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Published: 30 June 2025

Citation in BibTeX format

AM '25: 20th International Audio Mostly Conference
June 30 - July 4, 2025
Coimbra, Portugal

Harmonic Materials: Composing with found objects and a camera-based synthesiser

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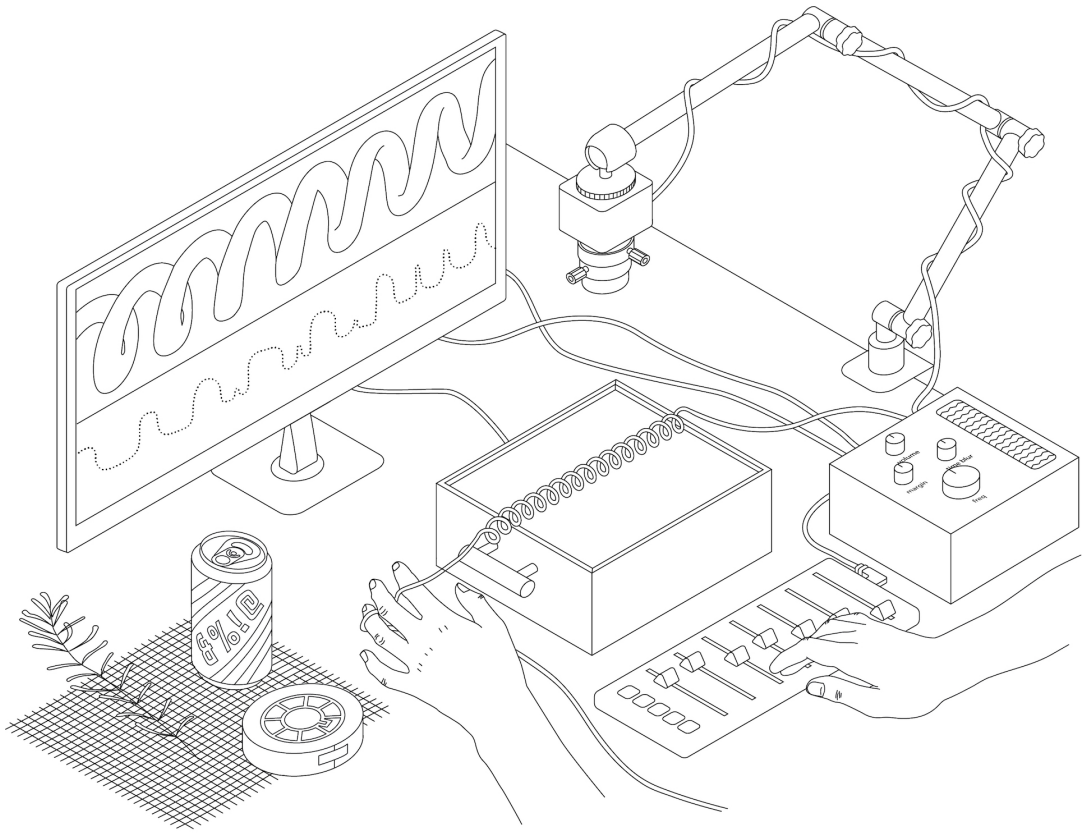


Figure 1: illustration of a bricolage compositional process, using the pattern organ, a camera-based digital musical instrument.

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AM '25, Coimbra, Portugal
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ACM ISBN 979-8-4007-2065-9/25/06
https://doi.org/10.1145/3771594.3771606

Abstract

Emerging discourse in Music Technology research relating to concepts of *material drift* and *decentring the human* often focuses on the design of new musical instruments, but has given comparatively less attention to the process of composing with them. In this paper, we investigate the sustained use of an existing interface, asking

how a materialist understanding might shift our conception of the compositional process.

Using a camera-based synthesiser called the pattern organ, we explore a bricolage approach to composition, where the agency of materials is made explicit, and where, at times, the composer influences rather than controls sonic output. Offering a fine-grained, reflection-in-action account of the process of composing a piece for performance, consisting of field notes, video documentation and a graphic score, we explore the compositional process through a long-standing 4Es theory of cognition, which proposes that cognition is Embodied, Embedded, Extended and Enactive.

