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Deconstructing Creativity: Non-Linear Processes and Fluid Roles in Contemporary Music and Dance

STACY HSUEH, Université Paris-Sud, CNRS, Inria, Université Paris-Saclay, France

SARAH FDILI ALAOUI, Université Paris-Sud, CNRS, Inria, Université Paris-Saclay, France

WENDY E. MACKAY, Inria, Université Paris-Sud, CNRS, Université Paris-Saclay, France

The stereotype of creativity as an isolated, individual activity has given way to a more nuanced understanding of creativity as a social process. Our interview study of 23 contemporary music composers and choreographers focuses on the role that artifacts play in shaping creative collaborations with performers. We found that creators and performers form relationships where the creator acts as *an author, a curator, a planner, or a researcher*, and the performer acts as *an interpreter, a creator, an improviser, or an informant*. Furthermore, we found that creators sculpt, layer, remix artifacts, moving fluidly across these different forms of interaction throughout the creative process. We conclude that the slippages that occur at the seams between roles and interactions drive creativity forward by opening up pathways into the future.

CCS Concepts: • **Human-centered computing** → **Empirical studies in HCI**; *Empirical studies in collaborative and social computing*;

Additional Key Words and Phrases: creative process; creative collaboration; distributed creativity; creative artifacts; contemporary art practices

1 INTRODUCTION

The traditional view of creativity as an individual process has given way to an *entangled* view [35], which recognizes the inextricable relationship between creators, social environment, and material resources in an ongoing process of co-creation. Recent scholarship in computer-supported cooperative work (CSCW) has foregrounded the social [22] and material [21] conditions of creativity. Works such as material roles in collaboration [54] and technology's role in remediating the traditions of craft-based creative work [13] aim to remedy the bias toward accounts of creativity as human organization of passive materials into preconceived forms. These works highlight instead accounts of what Ingold calls reading creativity *forwards* [33], revealing the unfolding character of materials and tools in creative work. Alongside this literature, cognitive scientists have contributed to the understanding of distributed creative cognition [40], conceptualizing creativity as a social and embodied process rather than a solitary activity that occurs in the mind.

The interplay between the social and material ecologies in creative work echos the larger CSCW perspective of practice as complex, ongoing interactions of people with each other and with artifacts [63]. Previous research has focused on the role of artifacts in collaborative work [49], such as sustaining cross-disciplinary collaboration [43, 59] and maintaining interdependent activities [57]. These works explore how the collaborative process is mediated by artifacts and seek an empirical understanding of the different ways they structure collaboration. From this view, work practices and artifacts mutually constitute one another.

Authors' addresses: Stacy Hsueh, hsueh@lri.fr, Université Paris-Sud, CNRS, Inria, Université Paris-Saclay, Bât 650, Université Paris-Sud, Orsay, F-91400, France; Sarah Fdili Alaoui, saralaoui@lri.fr, Université Paris-Sud, CNRS, Inria, Université Paris-Saclay, Bât 650, Université Paris-Sud, Orsay, F-91400, France; Wendy E. Mackay, mackay@lri.fr, Inria, Université Paris-Sud, CNRS, Université Paris-Saclay, Bât 650, Université Paris-Sud, Orsay, F-91400, France.

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CSCW researchers have examined artifact use in different practices such as architectural design [57], nomadic practices [55], and software development [15], but less often in artistic creative collaborations. It is here that boundaries between old and new, constraints and possibilities, designed and found objects are contested and negotiated. This paper focuses on the collaborative process seen in contemporary art practices. We seek to shed light on how artifacts configure practices and relationships in the creative process and to challenge the assumed linearity of this process and the rigidity of participants' roles.

Contemporary artists critically appropriate and invent tools, computational or otherwise, making these often transgressive practices a fruitful terrain for uncovering new insights about creativity [38]. This paper presents our interview study of the artistic practices of 23 contemporary music composers and choreographers, with a focus on the role artifacts play in shaping their creative collaborations with performers. We use artifacts as a lens into these creative practices to address two key questions: How do creators relate to performers throughout the creative process? What are the different ways creators interact with artifacts during collaboration?

Based on the results of the interview study, we first present a descriptive framework for understanding the different relationships between creators, performers, and artifacts across different contemporary music and dance practices. We characterize in detail the nuances of these analytic categories, charting the spectrums spanned. We then discuss how examining collaborative relationships and interactions in this lens lets us specify their effect on the creative process, deepening our understanding of how creativity unfolds.

2 RELATED WORK

We are interested in how creative processes are mediated by artifacts. We first discuss the different strands of research in CSCW and CSCW-adjacent fields that study artifact use in creative and collaborative contexts. Next we review literature on studies of the creative process as well as tools developed to fit within those processes. Finally we discuss the gap between theories on creativity and design of systems supporting creativity.

2.1 Material resources for creative collaboration

The CSCW literature studies both the role and use of artifacts during collaborative creative processes, particularly design. In architectural design, artifacts serve as external representations of information in the designer's head that helps them interpret the design [51]. Artifacts also serve communicative purposes in order to stimulate discussions around designs [45]. Henderson [28] argues that sketches are important because "they enable visual thinking, revision, and communication among designers".

Apart from facilitating the design process, artifacts also play important roles in coordination. Henderson [28] and Schmidt and Wagner [57] recognize the role of CAD diagrams as boundary objects [59], which serve as interface between different communities of practice, such as architects, engineers, and owners. Schmidt and Wagner [57] describe how design artifacts support group activities by enabling divisions of labor.

In addition to drawing attention to the artifact's ability to coordinate collaboration, other researchers demonstrate that, alongside the social and material arrangement of artifacts, the mechanics of human *interaction* with artifacts are important points of analysis [63, 64]. The goal of such interaction analysis [37] is to identify patterns of how people utilize material resources in complex social settings. For example, Mackay [46] observes how air traffic controllers communicate via physical interaction with paper flight strips: their annotations and gestures with regards to shared artifacts serve to structure and organize their group collaboration. In a creative context, Robertson [53] analyzes how designers of an educational computer game use various objects to facilitate communication among members of the group, introducing a taxonomy of embodied actions in

relation to physical objects, other bodies, and the physical workspace. Hsueh et al. [29] investigate the use of interactive visualizations in improvisational dance settings and develop a taxonomy of interaction patterns dancers form with technology.

2.2 Studies of creative processes

Parallel to the discussion of artifact use, scholars have investigated the socially and ecologically distributed nature of creative practices. More recent works advance the understanding of creative process as *entanglement* with sociomaterial dynamics and forces [13, 31, 50, 54], challenging and blurring the ontological separation between humans and objects in creative collaborative processes. Design research echoes this situated view of the creative process. Redstrom et al. [52] explores how designers engage in reflective interactions with design materials. Here, designers discover the emergent properties of the designed product through use that feed back into the design process. Similarly, Tholander et al. [65] argue that materials are not only "representational objects, but actants" that continually talk back to the designer. Drawing from a field study in architectural design, Jacucci et al. [36] argue that material objects actively contribute to the design process by providing "resources for persuasive, narrative, and experiential interactions". Lowgren and Stolterman [44] show examples of artistic practices where artists use the properties and qualities of the materials they find to guide and constrain their explorations.

