creating "*an exhaustive checklist that maximizes the chance that everything on the tech side runs smoothly*". As the technical developer, I was confident that we could account for "*not everything, but at least [...] talk our way [through] and have contingencies for, you know, at least 75 to 80% of all plausible scenarios of any sort of technological breakdown.*"

As recounted in 3.4.4, we worked in the final days and hours to ensure the technology was robust and put backups in place wherever possible to ensure that the piece would run smoothly, which it did. Nonetheless, concerns over technical issues were a constant presence.

B2. Trusting and relying on technology. Nearing the end of the second residence, almost everyone commented on how integral the technology had become to the piece. Santoro noted the way that the interactive lighting blended the functional structure (the cueing system for the performers) together with the scenography:

> "*I felt like I saw for the first time the automation of the actual lighting from the codes... I feel there's a sort of architecture and environment that really materializes in a different way, like with the space and the light.*"

For performers like M3,through practice, they became more comfortable with the technology. They could rely on it as the ultimate source of truth in the gameplay: "*Whatever happens, we trust what we see [in the onstage cue] lights.*" Unlike those of us on the technical side, where the increasing layers and complexity of the technology heightened our worries, we found a contrasting effect on the performers. As the interactive systems improved, becoming more integrated with the choreography and gameplay, the performers became more comfortable and more reliant on them.

B3. Technology as an invisible and supporting layer. Despite its central role, the interactive technologies were intended to largely exist in the background of the performance. Santoro described her conservative approach to incorporating technology onstage:

> "*We're not like, putting machines in the center of the stage. [The visible technology — primarily the onstage cueing lights] has this continuous feedback connection to a physical, moving structure in the stage space. I think it's a really exciting and lovely way for that technology to be present on stage.*"

The non-obvious nature of the technology was also considered from the audience's point of view by D2: "*[The audience] won't necessarily see that there was all this technology work before them, even though it's hyper-important for the piece.*" Whether this is desirable for the spectators or keeps them from fully understanding the work can be seen as an artistic choice by the creators (for example, in their decision to *not* put machines at center stage).

Functionally, technology was seen to have a supporting role in the piece. For performers, it was an important communication tool, showing them what the next step could be, who onstage they were collaborating with, and indicating the changing tempos. And for the scenography, it was an integral part of the dynamic stage and lighting design.

Having the technology "blend in" was important in the interaction design. For example, early versions of the HR scaling algorithms in module 2 created tempo modulations that felt unnatural to perform, where performers felt forced by the technology against their will. After experimenting with different scaling algorithms, ranges, and levels of responsiveness and ranges, we ended up with modulations that fit the piece and performance. Rather than the performers feeling controlled by the technology, the moving tempos felt organic and a part of the expressive movements and music.

B4. Towards embodiment and play. The final theme expressed the trajectory of the performers through the residencies and rehearsals, from learning and building the movements and music to a state of embodied and playful performance. In the final rehearsals, D2 observed: "*We are faster with recognizing all the codons... It's really a huge difference if you are able to think less [and] it's very pleasant to be able to play more each day in the piece.*"

The progression towards more embodied states of performance also relates back to the balance between technology and human interaction. With the technology, the performers needed to concentrate less on cognitive tasks (like finding the next codon or identifying the correct choreography/music to perform). They were able to focus more on their interactions with each other: "*How do we check in with the technical information and still check in with each other to say it's a human endeavor, finding the next codon*" (D1). With time, the performers' use of, and reliance on, the onstage technology became a part of their embodied performance rather than a separate external process. In addition to the performers learning a new system, we also see the evolution the technology played. Through constant design iterations, the technology became more seamless and integrated into the dancers' and musicians' performances, supporting their embodied state and sense of connection to one another.

5 DISCUSSION

5.1 Embracing the artistic chaos

The themes identified in the interview analysis gave valuable insights into different and sometimes opposing points of view about the interplay between technology design and artistic creation. Our results show how people understood and embraced the creative process and technological integration in different ways. For example, the short timeline was alternately seen negatively as a limiting factor for creative exploration and learning of the piece and positively as a unique singular environment for highly focused and intensely creative work to take place. Interacting with the technology was also viewed through different lenses. For the performers, it imposed an additional and largely unfamiliar cognitive task on top of their own dance or instrumental performance (for example, interpreting binary codes delivered by the lighting cues), but it also

[10] http://www.lpdi.org/projects/stereo
[11] http://www.lpdi.org/projects/relative_collider

became a trusted and embodied part of their onstage performance that ultimately allowed them to perform the piece more easily. The ambivalent feelings that emerged from our interviews highlight the complex and occasionally chaotic relationships between stakeholders (performers, creators, and designers) and systems (interactive technology, gameplay, and dance/music performance) that underlie the creation of a digitally mediated performance.