We found that inserting physical materials into the feedback loop between the composer and the instrument encourages playfulness and indeterminacy in the compositional process, where shifting constraints choreograph unforeseen interactions. These interactions interlock in different ways, shaping a composition that emerges through the instrument's self-disclosure, as entanglements between player, instrument, environment and materials gradually reveal themselves.

CCS Concepts

• **Human-centered computing → Interaction design theory, concepts and paradigms**; *HCI theory, concepts and models*; Gestural input; Auditory feedback; Graphics input devices.

Keywords

Materialism, Bricolage, Distributed Cognition, Composition

ACM Reference Format:
Jasmine Butt, Nathan Renney, Benedict Gaster, and Tom Mitchell. 2025. Harmonic Materials: Composing with found objects and a camera-based synthesiser. In *20th International Audio Mostly Conference (AM '25), June 30–July 04, 2025, Coimbra, Portugal.* ACM, New York, NY, USA, 9 pages. https://doi.org/10.1145/3771594.3771606

1 Introduction

> *What indeterminacy in composition (which is to say, chance operations) and indeterminacy in performance share in common is their focus on the physical specificity of materials. Any result obtained through the physical nature of materials external to the mind is indeterminate because it is unforeseen to that mind.*
> Nakai on Cage and Tudor's *Variations II* composition, 2011 [21]

Following the critique of 'natural interaction' as a 'false holy grail' in HCI [12, 26], Music Technology research has increasingly been underpinned by entangled understandings, often informed by Barad's theoretical writings [4]. Within this framework of entanglement, interactions are not predetermined, or solely intuitive on the part of the player, but are the result of a process where instrument, player and environment mutually shape one another. Recognising these entanglements involves focusing on the interconnectedness of data, sound, material, and player, with the understanding that these elements are deeply interlinked.

This shift in thinking has encouraged greater focus on material agency in digital musical instrument design, however, emerging discourse has paid comparatively less attention to the compositional process. Research relating to materialist composition often draws heavily on the experimental works of David Tudor, John Cage and Alvin Lucier, and their notions of *self-composed instruments* and *inherent scores* [14, 21]. Contemporary researchers have applied these concepts to digital musical instruments, exploring how an entangled understanding of 'system' and 'composition' might shape the design of New Interfaces for Musical Expression [15, 33, 34]. Informed by this work, we ask how a decentred, materialist understanding of composition might be further developed through the use of a camera-based instrument that can be played using a variety of different materials.

To inform our approach, we draw on prior research around bricolage practices and 4E Cognition Theory. Bricolage aligns with a post-optimal worldview, involving a process of 'making connections between the tools and materials at hand rather than looking for globally optimal solutions' [35]. The 4Es theory helps us understand how such connections might be made, proposing that thinking is distributed across mind, body, and environment, and is Embodied, Embedded, Extended, Enactive [22]. Considering these concepts through one another gives us a framework for understanding composition from a decentred, post-humanist perspective.

This paper offers a fine-grained account of composing *Harmonic Materials #1*, a piece for live performance. The work uses a camera-based synthesiser called the pattern organ [6], inspired by optical sound technologies that translate patterns of light and dark into signal amplitude. Sound is synthesised through the particular way the instrument reads a physical object that is 'in-frame'. This form of agential noise-making, capable of unfolding without a human player, encourages composition that is not generated *for* a material, but *with* it. Though the pattern organ was designed to be used with visual patterns that are deliberately fabricated to produce certain sounds, this study followed a different path: The composition was co-created by different materials found close to hand. This process was documented using reflection-in-action field notes, video documentation and a graphic score.

The material generated in this study led us to consider a decentred view of improvisation and composition, where structure emerges through playful engagement with material differences. To better understand how structure arises from these interactions, we can frame this as a bricolage process, where human and non-human agents co-choreograph interactions that interlock differently based on constraints, imposing and shaping boundaries, and guiding the flow of an emergent piece. We also examine this co-constructed composition as a process of the instrument's self-disclosure, where relations and behaviours can be *tuned into*. Different discovered *tunings* can gather into an unfolding structure to be shared with an audience.

2 Related Work

This research is part of a larger project around the experimental use of analogue optical sound technology, exploring the experimental film community's engagement with materialist, audiovisual synthesis practices [1, 17, 18, 29, 32]. Considering how insights from

these communities might add to emerging discourse in HCI and Music Technology, we have outlined a number of areas in contemporary discourse that align with these practices, including *material drift*, bricolage practices, *inherent scores* and theories of distributed cognition. Although this paper departs from a focus on analogue optical sound practices, our ongoing research centres on the ways in which these areas intersect.