We are particularly interested in studies of choreography [14, 39] and music [16], which offer a different lens into the creative process. Kirsh [40] examines choreographic method from the perspective of distributed cognition; Ciolfi et al. [14] study the general patterns of interaction in choreography in order to inform the design of interactive tools to support dance; Tsandilas et al. [66] investigate creative uses of paper in the music composition process; and Collins [16] studies the entire music compositional process, tracing the different phases of activity within that process. We build on these works to examine the use of artifacts in collaborative processes in music and dance: the relationships and forms of interactions that result, as well as their effect on creativity.

2.3 Digital tools for supporting music- and dance-making

Digital tools for music and dance aim to support different activities over the course of the creative process. In music, Buxton [9] identifies two types of digital systems for composition: computer-aided composition tools and algorithmic composition software. Algorithmic composition software generates musical content programmatically, "making music with minimal human intervention" [2], whereas computer-aided composition tools support exploration and rendering of musical ideas during composition. Although they share a common purpose, Buxton [9] argues that their difference lies in "the degree of interaction between the composer and the program during the realization of a composition". Computer-aided composition tools support various creative actions during composition, such as music representation and notation (e.g. OpenMusic [3], Sibelius [4]), sketching (e.g. Sonic Sketchpad [17]), and exploration (e.g. Inksplorer [24]).

Current creativity support tools in dance-making can be classified into four categories [1]: *reflective*, *generative*, *interactive*, and *annotative tools*. Reflective tools support viewing dance from various perspectives. *Synchronous Objects*¹ based on William Forsythe's *One Flat Thing Reproduced* is a series of collectively produced visualizations that reveal different choreographic structures and thus different perspectives of the dance piece. Generative tools generate movement materials that can be used by the choreographer during the making process. *DanceForms* generates different 3D skeletal postures [56] that serve as choreographic inspirations. Interactive tools support movement exploration by allowing dancers to interact with digital media. Examples such as *DS/DM*, an

¹*Synchronous Objects* website: <http://synchronousobjects.osu.edu/>

interactive system developed by Fdili Alaoui et al. [20], allow dancers to explore the dynamic aspects of their movements via embodied interaction. Finally, Choreographer's Notebook [10] is an annotative tool that serves to document choreography for review and editing.

Although empirical studies of creative practices argue for a more distributed view of creativity, bridging the gap between the creator and their environment, many prominent creativity support systems focus on supporting individual creativity, thereby reinforcing normative creative roles. This discrepancy between theory and existing tools raises important questions around the nature of the relationship between people and digital tools as well as artifacts in general: What roles do artifacts play in collaboration? What forms of interaction do artifacts enable? This paper addresses these questions by studying how contemporary artists appropriate existing tools as well as inventing their own. We argue that by mobilizing the social and interactive lenses of the creative process, we can deepen our understanding of what "moves creativity forward" [13].

3 METHODOLOGY

The choice of contemporary music and dance practices was motivated, first and foremost, by their practice of inventing or appropriating tools to achieve their desired ends. Their creative tool uses and inventions offer a nuanced view into a wide variety of artifacts, ranging from hand-drawn sketches to programmed computer scripts. In our case, artifacts include tangible, physical objects such as musical scores and instruments, but also non-object materials such as verbal cues and body movements. We adopt the view that design materials are not limited to physical materials [48, p. 175]: "Material (...) also applies to the abstract material used in the composition of a process (...) such as number, essence, and nature (...) Materials are what a designer brings together using structural connections or compositional relationships". By broadening the scope of artifacts to also include more abstract materials, we hope to more accurately capture the traces left during the creative process.

As critical users of technology, contemporary music and dance practitioners often challenge its presumed uses and apply it for other than its intended purposes. By deliberately "misusing" technology, they constantly redefine the boundaries embedded in and enabled by it. Former Guggenheim Museum curator Jon Ippolito likens the misuse of a tool to "peeling off its ideological wrapper" – doing so "exploit[s] a technology's hidden potential" [34]. Understanding the various ways artists use and (mis)use artifacts produces rich insights into different forms of working with people and materials.

We are interested in the collaborative role artifacts play during the creative process. We chose to study contemporary music and contemporary dance in tandem because they share a number of meaningful differences and similarities whose comparison should deepen our discussion around the collaborative aspects of artifacts. Music and dance can differ in how creative materials are captured and represented. Music composition, as a practice grounded in score writing, often structures work around physical artifacts such as paper and notation software. Choreography, on the other hand, is built on techniques about the body, movement, and time, and therefore keeps artifacts that are embodied (e.g. bodily movement) or dynamic (e.g. video). Despite these differences, contemporary composers and choreographers are similar in their focus on performance and that each pushes the limits of traditional creator-performer roles, exploring creative, collaborative relationships that go beyond "following" a score or choreography. These relationships are nuanced and complex and may involve a wider ecology of actors, including instrument-makers, sound designers, theater directors, etc. that are specific to each unique context. By focusing on the collaborative relationships shared between the two practices (namely, creator-performer relationships), we are better equipped to engage with the nuances in the distinctions between the two practices as well as compare across the artifacts produced and the processes pursued.

To understand how choreographers and composers generate materials for dance and for music, we chose to look at artifacts from the creator's point of view. This focus enabled us to trace the evolution of ideas from conception to their final form. We however recognize that there is not a clean distinction between creators and performers and that creators are not the sole generators of artifacts that contribute toward the creative end. We began from the creator's perspective in order to limit our scope to compositional practices in music and dance.

Participants: We recruited 23 contemporary creative professionals: 9 choreographers (7 female, ages 30-47) and 14 composers (4 female, ages 31-53) based in France (20), the UK (1), the US (1), and Germany (1). Of the 9 choreographers, three created pieces for solo dancers, the rest created pieces for multiple dancers (ranging from 2 to 6 dancers). Of the 14 composers, five wrote ensemble or solo pieces with electronics, four for orchestra (2 operas, 1 choir), three for non-traditional Western instruments (e.g. erhu, gamelan) or new instruments, and two for instrumental ensemble. The choreographers have between 5-20 years of experience, while the composers have 3-15 years of experience. All participants use at least one type of digital tool during their creative process.

Procedure: We conducted a variation of critical incident interviews [23] that focuses on uncovering stories about artifact uses. Each interview lasted approximately 90 minutes and took place at the participant's studio or a location of their choice. Two of the interviews were over Skype. We first ask each participant to choose a piece, either recently completed or in progress and to bring any work notes, sketches, or other artifacts used during the creation process. Next, participants describe each step of their creative process with regards to that piece, with particular emphasis on the artifacts or strategies they used to capture, represent, and transform their ideas. With the physical and non-physical traces of composition serving as a scaffold, we probe for stories during the compositional process about how they generate, explore, and communicate novel ideas, especially with respect to their collaborations with musicians and dancers.

