



Human-Computer Counter-Choreographies: Raising Awareness of Data Tracking through Live Coding

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Abstract

In this paper we describe how we designed the performance *Human-Computer Counter-Choreographies* (HCCC) using a methodology that borrows from artistic research, critical design, choreography, and embodied sense-making. HCCC is a live-coding performance in which I (the first author) manipulate JavaScript code and use a modified version of the open-source DuckDuckGo privacy extension to unveil online tracking algorithms on stage. Throughout the performance, the audience is encouraged to participate in a sequence of choreographic prompts where they embody aspects of online tracking such as fingerprinting and profiling. We analysed audience responses to questionnaires after three performances of HCCC and found that it allows audience members to gain awareness and engage their bodies to critically reflect on online tracking. We contribute a new approach to live-coding that bridges choreography with online tracking, and we present empirical findings on the efficacy of this approach to engage audiences in reflecting on data tracking.

CCS Concepts

• **Applied computing** → **Performing arts**; *Media arts*; • **Human-centered computing** → *Systems and tools for interaction design*; **Web-based interaction**.

Keywords

live-coding, performance, online tracking algorithms, user-data, extractivist technology, algorithmic awareness, choreography, embodiment, critical reflection

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1 Introduction

Algorithmic systems are often made opaque by design, and users are unaware of how much of their data is being collected [53] and for what purposes. Algorithmic systems have been reported to inflict harm and perpetuate inequality in various ways [42]. Among these systems are online tracking algorithms, which are present in most web services [43]. Surveillance capitalism [75] has been the driving force of online tracking technologies for decades. The advertising sector is at the forefront of collecting extensive datasets on online user activities to perform predictions and feed advertising technologies that serve targeted content and ads to influence user behaviour [71]. Tracked data can be demographic data, such as age or geographic location, or metrics associated with user engagement, such as number of clicks, scroll percentage, or time spent on a webpage.

Various countries are regulating the use of user data in algorithms and computational systems. An example is the General Data Protection Regulation (GDPR) law in effect in the European Union (EU) since 2018. This law established new parameters for data rights, privacy policies, and transparency of data processing, and introduced binding sanctions that can be imposed on companies that fail to comply [43]. However, a study measuring the impact of GDPR on the Web concluded that although overall transparency in data collection and processing has increased, there is no evidence that online tracking has decreased [43]. The reasons for this are many; including the violation of GDPR requirements [68], the use of deceptive design and dark patterns. Dark patterns are manipulative and deceptive functionalities employed in digital systems against the best interest of the user even where they comply with GDPR [12, 31].



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In this paper we present an artistic research which aims to heighten people's awareness of online data tracking. To do so, we pose two research questions:

- RQ1: How can we design a choreographic live-coding performance that reveals data tracking algorithms in web environments?
- RQ2: How does such live-coding performance support audiences in gaining awareness of data tracking?

To address RQ1, we first present a performance called *Human-Computer Counter-Choreographies* (HCCC). We introduce the performance design, detailing the methodology used to create it that borrows from artistic research and critical design (Section 3.3), followed by a description of the performance design from the first-person perspective of the first author who is also the maker and performer of HCCC (Section 3.4). HCCC combines live-coding with choreographic methods to expose online tracking on stage. HCCC uses custom-made programming scripts and a modified version of the DuckDuckGo privacy extension [30], an open-source tool that monitors online tracking, to make the trackers visible and audible on stage. Throughout the performance, the audience is also encouraged to participate by following a sequence of choreographic prompts that embody various aspects of online tracking, such as fingerprinting and profiling.

After three performances of HCCC, and to address RQ2, we gathered the audience's responses to questionnaires (Section 4) and analysed them using thematic analysis. Our findings show that HCCC allowed audience members to gain awareness and engage their bodies in critical reflection on online tracking. Our contribution in this paper is two-fold. First, we present a new design approach to live-coding practices and human-computer interaction (HCI) that bridges choreography with online tracking. Second, we share our empirical findings on the performance's efficacy in engaging audiences in reflecting on and critiquing data tracking.

2 Related Work

We begin with a summary of live-coding approaches in HCI. We then discuss works in HCI and artistic communities that engage the body to critically reflect on technology and its impact on society. Lastly, we focus on performance approaches that use browser-based technologies on stage. We describe how our work builds on, complements, and extends existing research in these fields.