2.1 Material Drift and Bricolage

Recent HCI and music technology research has increasingly recognised material agency, countering dominant paradigms that assume their passivity. In recognising the 'vitality' of materials, we may begin to consider a *decentring* of the human in our design processes [9, 23, 24]. Research that adopts this perspective often adopts the language of transition and movement, where we can enable *material drift*, *becoming travellers* [10] and following the grain of a material, or the fields of force they impose. Ingold describes this as a forward creative process, weaving creative pathways in an ongoing, itinerant and improvisatory movement towards an idea [13]. This contrasts with approaches that begin with an idea and move backwards to figure out how to reach it, frequently relating to concepts of correct or optimal design. A post-optimal creative approach, one that embraces the notion of material drift, might engage in the process of 'ironing in the creases' [8], where perceived imperfections of a material or assemblage of materials are actively leaned into. Working with material drift requires an embodied skill, developed through the experience of practice [25]. Acknowledging the dynamism of materials, practitioners do not impose preconceived forms onto inert matter, but engage with materials as active entities in the process. A notion of Material Drift might extend to the wider surroundings, where an environment and the materials within it might provide mental scaffolding in improvisatory creative thinking [16]. From an entangled perspective, recognising the inseparable relationship between matter and meaning, material agency becomes particularly evident when considering the cultural values embedded within materials, such as a keyboard enforcing a discretized Western scale [19].

Bricolage is a design practice that draws on available materials and resources, creating through the connection of these materials, tools, and cultural relationships. It involves using 'whatever is at hand', often drawing from a treasury of materials and ideas [3] that have been accumulated from previous projects, and producing an output that represents the intersection of what is already there, and what is needed [35]. The bricoleur's task involves a process of deconstruction and reconstruction, using structural patterns and engaging in a dialogue with the available resources. This approach, characterised by in situ assemblage and modification has been explored in an audio HCI context in a number of ways, including the act of 'un-crafting' to construct new interfaces from the dissassembled pieces of others [2, 20], and the act of 'Rummaging', where found objects collide with player, microphone and each other in different ways, resulting in a multitude of sonic textures [5]. At the heart of the bricolage process lies improvisation, which is often regarded as a cornerstone to the theory of distributed cognition [7].

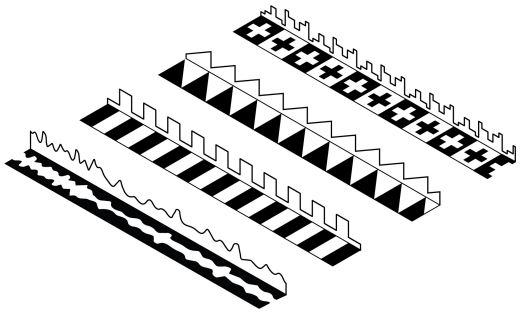


Figure 2: illustration of an averaged, one to one luminance to amplitude visual to audio mapping

2.2 Distributed cognition - the 4Es

Understandings of a materialist, bricolage practice can be framed effectively using the 4E's theory of cognition. This theory presents cognition as embodied, embedded, extended and enactive.

Embodied cognition suggests that cognition is inseparable from and moderated by bodily conditions that reflect physical aspects of reality. This encompasses sensorimotor capacities, sensation, emotion, and physical movement, bridging body and mind. A bricoleur's ability to work with materials is deeply rooted in embodied cognition, shaped by tacit knowledge, existing skills, and the ability to translate sensory-motor experiences across contexts [11, 36].

Embedded cognition positions cognitive functions within the environment, extending through interaction with external structures and the information they encode. It emphasizes that thinking is not siloed, but is shaped, supported, and scaffolded by wider ecological dynamics [30]. Bricolage provides a compelling example of this relationship, where practitioners draw upon objects and their embedded meanings within their immediate surroundings to create something new [35].

Extended cognition recognizes tools as integral to cognitive processes, functioning as amplifiers that enhance thought and action. This might incorporate interactions with other agents, forming a shared cognition facilitated by their interactions. In musical contexts, this can be seen in co-performer interactions, while for the bricoleur, it is evident in the repurposing of tools and artifacts, which extend cognitive capacities into new creative domains [3].