Data collection: We recorded audio and video of each interview and typed or hand-wrote notes. We also recorded video of the composer or choreographer as they interacted with their physical or digital artifacts. Finally, we photographed each artifact they created for that piece.

Data analysis: We anonymized all interviews, and assigned each participant a unique ID: PM# for composers and PD# for choreographers. After transcribing the audio and video data, we used thematic analysis [8] to extract stories related to idea generation and exploration from all participants. We then assigned one or more categories to each story, looking for provisional trends to emerge during the first passes. After each pass, we performed both inductive and deductive analyses and iterated between story details and concepts until themes stabilized. All generated codes at each pass were reviewed and discussed together during weekly meetings.

4 RESULTS

We first introduce the creator-performer (composer-musician or choreographer-dancer) relationship types observed across participants and discuss them in the context of each interaction style. Each example includes illustrations of the artifacts created and used.

We use the term artifacts to broadly capture the material traces left during the creative process. We classify them as either providing structure, or *substrates* [25], or as structurable *content*. Examples of *substrates* include physical artifacts such as musical instruments, musical scores, and computer scripts for generating random pitch sequences; they also include abstract artifacts such as verbal prompts. They exist on a continuum, ranging from loose structures that are conducive to exploration to tight structures for interpretation. *Content*, on the other hand, groups together raw materials that are either tangible or embodied. Examples of content include musical notes and bodily movements.

4.1 Creator-performer relationships

We identify four types of relationships between creators and performers. Each category shows the respective roles the creator and the performer take on when interacting with an artifact, differing in skill and creative agency.

4.1.1 Creator as author, performer as interpreter. This relationship is the most familiar one, where the creator controls the overall structure and content of the piece and represents and communicates them via a physical medium (e.g. a score). The performer's role is to process and understand the creator's instructions and to develop their own interpretations. The performer's relationship with the creator in this scenario is both passive and active – passive in generating new content, but active in exercising one's expertise and negotiating it with the creator when necessary. Activities between the creator and the performer are separate; neither interferes with the other expertise. This relationship appears in all of the composers we interviewed, perhaps unsurprisingly, as music composition has a long tradition in the practice of writing scores. However, it can also be found in some of the choreographers (2/9) we interviewed who use written scores to communicate ideas to dancers during rehearsals.

4.1.2 Creator as curator, performer as creator. Some creators interactively create content with the performer. The performer provides the raw material (such as movement sequences produced during improvisation), and the creator acts as a curator, selecting from the repertoire of material to gradually construct the piece. The creator plays a directorial role, giving occasional prompts to guide the improvisation. Both the creator and the performer actively engage in dialogues about the creative content. This relationship is found in the majority of the choreographers interviewed (8/9), since dance-making often takes place during rehearsals with dancers. Several composers (3/14) also improvise with the performer at the beginning of the compositional process to generate content. One composer (PM10) in particular, adopts the improvisational approach throughout his entire process.

4.1.3 Creator as planner, performer as improviser. Other creators also improvise with the performers, but instead of selecting materials, direct their attention to the construction of the conditions within which materials are generated. Once the conditions are designed and set up, the performer has comparable level of authorship as the creator over the creative content, generating materials according to the conditions without further molding from the creator. The creator makes tweaks, when needed, at the structural level rather than at the material level. For example, a creator can design a rule system within which the performer improvises; the piece exists in improvisation form rather than a written or memorized score. This type of relationship can be found in both composers (6/14) and choreographers (4/9) interviewed.

4.1.4 Creator as researcher, performer as informant. Some creators initiate "consultation sessions" with the performer, usually at the beginning of the creative process as the creator tries to gather information about an unfamiliar area. For example, a composer (PM8) consulted a gamelan player in order to understand the harmonic possibilities on the instrument as well as playing techniques. Similarly, a choreographer (PD7) held rehearsal sessions with dancers in order to understand their individual styles so as to build the piece around them. The materials gathered here inform both the content and direction of the piece. This type of relationship is common across the composers (8/14) and choreographers (3/9) interviewed.

4.2 Forms of interaction

Below we describe the three primary ways creators and/or performers interact with creative artifacts, placing the relationships described above in context.

4.2.1 Sculpting. This type of interaction is characterized by the ways in which artifacts serve as sites for shaping activities. In these scenarios, the artifacts take the form of *substrates*, providing structures out of which materials may emerge. These materials may be generated by the creators themselves or by the performers, or even by a computer. Creators then iteratively *sculpt* these materials, which live across a spectrum of varying structural tightness, affording a range of interactions, from open exploration to constrained interpretation. All composers and choreographers form this type of interaction with artifacts at some point during their creative process.

Sitting at the exploratory end of the spectrum are musical objects and verbal prompts for improvisation. Composer PM14 composed a piece for a new instrument, called Babel Table (Figure 1), that consists of air pockets made out of latex. One changes the pitches on the instrument by turning nozzles that control the amount of airflow filling each pocket. The instrument-designer (who was also the performer of the piece), gave the instrument to the composer, who spent hours playing with it at his studio, paying particular attention to its sensual and material qualities. He described his exploration process:

The one master nozzle [on the new instrument] was the one thing that I knew immediately material-wise that it's what I'm going to end the piece with. Certain materials just have a level of gravity that it demands to place itself within whatever form emerges as you compose. There are two types of sounds that immediately demanded to be the beginning and the end and in between I [don't yet have a] clue. (PM14)

His exploration relied on evoking different responses from the instrument and letting them guide further explorations. He described the instrument further:

These membranes are latex-based. That latex is of a certain sort of age and [the instrument-designer] just replaces them when he knows they don't have the same flexibility they used to have. So the idea of pitch ends up being a question. Every single one of the nozzles have so many different possibilities in touch and it changes depending on the membrane and the airflow. (PM14)

In this particular example, we see that the instrument serves as a loosely structured space with rich musical possibilities within which the composer navigates in an improvisational way. The specific properties of the instrument determines how he will structure the piece:

"I've been recording all sorts of sounds I've been coming up with on the instrument (...) I will be sculpting actual phrases that will demand, just like the instrument demanded certain placements, it will also demand to be here and there in relation to [other sounds]. I will just be filling in the more totemic moments in the form. As I get to more and more details, the music will speak back to me. I will have a dialogue with it until the end of the piece." (PM14)

His process is similar to what Ingold refers to as following the "generative fluxes" of the materials [31].

The emergent character of PM14's composition process is also echoed in his relationship with the performer/instrument-designer. Unlike composing for a familiar instrument such as a violin, where the composer and performer have a shared understanding about how the instrument works, composing for the Babel Table involves the composer consulting the performer frequently about possibilities on the instrument or getting inspired by the particular ways in which the performer plays the instrument. Because only three people have written for this instrument before him, the

composer has to invent a lot of the notation. Traditionally, the composer-performer dialogue takes place through the medium of notation, usually towards the end of the composition process, where small adjustments to the notation can be made during rehearsals between the composer and the performer. In this case, notation is developed *with* the performer who offers suggestions such as creating a short-hand for a set of gestures he has already committed to muscle memory. The score produced is the product of tight negotiation between the composer and the musician, highly adapted to the individual and the context.