2.1 Live-Coding in HCI

Live-coding, also referred to on-the-fly or just-in-time performance [8] is a practice where computer code is written live in front of an audience, making visible the algorithmic processes the performers undertake. A live-coding performance is typically set up with projections that allow the audience to follow the algorithmic compositions being created. It usually incorporates other practices and expressions, including visual and music composition, choreography, and poetry.

The principle of making the code visible, by displaying the performer's screen, is a common characteristic of most live-coding performances. One of the lines of the TOPLAP manifesto, first drafted in 2004, says: 'Give us access to the performer's mind, to the whole human instrument. Obscurantism is dangerous. Show us

your screens.' [70, p. 247]. There are different motivations for live-coding performers to want to share their software and tools with audiences. Inherent in this gesture is the quest for transparency that gives 'technical credibility (even virtuosity)' [8, p. 4]. For others, the didactic quality of exposing the coding process is the driving force. However, transparency in live-coding is always partial and selective [20], as live-coding languages have many levels of operational abstraction that are not entirely visible to the audience. Sound, visuals, movement, and audience interaction complement the display of the code and the resulting sensorial experience. Blackwell *et al.* highlight the capacity of live-coding to ask 'questions about liveness, inviting us to reflect on what it means to be live — to have bodies, to communicate, to act' [8, p. 2].

Various contributions from HCI have explored live-coding to better understand live-coding processes and performance work [56, 66] or its potential in pedagogy [61]. Although most of these examples are centred on music composition and tools, recent approaches embrace interdisciplinary work. An example is the live-coding environment *CO/DA* that facilitates the real-time manipulation of motion data of one or more dancers and can be programmed to generate audio feedback on the fly [28]. To add to the diversity of approaches, the research project *MosAIck* [72] connects live-coding practices with dance mediated by e-textile sensors.

In 2023 the International Live Coding Conference (ICLC) hosted an evening programme dedicated to the theme 'Choreographic Coding'. Two out of the three keynote speakers, Kate Sicchio and Marije Baalman, presented their embodiment-focused live-coding practices. In Baalman's theatrical piece *The Machine is Learning*, she trained a machine to detect simple gestures that she performed, yet it repeatedly failed to do so accurately. In her piece *Untitled Algorithmic Dance* [62], Kate Sicchio fed images of bodies in motion to a t-distributed stochastic neighbour embedding algorithm (t-SNE), producing new choreographic scores which were interpreted during live performance. In *Codes for a Dance* [63] Sicchio and McLean interact with two robots on stage through a series of gestures that influence the soundscape. These works explore the tensions between machinic interpretation and human agency, often resulting in broken expectations. At times, the algorithm misinterprets the dancer and vice versa, which invites the performers to embrace improvisation and adapt their response to the algorithms.

The work in this paper draws from this history of novel approaches to live-coding that, like our work, integrate choreography and embodiment as integral aspects of the performance. The specificity of HCCC is to add choreography to live-coding in order to engage the audience in embodying the algorithmic concepts displayed.

2.2 Embodiment and Choreography as Critical and Reflective Methods

HCI has seen an increased interest and attention to bodily, felt experiences and tacit knowledge. Established methods include live-action role-playing and scenario enactment [55] and bodystorming [36], among other examples drawn from theatre and performance practices [51]. These methods emphasise the generative and creative potential of physical involvement through learning by doing or using physical movement [48].

Beyond being valuable for HCI, there has been a growing interest in incorporating embodiment and sense-making approaches as a means to foster greater algorithmic awareness [35, 41, 49]. Some approaches incorporate immersive theatre or artistic performance, such as the *Embodying the Algorithm* project, in which a group of performers embodied algorithmically produced instructions [40]. The authors investigated how embodiment can be a useful lens to examine Large Language Models, such as GPT-3, and their lack of consideration for the human body.

Another example is *Quantified Self*, an immersive theatre experience that combines design fiction and user enactments to engage audiences in the discussion of technology ethics [64]. For each performance, audience members supply their social media data (e.g., Facebook or Twitter) to shape a personalised experience where they interact with performers and technological artefacts in the performance setup.