Enactive cognition provides a description of cognition as mediated through patterns of interactivity with the world, shaped by the continuous exchange between embodied and embedded processes. Meaning and intention arise through a bidirectional relationship between beings and their environment, described as co-adaptive links [7]. In a bricolage process, this enactive process weaves together the sensory processes of embodied cognition with the embedded knowledge of materials and surroundings, fostering an intertwined relationship with tools and resources [30].

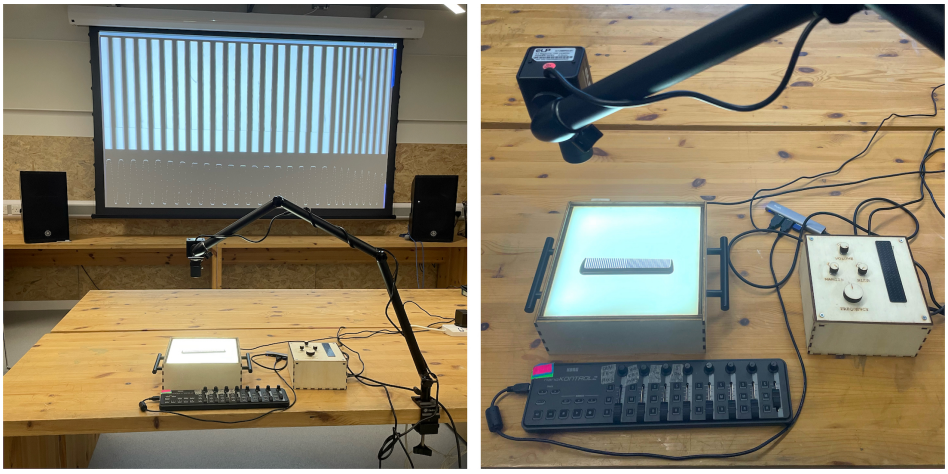


Figure 3: photograph of the pattern organ in its current configuration, using a light-box and found objects (in this case a comb).

2.3 Inherent Scores

Recent discourse in Digital Musical Instrument Design has noted a collapse of the boundary drawn between instrument and composition. The concept of the *inherent score*, first articulated by Alvin Lucier [14], suggests that the structural configuration of certain musical instruments can embody a composition. In his book *Sonic Writing*, Thor Magnusson notes that the words 'system' and 'composition' are etymologically linked, and that the understanding of a 'system as a composition' has roots stretching back at least two millennia [15]. Tomás and Kaltenbrunner have examined how the notion of the *inherent score* can inform musical instrument design, through their Tangible Scores project, where scores are inscribed into interfaces in a way that entangles 'reading' and 'playing', as well as gestural and sonic input [33]. Tomás has explored how design concepts like *Tangible Scores* and *Choreographic Objects* (objects that instigate and organise movement and awareness [37]), reveal 'the mediated relationship between performer, score and instruments' [34].

While this research increasingly draws on discourse around the *inherent score*, this particular study explores the compositional agency of a collection of objects. It outlines a process of composing that makes use of a graphic score, separate to the instrument's interface. This approach is inspired by the graphic scores of John Cage [21] and Eliane Radigue [28], which often detail actions to be performed rather than predetermined sonic outcomes.

3 Method

This research presents a fine grained account of the composition of *Harmonic Materials #1*; a piece for a public performance using a self-designed instrument. Using a 'reflection-in-action' approach [31] that aims to account for the more-than-human [27], the first author created field notes over the course of multiple compositional sessions, paying attention to the interplay between materials, environment, instrument and themselves, extending reflection past their own intentions and critiques. Video documentation was made of certain material experiments in order to share the multi-modal details involved in the process (links are embedded in the text next to the play symbol: ►) A graphic score was developed over the course of the compositional process which served as a guide for the performance itself, as well as a visual document of the way that the composition came together, offering further material for analysis and discussion.

Although documentation and materials were made for the whole composition, the authors chose to narrow the focus to one section of the piece in order to offer a fine-grained account for the purpose of this paper.