Fig. 1. PM14's air membrane instrument

Composer PM11 designed a series of interactive musical objects to be used as props on stage in an opera. Taking inspiration from objects found on the playground, such as sea-saws and merry-go-rounds, she created kinetic, mechanical objects embedded with sensors whose movements are translated into sounds. Like the Babel Table, these interactive objects contain a set of performative qualities she finds generative which delineate the space for exploration. She spoke about one of her initial ideas of a tube with a floating ball inside that makes different noises when one breathes into it:

I want the interactive object to be a toy that everybody knows and that isn't strictly a "sonic object". [The ball inside this tube] floats and has a random rhythm. It creates a sonic situation that is interesting. (PM11)

She described her process for choosing and designing these interactive objects:

I'm looking for something that evolves. It's not something that produces only one result or something that makes one [type of] sound (...) Actually I think about it in terms of instruments. With instruments, we talk about "degrees of freedom": you are free inside a "frame". You change the pitch, the speed, the timbre – those are the degrees of freedom – and as a composer, I make decisions about them within that frame. (PM11)

By identifying the manipulatable parameters of an object, she is able to exploit the musicality of them, i.e., the different ways one can control those parameters. She deployed these objects in rehearsals with performers where they explored the sonic space the instruments provided by mixing different pitches, speeds, and timbres, yielding interesting musical materials that she could compose with later.

Examples of similar structured improvisation abound in the choreographers interviewed (8/9). For example, PD7 remarked:

When I am developing movement vocabulary with the dancers (...) I often begin with a set of constraints to delimit behaviors, which I develop iteratively based on what I

am observing. This forms a type of "score", and within a performance there could be 10-100 of these, some of which I keep and some of which fade from the memory of the dancers over time. So, this score is in the form of verbal directives and physical memory, negotiated between myself and the dancers, and dancers with one another, as well as the shifting context in which they perform the "score" or "scores". In all cases, these "scores" are extremely mutable, and usually intended to construct a context in which the performers have to negotiate their habitual ways of moving in terms of quality, tempo, and pathways. As soon as the constraints are no longer constraining, they have to be tweaked. (PD7)

PD7's "verbal directives" help define the contexts the dancers inhabit. Just as tweaking nozzle configuration on the air-membrane instrument creates new contexts for exploration, modifying verbal directives sprouts new possibilities for movement. The verbal directive can be seen as puzzles dancers need to solve with their bodies. Instead of teaching the movement phrases directly to the dancers, PD7 plans conditions for novel problem-solving during improvisation by deliberately constraining the dancers' bodies in disorienting ways so that they break away from their movement habits.

In addition to the loosely structured artifacts for open exploration seen in the examples above, creators also create artifacts that more tightly scaffold a piece.

For example, composer PM4 planned rhythmic or melodic structures for specific sections before writing the music notes. He designed an algorithm that produced a random walk process, generating pitch sequences with behaviors he wanted for a particular section (Figure 2a):

In one section, I decided that I want the entire ensemble to start around a certain pitch and gradually climb to another pitch over the course of the section. So I built this little algorithm, which is this graph. Each instrument has its own line, and it's basically a random walk from the starting pitch [in midi] up to a different pitch. I had control over how much they can deviate. With one set of parameters, it would just be a straight line – everyone would go together. So what I did was (...) one of the parameters became a function of time that would become more random through [the middle], so gradually the different instruments begin to spread a little bit (...) making a big detour, and then gradually, everybody comes back up again. (PM4)

This pitch movement plot, if translated directly, "doesn't make much musical sense". It serves as a kind of constraint for the composer where he is "confronted with having to translate it into something playable" for the musicians, because not all of the frequencies generated by the algorithm are within the range of pitches possible on all instruments. In order to reconcile between staying faithful to the plot and composing feasible instrumental parts, he takes the pitches prescribed by the random process as suggestive musical directions. For example, when all the instruments were in a cluster on the plot, he ensured that the cluster could be heard ("if you're going to have somebody sit out, don't do it here, because you want that to be as dense as possible"). Similarly, when the plot showed a widening of space between instruments, he let that inform the musical decisions he would make later.

In addition to using an algorithmic process to generate reference pitch material, he also used it to build temporal structures across sections of the piece. Figure 2b shows the different tempo curves and alignments for different instruments over time. The vertical lines are moments where the instruments align. These lines were generated by a random process built in MaxMSP. The random process was shaped by his compositional decisions. For example, he knew he wanted "roughly 20 of these moments", with these moments "roughly equally distributed...sometimes close, sometimes not". With the process built, he can start "hitting the button" and tweaking things at the algorithm level until he finds a set of distribution he likes.

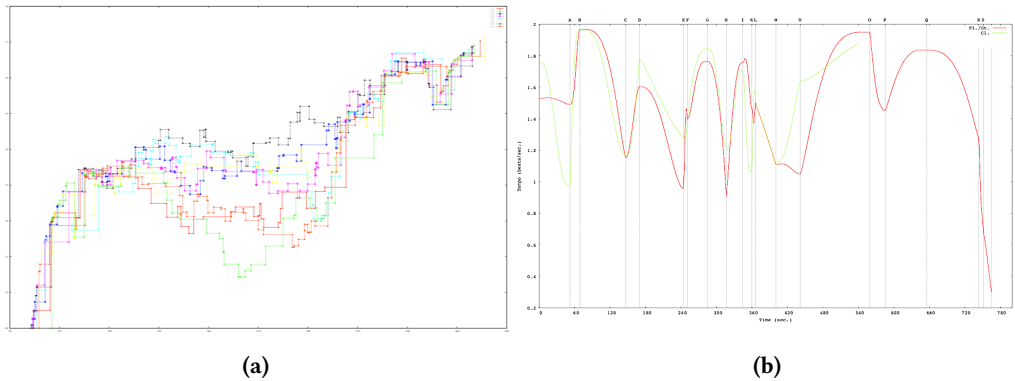


Fig. 2. PM4's sketches generated by algorithmic processes: (a) pitch sequences (b) tempo curves for different instruments (red: flute and strings; green: clarinet) and alignment lines

Composer PM7 also used algorithms to simulate a particular type of behavior:

I start building a diagram for the durations based on Fibonacci numbers. Fibonacci series allows me to have a proportion that maintains equilibrium. I improvise within this frame. During improvisation, I may change the durations, making them shorter or longer. I use [the Fibonacci] series to give me maximum variations, but it's not strict. (PM7)

In this case, this composer began with a general idea of the "type" of temporal progression he would like in the piece and let the algorithm guide his composition.

Composer PM6, while writing a piece based on Emily Dickinson's poems, created graphical sketches (Figure 3b) that captured her instantaneous reactions to each poem and turned them into something that could serve as musical direction. She invented symbols to capture specific "musical moods" and noted down any compositional information that may be of use later, such as sound registers and instrumentation (e.g. "woodwinds with percussions"). Composer PM1 followed a very similar process of graphical sketching to structure his composition (Figure 3a).