Backhouse *et al.* made use of Forum Theatre, a technique by the Brazilian theatre maker Augusto Boal, to involve audiences in reflecting on the impact of engagement-based algorithms [3]. The authors describe engagement-based algorithms designed to boost platform engagement by prioritising content that will provoke a user's reaction, such as 'liking' or 'sharing' types of interactions [3]. Backhouse *et al.* demonstrate how Forum Theatre is an effective tool to increase algorithmic awareness. In a similar vein, Bhargava *et al.* [7] introduce the concept of Data Theatre as an entry point to growing data literacy by engaging participants emotionally in the embodied performance of data stories.

The DoxBox Trustbot by Alistair Gentry [29] is a mobile, digital puppet device designed to conduct interviews with users about their interactions with various apps and digital services. It detects the extent of information these providers have about their users and shares stories about the potential consequences of this knowledge. It also offers recommendations on the trustworthiness of these entities, considering both the individual user and others who might be affected to varying degrees by the collection and potential misuse of their digital data.

Dance and choreography have also been critically engaged in these topics. One example is the initiative *Cryptodance* [11], which hosts events with the intent to collectively reflect on issues of privacy, safety and surveillance through embodiment and dance. Another example is the piece *Data Sensorium* which uses dance to visually convey environmental migration data [23]. Through choreographed gestures symbolising various disasters, and spatial movements representing population displacements, the performance offers both dancers and viewers a visceral and visually engaging experience.

Sarah Fdili Alaoui developed a performance called *RCO* [2] that creates situations where dance and technology converge, asking both participants and artists to respond to instructions on their mobile phones. Although *RCO* doesn't explicitly focus on online tracking, it more broadly asks those involved to reflect on social and technological norms. It also provides a means of resisting and breaking free from these influences, offering alternative perspectives with humour and irreverence.

The works referenced above bridge embodiment with performance practices, including dance and physical theatre, to increase data literacy and critical reflection on data and surveillance.

HCCC adds to this body of work by integrating embodied sense-making to prompt audience members to enact physical and choreographic actions (e.g. standing up or making hand gestures). In doing so, we guide the audience to embody concepts related to online tracking, to grow awareness and provoke reflection on user agency (or lack thereof). The choreographic influence here comes from the view of the Brazilian theorist André Lepecki of choreography as a control mechanism and the need to question how to assert our freedom of movement and agency in societies that are intricately, if subtly, controlled [46].

2.3 The Browser as a Stage

As browsers have expanded their graphic and audio capabilities, a growing number of browser-based live-coding environments have emerged [58]. The development of these environments started as early as 2012 [52], examples include *Gibber* [57], *LiveCode Lab* [39], *Hydra Synth* [38], *P5.js Live* [22] (which integrates various creative coding libraries), the node-based platform *Nodysseus* [54], *Cascade* [4] (which maps HTML and CSS attributes to sound), *Strudel* [59] (the web version of *TidalCycles*), *Sema* [5] which integrates machine learning, and others.

The artist Joana Chicau has produced various live-coding performances (e.g. [18, 19, 69]) using built-in browser developer tools to manipulate code in real-time and modify the appearance of web-pages. She also incorporates dance and choreographic notations into her performance work.

Another example of sourcing and remixing material from a pre-existing platform is the project *Live Coding YouTube* by Lee, Bang and Essl [45]. This approach differs from the previous one in that the authors use a custom interface that allows them to search and display streaming media instead of using the YouTube platform itself.

In the online publication *Flee Immediately* [17], the editor Renee Carmichael created a series of instructions using the iconography of hand gestures to guide the user, step by step, on how to navigate the browser. In her editorial text *Care to Dance?* [16], she repurposes the dance notation Laban, to define a user choreography that involves actions such as 'scrolling', 'zooming' and 'breathing'. In doing so, she draws attention to the design of the user experience, the interface environment, and the specificities of the browser.