4 Instrument

The pattern organ in its current configuration, visible in Figure 3, comprises a Raspberry Pi running a Pure Data (PD) patch which processes graphics using the Graphics Environment for Multimedia (GEM). The patch takes a 1-500 pixel variable horizontal slice from the middle of a 2448 x 1080 pixel live camera feed. To construct a wavetable, the mean average pixel luminance across the height (y dimension) of the slice is computed for each x pixel, resulting in a one dimensional array that refreshes at the camera's frame rate. This mapping is illustrated in Figure 2. This dynamic array is normalised to a float in the range -1.0 to 1.0, and written into a wavetable, to be scanned at a controllable speed. The graphical interface, visible in Figures 3 and 6, shows a black and white slice of the camera feed, a visual graphic of the one dimensional array, and a visualisation showing the shape of the shifting wavetable.

The instrument has a time blur parameter, that smears information in time, smoothing transitions between frames. For this composition and performance, the wavetable was continually read by 7 oscillators, ranging between 20 and 200Hz. A midi controller is used to switch between different oscillator tunings and control the volume of each oscillator with separate faders. The pattern organ is open-source, and PD patch and documentation can be accessed here.

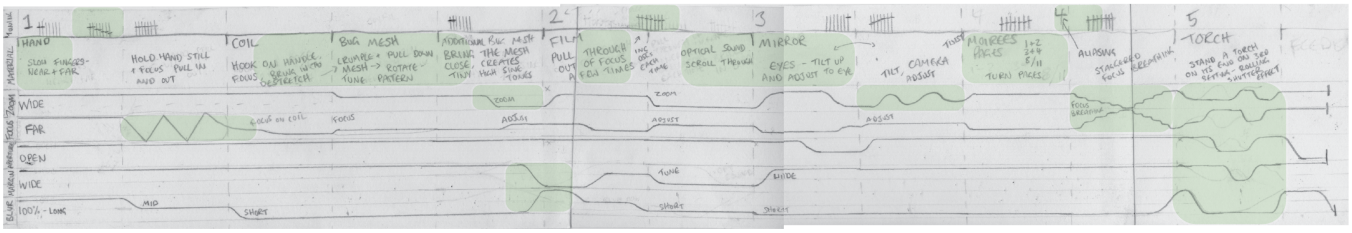


Figure 4: sketched out score of *Harmonic Materials #1*, used to guide a live performance (with additional highlighted parts for analysis)

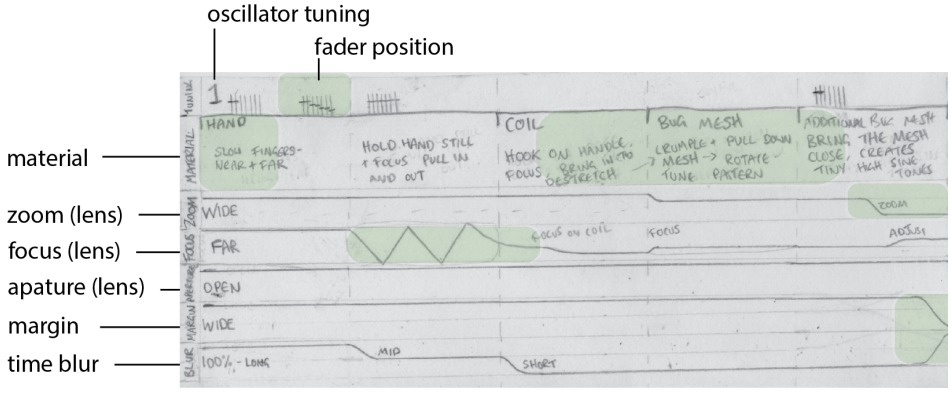


Figure 5: A section of the *Harmonic Materials #1* score

5 Composition

The materials used across the *Harmonic Materials #1* composition are: the performer's hand, headphone wire, insect mesh, 16mm film strips, a mosaic of mirror, a book of moirée patterns and a torch. We will explore a fine-grained account of the process of composing with the first three of these objects. Excerpts from field notes are quoted as written, and presented in italics. The resulting compositional score, developed during this process, is visible in Figures 4 and 5. This score was sketched and rearranged as interactions played out, aligning with Ingold's view of a forward momentum. Once the opening material interaction was decided, the compositional process took on bricolage tendencies, where interesting interlocking and contrasting interactions, arising from what was available, were discovered, noted and utilised.

5.1 Hand

The hand may not be easily considered a 'found object', but it has always served as a test tool in the context of using the pattern organ, used to check that the sound engine is running before a material is placed into frame. Having settled on a plan to use the instrument to 'tune in' to objects found to hand, the hand felt like a natural place to start. While exploring instrument's parameter limits, as well as gestural movement in and out of the frame and focus range, possible compositional pathways began to emerge.