In these examples, the external structures (read: *substrates*) constructed by the creators directly organize the compositional material, delimiting its direction and overall form. The creator *sculpts* the work, shifting from open-ended curation to form-level adjustments.

Finally, at the constrained end of the sculpting spectrum sits material-level refinements, as exemplified by the different kinds of scores generated by composers and choreographers. The structuring capacity of scores are even more explicit here than in previous examples. The *direction* of material progression is relatively set, while the *expression* of the material is often left to the performer. Performers here have interpretative freedom and the creators further sculpt the materials generated by the performers. This is where all the composers end up in their creative process.

While not as common among choreographers, a few choreographers (2/9) generated scores for the dancers to follow. For example, choreographer PD4 spent a lot of her time producing scores adapted from Laban notation. She started by translating and organizing the conceptual ideas gathered about breathing techniques in yoga into different sections. She then began to draw spatial movement trajectories inspired by these breathing techniques, representing them in notational form. This became the first score. This score was then given to the dancers during rehearsals, where they interpreted and questioned it. She considered these rehearsals the "research" stage. At each rehearsal, she adjusted the score, which structured the dancers' movements, to align with what

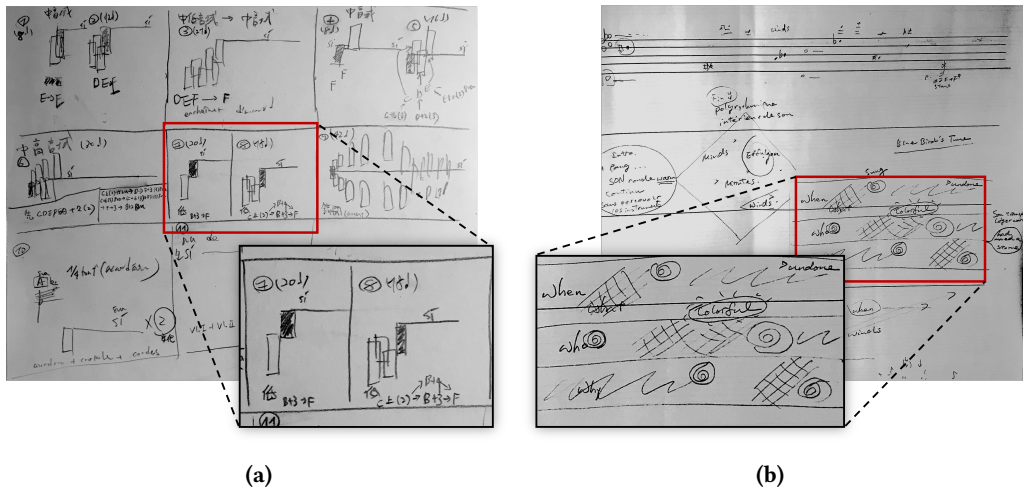


Fig. 3. Structural artifacts for *sculpting*: (a) PM1’s graphical representation of his "sonic ideas" for a particular section (b) PM6’s graphical sketches of his musical impressions when reading Emily Dickinson’s poem

she saw during rehearsals. She had "pages and pages of notes for correcting the score". While her "writing" process emerges alongside the dancers, it follows a clear structure centered on the score.

The artifacts used during *sculpting* provide scaffolds for improvisation, with varying levels of openness. These "scaffolds", be it a musical instrument, an algorithm, or a draft score, are sharable objects that structure co-exploration between creators and performers. The creator-performer relationships observed here span all the types identified. The key distinguishing characteristic of a sculpting activity lies in the *structuring* capability of the artifacts in supporting a tight feedback loop between creators and performers during idea generation. Instead of shaping the materials into a pre-defined form, *sculpting* focuses on designing the conditions to let the materials emerge, favoring active negotiations (where sculpting occurs) of material forces and creative tensions over uni-directional application of existing form over shapeless matter [32]. In other words, sculpting is a collective effort rather than an individual one.

4.2.2 Layering. This type of interaction is characterized by the different ways creators *layer* multiple artifacts together. These artifacts can either take the form of a *substrate* or embody *content*. Our interviews reveal that this form of interaction is the most popular amongst composers (11/14), whereas only one choreographer takes this approach when interacting with artifacts. The examples below illustrate how creators prepare different types of artifacts separately, and, once these artifacts reach a certain level of maturity, how they weave them together, overlapping them or stitching them together. The creators subsequently compose or improvise at the interstices of these layers.

For example, composer PM1 started his composition by first producing snippets of sonic materials that guided sonority, which later informed how he orchestrated the different instruments in the chamber ensemble.

I must know the direction of the sounds and know how to express them before I can start writing. For example, I may want a breathy effect for a particular section. I ask myself, "What can I make the instruments do to achieve that?" I can have the winds play pitched air notes and the strings play tremolo for example. (PM1)

During this process, he frequently consulted the saxophonist for whom he was writing the piece in order to understand his playing style. He held rehearsals with the saxophonist, asking him to create specific sounds (such as "*birds flapping their wings*") on his instrument. He collected a series of these "sonic ideas" in either audio-recorded or written format (sometimes graphical, sometimes notational) before stitching them together, arranging them in a rough order and filling in the gaps in between.

PM6 spent most of her composition time on creating different materials that would later be layered on top of each other to guide her score. First, she listed all the sonic possibilities of instruments that interested her ("*verify the kinds of sounds I want for strings and flutes*"), a process she referred to as "*instrumentation*". Only after the instrumentation was set did she begin to organize sounds ("*think about how these sounds can be combined together*") into specific textures (e.g. "*metallic*", "*wooden*"). Once she had created the texture reference sheet, the harmonic sequences (which she created separately from the textures), and the overall structure, "*the whole piece is there*", and she began to weave these components together.

Instead of layering *content* artifacts, composer PM4 created a series of structural artifacts, or *substrates*, separately before layering them. He wrote custom scripts in MaxMSP and Lisp which generated the data that served as the foundation on which he built the texture of tempos for his piece. Exporting the data generated by these custom programs to Illustrator, he wrote another script to generate 70 pages of blank score that had all the measures, beats, and subdivisions that he wanted to work with in the piece. He subsequently composed in front of a big table where he laid these score papers before him and started to mark off elements:

It's a combination of looking at the pitches that are prescribed by that process and looking at the notes I've made about the type of rhythmic texture I'm going to do. I then do a kind of free composing [while] looking for opportunities. For example, [there was] a random moment where [the beats and subdivisions] aligned, so I just stuck everything on. I also look for interesting relationships between things [such as pitches and rhythmic textures]. There's a goal of progressing from sustained note-y stuff to complex pointillistic stuff. At that point there's enough information to sit and work stuff out. (PM4)

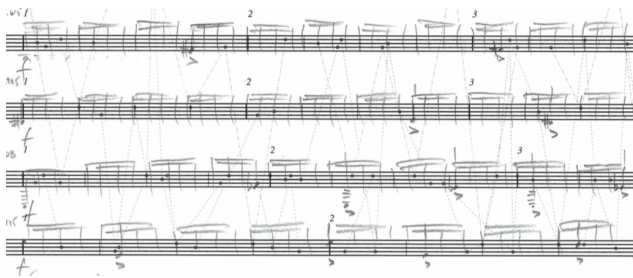


Fig. 4. Layering: PM4's draft score after free improvisation with the pitch sequence and the rhythmic textures (in dotted lines)

PM4 combined layers of structural artifacts (e.g. measures, beats, and subdivisions) and musical materials (e.g. pitch sequences), letting these components react and saturate into each other and then composing between the spaces.