It is impossible to think about the interactive systems design work without situating it within the larger creative process. We worked within a complex design space that unfolds according to the specific needs, contexts, and timelines of the work that contains it. Our findings echo previous literature that shows how designing within artistic contexts is a process that is both messy and non-linear [10, 17, 25], that can benefit from on-the-fly, iterative development to support interdisciplinary design environments [19]. Indeed, in our case, the technology needed to be able to support the creative work, a work (dance and music performance) that shapes itself according to the idiosyncratic approaches of a group of creative people working together during a constrained period of time. Developing technology within such a design space does not align with formal design methods. Our process consisted of small iterative loops where opportunities, problems, and solutions were identified and addressed on the fly as they came our way. For this reason, our design work required flexibility and, often, a degree of improvisation. Interestingly, in this way, it began to blur the line between "design" and "artistic creation", embracing the non-linearity and messiness as part of the process. At best, we viewed our work as a complex choreography of its own, with art and design freely intermingling.

5.2 Revisiting tensions between art and technology

In a sense, Godard and I (the first author) lived in different worlds when it came to designing and integrating technological systems. Godard was focused on the larger artistic creation and creating interactions that would support and advance the artistic vision. I dealt with the technical implementation of these interactive systems and was accompanied by ongoing stress and anxiety over the reliability of introducing experimental and untested systems that, at the end of the day, would need to "just work".

This divide highlighted tensions between the appeal of creating increasingly complex technical systems as part of the creative artistic process and pragmatic decisions to limit, simplify, or in some cases, abandon elements that could be more risky or unreliable from a technical standpoint. While the artist may strive to push the boundaries of technology for the sake of novelty, expression, or experimentation, the designer of the technology is bound by the reasonable expectation that systems need to be reliable and robust, particularly when the artwork is publicly shown and toured. Ultimately the sweet spot between the two has to be carefully negotiated, with consideration given to technical feasibility and artistic vision, as well as potential consequences of failure: what could be an acceptable risk for a relaxed performance in front of a familiar crowd will likely be unacceptable for a professional touring production.

This also raises the specter of funding as an additional, albeit highly important, consideration. Dance works (and artistic works of all kinds) are often produced on a limited budget. Therefore there are simple financial constraints when it comes to designing and implementing technology, as well as ensuring it is robust and reliable. While an unlimited technical budget could certainly alleviate some technical risk, this is seldom the case. Instead, we see limited funding as just another factor that comes to play in the negotiation between pushing and limiting the scope of technological integration in an artistic production.

5.3 Moving beyond technological demonstration

Negotiating technology within the artistic practice is not simply considering whether or not a particular system will function but also considering how it will fit within the artwork. For the third and fourth authors, it was important for the technology to exist in the background, without an overt visual presence, despite it being responsible for much of the structure of the piece. Much of the technology design was aimed at hiding it, making it an element that supports the performers while they focus on their embodied performance. In that sense, it is distinct from much of what exists in the literature on augmented and digital performances, where there is a strong tendency to adopt a technological focus and to give technology a leading role on stage and during the making process [27]. In our case, even the design and development of technology happened mostly off-stage. The tests were done mostly in intervals where the stage was not primarily dedicated to the embodied and choreographic work.

As discussed in Section 2.4, the physiological sensing systems designed for Fdili Alaoui's *SKIN* [17] were ultimately simplified or, in some cases, removed because they didn't serve the artistic aims of the work. Despite feeling disappointed by moving away from a fully interactive system, feedback from audience members indicated that they weren't missed. This prompted Fdili Alaoui to suggest that "the technology per se does not hold artistic value unless it is materialized by the interaction with the dancers on stage." [17]. Similarly to the work of Sarah Fdili Alaoui, instead of embuing technology with aesthetic value, we relegated it to its functional role, where it became a layer that allows artistic expression to unfold through the body and sound. The piece was thus not about showcasing the technology; instead, it relied on it to do the work of performing with the body and the instruments. This echoes Godard's goal to make a piece that is "a piece" and not a demonstration of technological features. By assuming such a background position, the technological design and integration were faithful to the intentions of the artists where the body is the work.

5.4 Reflecting on performance-led research

Benford et al.'s [2] three-phase model of performance-led research in the wild has offered a useful framework for the work we have undertaken. We began with the practice phase, building out technologies in a dance piece that is now touring. The interview study phase provided themes around designing and performing with technology in the interactive dance performance. Theory emerged

through reflection on the value and impact of our design on the creative work.