> *start light with a long blur - allows for very simple and soft harmonic movement. The first time I felt emotional playing the instrument.*

The use of maximum blur and a wide open aperture offered a space at the extreme limits of softness and ambiguity. This afforded an opportunity to slowly reveal visual and sonic textures.

> *The nice thing about the time blur control is that if you hold your hand still - a form will shift into focus - it gives a really nice attack, and so a gesture only comes into 'focus' and informs the sound if you really want it to. You can bring a slow pulse - a rhythmic element in by resting on certain gestures. This slow pulse allows me to gradually introduce the higher frequency oscillators and allow an atmosphere/emotion to build.*

The shifting latency of the time blur parameter allows subtle harmonic capabilities to be introduced slowly, using spacing between fingers. This gestural interaction gives two opportunities to disclose the workings of the instrument: to show that different intervals of light and dark give different harmonic results, and to provide a gap between gestures, where different oscillator volume faders can be brought up, building polyphony.

> *Once all oscillators are up - the crescendo of the hand will be to introduce focus sweeps that bring the fingers in and out of focus ... the contrast introduces some harsh square wave type sounds. So they can emerge and shrink in the sound as the camera is 'tuned'*

- ▶ Finger Counting Harmonics
- ▶ Focus Sweeping

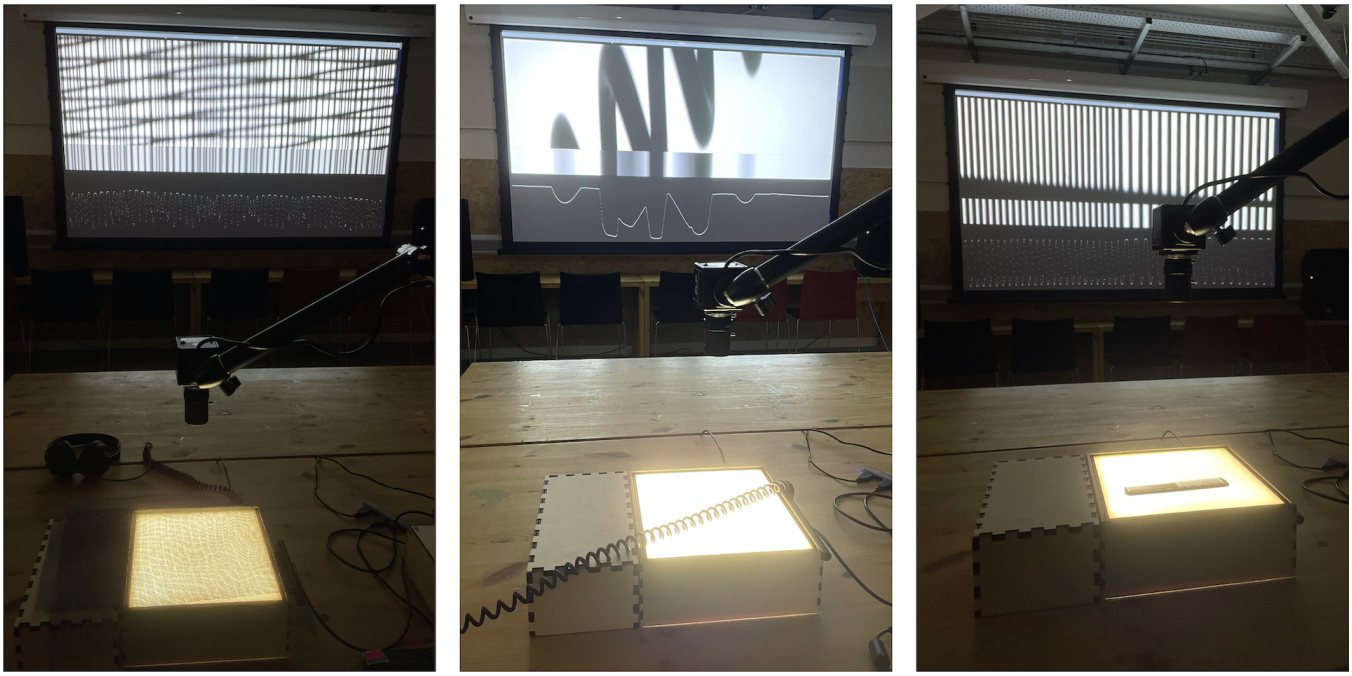


Figure 6: the pattern organ with different physical materials: insect mesh, headphone wire and comb.