Choreographer PD8 spent the beginning stages of his making process programming a system based on a video of pendulum waves that his collaborator brought in one day. The beads in the pendulum swayed back and forth in different directions before gradually synchronizing into a

harmonious wave-like motion. Inspired by it, the choreographer derived an equation that reproduced this motion and discretized it so it can be mapped to beats on a metronome ("*mapping each step in the sine function to a beat*"). By doing so, he recreated this visual motion along the temporal dimension. He translated the same sine-based function into a spatial floor map (Figure 6a). Overlapping the beats and the floor map defined a set of rules about how dancers can interact with and relate to each other, spatially and temporally.

As seen in earlier examples, artifacts used in this type of interaction are layered to provide roadmaps for further composition or improvisation. Depending upon how closed, e.g. *content*, or open, e.g. *substrate*, the original layered artifacts are, the new composite artifact can resemble a score or can structure an improvisation. This process takes place mostly between the creator and their artifacts. The collaboration with performers happens usually when the creator needs to collect information to inform the composition (*creator as researcher—performer as informant*). The creator translates this information into customized representations. Therefore, the artifacts can be seen as encapsulating localized expert knowledge of the performers and embodies a specific community of practice.

4.2.3 Remixing. The goal of this type of interaction is to generate alternative creative materials. The type of artifacts used here can either be *content* or *substrate*. This is reminiscent of the collage technique in visual art, in which cut-up scraps of images and texts are re-combined to form a new patchwork. Both composers (4/14) and choreographers (3/9) interviewed actively engage in this type of interaction with their artifacts.

Composer PM14, for example, talked about his practice of cutting up pieces of paper with the written score on them and putting them in different places:

Sometimes the materials that you write have too much directionality. They serve a lot of purpose. It's not interesting enough for the material to write itself out to an almost through-composed, teleological form. Instead, I try to use [the directionality] by recontextualizing certain material in certain ways that it didn't originally serve. I'll write a certain amount material, and I'll cut it up in a couple directions. I'll re-sequence it. Or say, "What happens if I take this material and put it over here?" [And I] see what kind of imbalances emerge within the form: "Do those imbalances actually suggest new pathways towards the end?" (PM14)

Similarly, PM11 and PM13 also actively chopped up composed bits and reorganized them to generate new materials. PM11 recorded snippets of her improvisations and worked with them in the Reaper software (Figure 5):

The "maquettes" are vocal improvisations that I use later for transcription. I record myself improvising with a metronome. I import them into Reaper. I then work directly on these recordings. It's really a collage. I make several versions of the same material. I listen, correct, choose, and iterate through these cycles. (PM11)

Similar to PM11, PM13 used a digital audio station (DAW) to arrange improvised bits during the compositional process:

With the lyrics from the lyricist, I start by improvising vocally on the lyrics. I record my own singing. I take apart words from 3 different languages and find the sounds that sound interesting together – especially ones with interesting variations in the consonants. I select [the ones that I like] and notate them. I use Logic or ProTools to select order for structural arrangement. I record different versions of the same phrase to find the better version. (PM13)

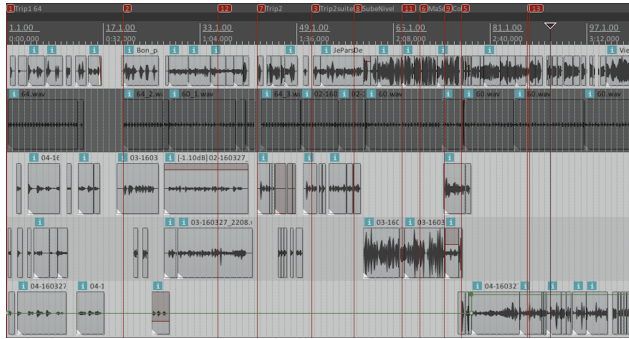


Fig. 5. Remixing: PM11's vocal improvisation "maquettes" using Reaper software

In these examples, musical materials have performative qualities that inform the composers. Composers decontextualize these materials by applying different types of transformations on them in order to gain different perspectives on the original material, suggesting directions to pursue that they may not have anticipated.

Choreographers often work in a similar fashion by remixing the movement materials generated by dancers. PD7, for example, choreographed specific movements that she taught the dancers after observing their movements. However, she saw the teaching process, not as faithful execution of the original choreographed movement, but rather as an "*interactive process*" within a shared movement practice, where movement materials were "*transposed*" from one dancer to another kinaesthetically and visually. Doing so allowed the dancers to sculpt and adapt the movements differently, letting their individual styles shine through. She then developed these movements further, negotiating her own aesthetic preferences into the process, often ending up with materials that she would not have come up with on her own. The transposition of materials, movement strategies, and ways of relating to one another or other stimulus in the environment provides a context into which she can bring the movement materials and "*let them be agitated*".

Choreographer PD2 also created a set of movement vocabularies with the dancers. Each dancer proposed a movement vocabulary (such as a *cartwheel*) and wrote it on a flash card (Figure 6b). All the cards were collected to form a pile from which random cards were drawn during "*fitness*" exercises at rehearsals. The dancers would then perform the corresponding movement on the drawn card. This is also a form of *transposition*, where different movement materials are transposed between different bodies, allowing dancers to try on movements generated by other dancers that may feel foreign to their bodies, thus breaking their original movement habits. After several rehearsals, the dancers could move fluidly between different movement vocabularies. Thus, they could perform the "random drawing" on their own during improvisation. Having the flash cards allows the choreographer to try and test different configurations, creating dances in real-time that cannot be choreographed by sitting and writing. PD2 echoed PD7's sentiment that this creates conditions for "*exquisite*" surprises to happen:

Cynthia, a seasoned performer (...) her ears are open. She sees someone doing something and can find a thing that's somehow complementary to it. In a duet with Maya, Maya started doing all these turns on the "cloche". And immediately Cynthia did a "pirouette" and a "noir". Maya turned this way, and Cynthia the other way. It was so stunning. It's the kind of choreography that you'll never be able to write. You can watch this for months. You can write it. But once it's fixed, it's no longer going to be interesting. They're writing choreography in real-time because they're listening to each other. (PD2)