We discuss hereafter how one of Benford et al.'s challenges for the theory phase is a more general reflection on their model for performance-led research: the challenge of putting theory into practice. Our experience with this work reinforced our outlook on that interaction design in the arts is resistant to formalization. We have found it to be a dynamic, unpredictable, and messy design space. While a framework or guidelines like that of Benford et al. may work up to a point, they will almost always fall short in accounting for the uniqueness and complexities that are defined by multiple entangled interests, points of view, skill sets, and stakeholders. We see modeling these kinds of messy situations as an endeavor that may work in the lab, but in the context of rehearsals in real productions with so much at stake and so many interdependent variables, it is very difficult to formalize the process through concrete separate steps and challenges.

We demonstrated through this paper how each project, artwork, or collaboration brings its unique dynamics between processes and personnel. We find that this must be met with flexibility, patience, and a capacity to negotiate between stakeholders' priorities. Thus designers and developers working within artistic contexts need to meet the artists at a place of common ground and be willing to work in non-linear fashions.

We also showed how each stakeholder contributed their craft, comprised of their individual and combined experiences as dancers, musicians, choreographers, designers, and more, with their unique experiences brought from previous creations, artworks, design projects, and relationships. Thus we pose that, rather than try to describe our work to fit a predefined model such as Benford et al.'s three-phase model, we embrace the intertwining of stages and steps and responsibilities that unfolds from the artistic process made of the unique personalities that generate them, as the fundamental essence of our design work.

5.5 Reflecting on our blurred roles and first-person perspectives

The particular views presented in our account are deeply mediated by the first author's lived experiences as an active researcher, designer, developer, and member of the creative team. Indeed, I (the first author) had a clear responsibility to deliver tangible results for the production in the form of functional interactive systems that would fit the needs of the piece and, at the end of the day, these needs took precedence over adhering to, or developing, formalized design or research methods.

This paper is written from my own perspective and is shaped by my personal experiences that emerged from conducting the research, developing the system and working as an integral member of the creative team. These lived experiences — for example, the stress and anxiety that came from an unexpected troubleshooting session at the beginning of the second residency (described in Section 3.4.3), or the last-minute design of an interactive system for venue lighting (Section 3.3.4) — allowed me to reflect on the sense of urgency and unpredictability that are inherent to the process of creation, and that would have been hard to understand or convey from an outside perspective.

This first-person perspective is also evident in the interviews that I carried out towards the end of rehearsals, and the insights that they produced. The choice for unstructured, conversational interviews was mandated by the intense personal working relationships developed over long days of close, collaborative work with the creators and performers, and informal evening conversations reflecting on the days' events. The embodied knowledge that we shared, having participated in the same rehearsals, meetings, struggles, and achievements, allowed for the interviews to proceed naturally, and for topics to arise based on our mutual experiences and understandings without the need for prompting.

We note that this first-person perspective as well as having dual research and design roles, embedded on a creative team, can be seen as an extension to Benford's version of performance-led research in the wild. In Benford's version, the roles of various stakeholders are clearly delineated, as are the research activities conducted therein, whereas for us, these roles are decidedly more blurred, providing a deeper, richer and more personal account of the complex inner workings of the creative design process, from within.

6 CONCLUSION

This paper has presented a case study of design carried out within a larger artistic practice. We report the project from the firsthand perspective of the first author, who joined the dance production of the third and fourth authors to design interactive technologies that would be used in a new dance work. From an interview study with the performers and creators of the piece, we have identified themes that help us understand their perspectives on integrating technology into their artistic performance.

To conclude, we offer our outlooks on design practice within artistic production and implications for research. First, from our own experiences as designers, artists, and choreographers, we support previous findings that artistic creation is a messy space filled with wicked problems. However, we don't see this as a criticism. On the contrary, it is a dynamic and uniquely creative space that holds the potential for design to progress in ways not bound to formal conventions or linear structures. Second, in reflecting on art and technology collaborations, we find it most important to consider the relationships between the stakeholders and negotiate the appropriate balance between the people, processes, art forms, and technologies that can fit the larger goals and ambitions of the containing work. These are likely always shifting and changing and would benefit from flexibility and oftentimes a degree of improvisation.

Finally, we show the spectrum of complexity found in performance-based design practices, which are subject to real demands of production timelines, budgets, and technical limitations, as well as informal and idiosyncratic processes related to artistic practice. In this context, the lack of standardization of design methods is not at odds with HCI research; instead, it stands out as an exemplar to be studied and better understood. In this way, we see the potential for our findings in design for dance productions to be of value in other HCI contexts that are also resistant to standard methods and may call for more flexible design practices. This could include situations where researchers are working with heterogeneous populations, for example in the areas of critical computing, sustainability, and

social justice, where diverse needs and points of view need to be considered.

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