5.2 Headphone wire

The headphone wire unintentionally sounded during the process of tweaking the pure data patch. This sparked a moment of gestural exploration using the coiled wire, stretching and releasing it in frame to create sweeping rising and falling harmonics.

> *While programming the instrument, leaning over - my headphone wires entered into frame.... Starting out stretched and creating a rise in pitch with slowly bringing the coils together.*

The tension in the coiled wire allowed these harmonics to be swept at a constant speed. This opposing force smoothed the gestural control, much like the bearings of potentiometer, offering a good first opportunity to reveal some of the harmonic capabilities of the apparatus. The materially constrained gesture introduced an interesting compositional challenge, that ended up dictating the material ordering of the piece.

> *The problem comes when this process finishes - what to do? My hands are tied, I have to use my hands - both now in frame - as a way to end this build up somehow...* (Next day) *What if I drag something down into frame - something thin that can be pulled down unexpectedly? So I tried it with the bug mesh, which I wanted to use anyway at some point. It is still very quiet - but introduces a high electric ringing, I really like the effect.*

This act of pre-positioning a prop gave the performance a sense choreography and flow between transitions, ensuring that the camera frame is not 'empty' and encouraging a more fluid use of gesture and material.

► Releasing headphone wire tension

5.3 Insect screen

The insect screen was in the vicinity as it had previously been used as a tool to demonstrate visual interference patterns. The intricacy of the material and the way that two layers interfered with each other created a multitude of surprising interactions and sonic outcomes.

> *It's so fine that any small movement has a really big effect on the sound. you can zoom right in and there is still a lot of detail and high harmonics... Rotating one over the other is interesting - a sort of heterodyning - creates these lower difference frequencies that can appear and disappear quite easily... focal range is small for such an intricately detailed pattern... nice when you bend it - if you do it right, you can create a swell of low freq as the bands gather...*

One of the most surprising of these encounters came about in learning that the instrument was seeing (listening to) patterns that were not discernable in the graphic interface - in this case, one that was so far out of the focus range that it became invisible.

> *Something odd happened - the mesh disappeared totally out of focus - but its movement was still audible. Really delicate light sinetones - like a whistle!*

A second unexpected discovery was the direct correlation between the visible interference pattern on the material itself (not just through the camera lens viewed through the graphic display)

and the wavelength of the beat frequencies. Despite its interruptions (existing within a wavetable) it remained perceptible as a continuous frequency.

> *If I see an interference pattern across the mesh itself, I can hear beat frequencies in the harmonics they produce! The narrower the pattern, the quicker the beating.*

One last playful encounter occurred in a game of chance afforded by the margin and time blur parameters. Turning the margin down to 1 pixel and the time blur up to full, the instrument took a course snapshot of the way the two pieces of mesh interacted.

> *I like that a 1 pixel margin (and high time blur) showcases just how different the freqs and tones can be when you place the bug mesh down differently - you don't even have to try to change it - it's that delicate... really feels like a game of chance.*

This sustained snapshot of ringing frequencies was used as a transitional tool to end the insect screen section and move on to the next material.

- ▶ Rotating one piece of insect screen
- ▶ Playing with insect screen interference
- ▶ 1 pixel harmonic snapshots of the two screens

6 Discussion

6.1 Physical Materials and Improvisation

Stepping away from the generation of new patterns, the first author instead explored the inherent structures within various found objects. This played out in a process of decentred improvisation, where the material agency of objects found close to hand was made explicit. This ability for the instrument to couple with different found objects extended material composition to include the act of foraging for objects in the surrounding environment. These different objects entangled in unexpected ways with the instrument, each one encouraging unanticipated interactions.

Viewing this compositional approach as a bricolage practice, we can observe that a treasury of interactions was built upon as each material was explored. These interactions became the building blocks from which the composition was constructed. The hand offered an immediate and simple way for the player to introduce harmonics: using the simple pattern of one, two, three or four fingers under the lens. The sprung headphone wire enabled a controlled rise and fall of perceived pitch, while the insect screen, when layered, introduced delicate beating patterns that required time for the listener to adjust. With the unfolding of these new interactions came new constraints that guided the work towards unforeseen compositional pathways, lending structure to an emergent plan.