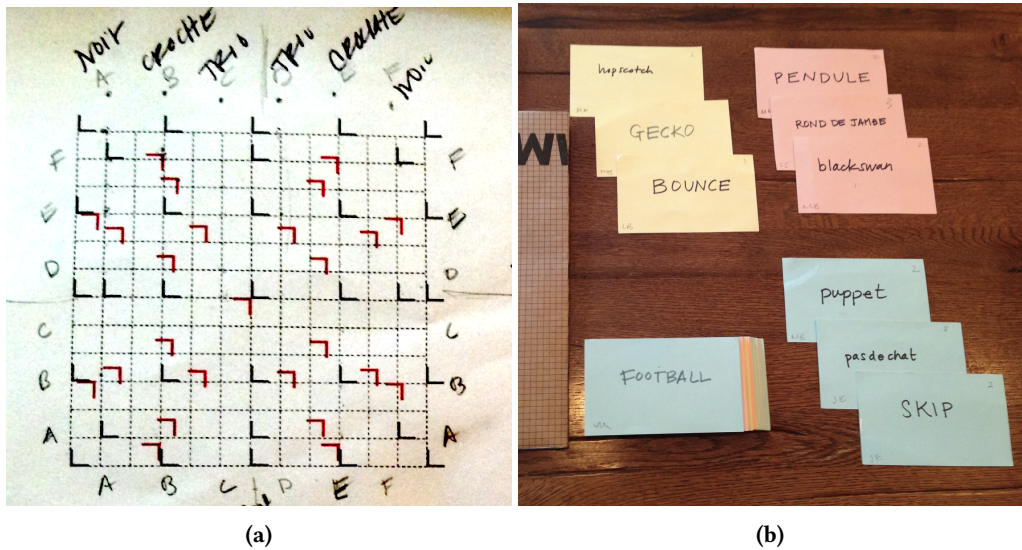


Fig. 6. (a) *Layering*: Pendulum-inspired floor plan by PD8 (b) *Remixing*: Movement vocabulary flash cards from PD2

In addition to remixing *content* artifacts, creators can create *substrate* artifacts that generate different alternatives. For example, composer PM1 created a model to generate musical materials. The model was based on the 12-tone technique, a common compositional technique in contemporary music used to generate variations in a melodic sequence. Instead of varying the melodies, he applied this method to vary chords where he "reversed" and "mirrored" the ordering of the notes in a chord. By doing so, he created all the possible variations of the chord, which subsequently became his compositional material. In this case, the 12-tone technique serves as a structure that guides how a variation can be applied to musical materials, such as chords.

In a similar fashion, composer PM8's piece utilized the idea of a "cycle", a structuring strategy he transposed throughout the piece:

This cyclic idea can be developed over the course of a chord, or over 4 measures, or 30. I also use this cyclic idea to change the timing of a melodic sequence (...) This cyclic idea becomes a structure that can be applied to the form [of the piece], the harmonics, and the chaining of harmonies. (PM8)

These examples demonstrate the generative capability of breaking up linear processes, juxtaposing and transposing them in order to bring into focus the latent possibilities residing in the fissures of the materials. While *remixing* can be carried out by the creators as they navigate through the material flows, it can also be implemented by structuring artifacts that set up recombinatory conditions, allowing space for permutations.

Unlike artifacts from *layering*, which are template-like, stable structures, artifacts shown here are ever-evolving and amorphous. They are characterized by their dynamic capability to generate multiple futures from existing materials. The most common collaborative relationships that form in remixing is that of *creator as planner—performer as improviser* and *creator as curator—performer as creator*. In these examples, the creator alternates fluidly between roles of a *planner* – making tweaks at the structural level – and a *curator* – selecting the materials generated by the performers during improvisation. The remixed materials often require an additional step of careful curation in order to sculpt these musical fragments into their final form.

5 DISCUSSION

Although we have "frozen the frame" and identified stable, observable patterns, the creative process is an ongoing, dynamic process in which these patterns are continuously mobilized. They weave together to form a textured space of social relationships, creative actions, and material ecology. The creative process can be characterized by the ways in which the creator weaves in and out of different forms of interaction with artifacts and different relationships with performers. For example, a creator can start by *layering* prepared structures and shift to *sculpting* the materials by improvising within the structure. The fluidity of the interaction patterns also influences the fluidity of the creative roles assumed by the creator and the performer, allowing the creator to shift from a *planner* to a *curator* for example. Over the course of the creative process, a complex assemblage of artifacts begins to crystallize and emerge, reifying patches of localized expert knowledge and compositional structures into an evolving ecology. We see, for example, how the saxophonist's extended technique of obtaining the "*flapping wings*" sound becomes embodied and inscribed into a paper fragment with scribbled symbols and notations the composer PM1 invents to represent the sound and technique. This musical fragment can be conceptualized as an "epistemic object" [11], or object of inquiry, that is characterized by its dynamic and open-ended nature, oriented toward "something that does not yet exist" or toward "what we do not yet know for sure" [47]. These stand in direct opposition to tools (seen as *technical objects*) that are used to achieve a particular end. Instead, epistemic objects raise questions and provoke people to collaboratively "find answers", developing a shared knowledge in the process [19]. PM1's musical fragments, for example, are epistemic objects because, by writing a proposition down on paper, the composer poses a question to himself ("*how can I create this particular sound on a saxophone?*") and subsequently attempts to answer it through a series of notational sketches. He also negotiates, through written fragments, with the saxophonist in order to come up with notations that align with existing instrument practices. Structuring artifacts such as composer PM4's algorithmic process that generates pitch sequences also share similar epistemic aims – the generated sequences serve as puzzles the composer poses to himself to be resolved. From this view, the creative process is not simply *mediated* by artifacts; it is an *enactment* of knowledge through interaction with artifacts [6].

Creative work, from this perspective, requires negotiation among a complex ecology of people and material. They create tension between two types of creative impulses: one that opens up divergent perspectives and another that synthesizes from existing ideas. These can be seen as a kind of "push and pull that moves creativity forward" [13]. In order to manage this tension, people mobilize diverse artifacts that allow them to easily shift between roles and forms of creative action.

While the artifacts generated in the creative practices we studied are in constant flux rather than fully formed [11], these can become temporarily immutable in order to scaffold the unfolding of other intertwining artifacts, as in the algorithmic process above. It is immutable when used to assign pitches, but quickly becomes mutable again when the composer adjusts the algorithm's parameters. We see similar *slippages* happen at the collaboration and process level – it is at these *slippery seams* that collaborative roles are redefined and creative focuses shift. We examine below how and when these slippages occur as well as how artifacts facilitate the shifting of roles and forms of interaction.

5.1 Fluid roles: perturbing creator-performer boundaries

Rather than developing separate practices with the dancers, choreographers construct custom environments within which a common practice between the choreographers and dancers is developed in tandem. This involves, for example, building a new movement language from scratch together with the dancers, as seen in the movement vocabulary flash cards by PD2. Each dancer contributes

choreographic materials that are remixed with the other choreographic materials created by others, and the authorship of the materials is distributed across the studio space. The choreographer, sometimes acting as a dancer, must also learn the language that emerges from joint practice. By teaching, learning, and negotiating choreographic materials together, the choreographer-dancer distinctions are blurred. Here, choreographers can easily become dancers, and dancers become choreographers. The constant re-definition of roles creates an embodied and constantly evolving practice that becomes incredibly generative. Because of the cross-pollination of different expertise in the studio space, the exchange of ideas is fluid and frequent. If a dancer wants to introduce new choreographic material into the piece, they can do so easily without worrying about disrupting the structural integrity of the piece, since movements are not constructed linearly but rather within an emergent structure.