We can understand this compositional process as a product of a distributed cognition, where thinking does not occur solely in the mind of the composer. The bricolage composition began by leaning into material exploration and indeterminacy, and gradually took on a more defined form, shaped by the properties and affordances of the physical materials themselves, as well as the shifting gaze and interests of the composer.

6.2 Materially Constrained Choreography

One significant constraint imposed by the materials concerned the gestural manipulation of patterns. The physical materials themselves informed an unfolding choreography, shaping the composition. Revisiting bricolage practice, these choreographed movements can be seen as building materials, not forming a predetermined whole, but interlocking in various ways, with some materials and interactions fitting together well, while others were more resistant. These moments of compatibility or friction play out noticeably in transitional moments. The clearest example of this can be seen in the headphone wire segment. The wire's coiled structure affords a controlled increase or decrease of harmonic content, perceived as a rise or fall in pitch. This enabled a gradual crescendo by manually reducing tension in the coil. At its peak, both hands were occupied within the frame, introducing a rigid constraint and preventing the use of the camera lens or other controls to exit the segment. In order to avoid moving everything out of the camera frame, and introducing a sonic gap, the only option that presented itself in that moment was a material one, requiring a suitable material to be within reach, graspable by the fingertips in order to transition to the next segment. These gestural interactions are not only constrained by the physical materials but also the instrument's configuration. For instance, gestures that fall out of focus or blur across frames due to the time-blur control lose their ability to interact quickly with the instrument. Here, composing becomes about actions and materials, not the resulting sounds. The sounds are the result of an entangled, choreographed action. This understanding comes with the precedent that all gestural interactions with an instrument are constrained. There is no such thing as a 'natural' interaction, and there is no separating the gestural interaction from the material it manipulates or the interface that senses it.

6.3 The instrument's self-disclosure

Another factor contributing to the unfolding composition lies in the gradual unveiling of the instrument's capabilities. In order to uncover these capabilities, the composition becomes a shifting gaze, bringing different aspects into focus at different times. Considering this, the first author highlighted sections of the graphic score, marking the parts of the instrument that seem to come into focus at different points in the piece. Sections with expressive parametric change such as the zig-zagged focus towards the beginning of the piece, turn their attention towards the particular abilities of the camera lens. To disclose these capabilities, we inevitably look *through* certain elements of the apparatus. The hand serves as a tool for observing the lens's behaviour. Composition becomes a matter of revealing possibilities afforded by the instrument's parameters, camera lens, physical materials and gestural manipulations. These possibilities can be seen as different tunings, not in that they require careful treatment in order for something to align harmoniously, but in that each tuning brings to light different possible entanglements between material, player and instrument.

7 Conclusion

This paper considers the ways in which a bricolage approach to compositional practice might enable *material drift*, and in so doing, decentre the human composer. In this study, we reflect on the



(a) Photograph of the first performance, courtesy of Adam Reid, Schwetphoto



(b) Poster of the Resonant Kinetics event, hosted by Copper Sounds, design by Guillaume de Ubéda

Figure 7: First performance of *Harmonic Materials #1* in February, 2025, at Strange Brew, Bristol, UK.

notion of an *inherent score*, but one that exists within the situated and emergent relations between instrument, composer, surrounding environment and found objects. A bricolage approach creates structure from a treasury of interactions, which inter-lock to build a composition that, when performed, unfold as the instrument's gradual self-disclosure. We can further ground this thinking in the theory of 4Es cognition, which would understand composition as the result of distributed thinking.

This research raises questions for further exploration, including:

- How might we further understand the concept of an *inherent score* in the context of the digital musical instrument as a loose assemblage, where composition exists within emergent relations between instrument, objects, players and environments?
- How might we consider 4Es cognition in relation to sustained making processes, when crafting patterned materials to constitute a composition?

8 Statement of Ethics

This work is part of broader PhD research that has been ethically approved by our university's Faculty Research Ethics Committee. Given the nature of this specific study, no additional ethical considerations are required.

Acknowledgments

Much thanks to Matthew Olden for his help and advice with GEM in Pd.

TJM gratefully acknowledges funding from UKRI (grant number MR/X036103/1)

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