This blurring of traditional creator-performer boundaries can also be seen in the wider music community. Lansky [42] challenges the overly simplistic Composer-Performer-Listener (CPL) paradigm (where "the composer writes, the performer plays, and the listener claps"), arguing for a more varied view of musical-social relations in the context of technology-mediated music-making practices. To show that the distinction between who produces sound and who creates musical content is more nuanced than one may think, he gives the example of composer Harry Partch who built and played his own instruments: "there was probably little distinction in his mind between building an instrument and composing the music for it." The multiplicity of roles performers and composers adopt and the flexibility with which they shift between these roles are echoed by Booth and Gurevich [7] who characterize creative roles as a set of "orientations" that can be dynamically taken up at any time during the creative process.

5.2 Non-linear processes: perturbing interaction boundaries

The traditional solutionist understanding of the creative process as composed of a sequence of linearly organized tasks, each disparate and intrinsically meaningful, suggests that the different forms of interaction can be packaged and codified into digital tools. Our interviews with contemporary composers and choreographers imply a more nuanced and complex view of this process that evades linear organization and clean separation of creative steps. The different forms of interaction from our study, i.e. *sculpting*, *layering*, and *remixing*, rather than existing as isolated activities, often seep into one another, reacting and mutually reinforcing each other. Creators move fluidly between these different forms. Cutting up written scores to find new directions is an example of switching between *remixing* and *sculpting*. Similarly, combining the different temporal textures (beats, subdivisions) and pitch sequences let composer PM4 transition smoothly between *layering* and *sculpting*. Creators mobilize a wide variety of tools in order to meet specific aims. The heterogeneity in the ecology of artifacts provides conditions for fluid transitions between these different interaction styles. Tools in these cases do not necessarily impose a particular form of working [18] that restricts the creators. Instead, creators re-appropriate various tools and reintegrate them into their existing work practices, performing what Suchman calls *artful integrations* [61], where "new forms" result, not from uncritical adoption of hegemonic technical systems, but from continual commitment to the coordination of different existing processes, environments, and structures. The ability to rapidly shift between different forms of interaction is enabled and supported by the complex ecology of artifacts. Each interaction style offers a particular perspective and associated creative focus, and by rapidly shifting between them, the creators position themselves at the center of constant flux, without fixating on a single point of view. In these examples, the transitions can occur at impressive speeds such that it becomes difficult to locate the precise point at which a particular creative action begins and ends.

These examples of transitions are similar to what Klemp et al. [41] consider the "coordination of past and future with the circumstances of the moment". Offered as a critique of the clean division between "planning and playing", they show how jazz musician Thelonious Monk turned a mistaken note during performance into a creative opportunity – in jazz, plans are "contingent formulations" [62] and are often abandoned for "nuanced innovation" [41]. Therefore, plans and mistakes are not ontologically separate phenomena but are interrelated and reflexively negotiated over time. When an emergent process is treated as a static entity that can be made more "efficient", the social and material dynamics that give rise to the "exquisite surprises" (PD2) disintegrate, giving way to monolithic, singular frames of reference. As shown by Henderson [27], the use of CAD/CAM system in an industrial design process replaces the messy, loosely structured [59] sketches with "pure logic, clean formulas, or computer-generated drawings", leaving out the crucial social mechanisms that help repair differences and issues and ultimately causing breakdowns in collaboration.

5.3 Slippery seams as catalysts of destabilization

Our study suggests that creativity should be understood as an ongoing process of negotiating a constellation of smaller mutually reinforcing processes [5], with continuously perturbed boundaries that are broken and rejoined. In other words, creativity can be seen "not just as activity, but as *interactivity*" [30], where boundaries between people, process, and artifacts do not circumscribe a stabilized activity that can be easily congealed and represented; rather, the boundaries are constantly redrawn in relation to the collectively coordinated practice. The artifacts produced and used in this process are characterized by their *epistemic* nature; their productive powers unfold through the slippages at the seams [12]. The type of work that catalyzes the slippages can be seen as a form of anticipation work [60], where pathways into the future are actively designed and maintained. This also echoes Ingold's view of creativity as following a *forward* trajectory [33], characterized by its "*becoming*" rather than solely by its "being".

We can understand the generative encounters between creators, performers, and artifacts as what Schön [58] calls the practice of "seeing-moving-seeing." It describes a kind of situated experimentation, where people test out hypotheses, try on new roles, and speculate futures. *Slippery seams*, from this view, are performative negotiations that take place in order for these experimentations to unfold.

The composers and choreographers from our study elaborate upon this dynamic by radically appropriating existing technology and inventing new ones. These artifacts, rather than closed systems with predefined functionalities, are open, fostering plurality of interpretative possibilities. Without privileging a specific point of view, the artifacts welcome multiple, distinct perspectives, enabling people to constitute their own relationships to them.

The slippery character of the various boundaries among artifacts, roles, and interactions calls into question the very nature of "boundaries" and highlights them as sites for critical inquiry. Deliberately perturbing these seams by creating *situations* for these slippages to emerge lets us explore alternative forms of anticipation work.

6 CONCLUSION

Our interview study with contemporary composers and choreographers contributes to the deepening CSCW awareness and orientation toward the social and material nature of creativity. It offers an analysis of the complex artistic relationships and artifact ecologies involved in contemporary music and dance practices. Furthermore, it provides an empirical account of how artifacts figure in creative collaborations by putting into relief the fluidity and multiplicity of roles assumed by creators, performers, and artifacts, as well as their effect on the shifting forms of interaction enacted among the same actants. We show that it is via these *slippages* between roles and interactions that

creative focuses shift and collaborative roles are redefined. To enable these slippages, composers and choreographers employ artifacts as *prefigurative* – rather than predefined and given – sites of inquiry and speculation for further assemblage and appropriation, provoking a kind of “collaborative search” [26] among people and material resources. Here, artifacts are not only used to execute or perform a creative task but also to stimulate processes of imagination, meaning-making, and new ways of looking, yielding creative contingencies that initiate surprises.

These slippages play an important role in pushing creativity forward by configuring the boundaries within social structures and material artifacts. They manifest the tenuous, oscillatory forces between spontaneity and originality. As we begin to understand boundaries as slippery seams – continuously crossed, redrawn, and permeated – we become attuned to the mediations and work that shift them. The accounts featured in this study illustrate how creators and performers create, shape, and reorganize artifacts together. They serve as evocative correctives to the accounts of top-down, isolated modes of creation. The unique and radically contextual tools and systems devised during these creative processes form an alternative view of creativity support tools that moves beyond productivist frameworks, toward revitalized values grounded in experimentation and openness.

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