Various web extensions have been created by artists and creative technologists in response to concerns about online tracking and algorithmic surveillance. For example, the piece *Listening Back* [34] employs an add-on for the Chrome and Firefox browsers that maps Internet cookies to different sounds, creating a melody while browsing. Although this work was presented as a performance, it focuses on the sonic qualities of cookies and does not involve other forms of embodied interactions. Other work includes *GoogleTeller* [37], a tool that makes audible each packet or tracker request sent to a Google service. The plug-in *Safebook* [33] removes all Facebook content leaving the interface as an empty grid of white, grey, and blue circles and squares. Finally, *Demetricator* [32] removes all metrics from the Twitter feed. These last two interventions question the quantifying nature of these platforms.

The performance HCCC expands on this prior work by exploring browser-based live-coding in order to critique online tracking.

Although online tracking is pervasive, bringing these algorithms to centre stage to reflect and interrogate them is far from a user's daily experience. The format of a browser-based live-coding performance in HCCC opens possibilities to witness in-action algorithms that are most often obfuscated and made invisible to users. HCCC does so by interweaving live computer programming of the browser, and choreographic methods in an engaging and interactive way.

3 Designing HCCC

3.1 Intentions Behind the Performance

In line with our research question 1 (introduced on Section 1), HCCC was created with the intention of increasing awareness of online tracking. The performance piece builds upon the artistic practice of the first author and her engagement with live-coding and its community (further contextualised in Section 3.2).

The design of HCCC focused on four main aspects: the browser design (Section 3.4.1), the visualisation and sonification of trackers (Section 3.4.2), the choreography of audience participation (Section 3.4.3), and the dramaturgy (Section 3.4.4). Note that choreography is not only a contained element, but also an overarching one which binds together trackers' exposure and audience involvement.

3.2 Positioning Who We Are

I, the first author, have been an active member of the live-coding community for almost a decade, and I have created several live-coding performances. In my practice, I explore the use of built-in web development tools, such as the console, and how I can manipulate content from existing webpages using JavaScript. I am inspired by web and net art and interested in the web browser as a medium for artistic expression and critique. The latter led me to investigate the algorithms that operate in that space, such as data tracking which became the focus point of HCCC.

In addition, I have dance training, in classical and contemporary among other genres, and I have collaborated with various choreographers and dance companies. My lifelong commitment to dance shapes my approach to creating live-coding performances and the incorporation of choreographic and embodied methods as described in 3.4.4.

For this performance, I draw a parallel between the web and choreography to reflect on data traces and user's agency online. More details on the connection to choreography and how this approach is deployed are given in Section 3.4.

The second, third and fourth authors constitute my Ph.D. supervision team. They collectively bring expertise in live-coding, dance, human-computer interaction, design, and data ethics. I have had sole responsibility for the performances. The roles of my supervisors in this work have been primarily to advise on the research approach, assist with reflexive thematic analysis (especially second author), and to advise on and contribute to the writing of the work.

3.3 Design Process

3.3.1 Artistic Research. We followed an artistic research methodology [13] where we focused on the act of creating a performance piece in relation to online tracking algorithms. Similarly to research through practice, our artistic research approach is based on the development of knowledge that emerges from the first author's

creative practice and her reflections on it. The research is reported from the first author's perspective, thus embracing a first-person perspective. First-person methods in HCI include autoethnography, autobiographical design and research-through-design [50]. They allow the researcher, designer, and author to continuously create, construct, and/or utilise their own designs [24]. Our process involves placing the first author at the heart of their design process and the lived experience of utilising a system.

In Section 3.4, we present our artistic research based on an autobiographical process that led the first author to produce a live-coding performance that uses custom-made programming scripts and choreographic prompts to reveal online tracking live on stage. The design process centres around the first author's background, skills and interests in live-coding to gain deep and long-term insights into designing the performance and reflecting on its impact on people.

3.3.2 Critical Design. In the fields of art, design, and computer science, there is a legacy of methods and approaches for critically reflecting on technological artefacts and their impact in society by investigating them as socio-technical systems [10]. An example is Critical Technical Practice [1], which sees technology development not as an end in itself, but as a means to reflect on the assumptions and attitudes underlying the relationship between technology and humanity [25]. Similarly, Critical Design is one form of research through design [74], that produces critical artefacts that encourage users to assess how assumptions, values, ideologies, and behavioural norms are embedded in designs that mediate their lives [26]. In the vein of Critical Technical Practice and Critical Design, we designed the custom web extension described in Section 3.4.1 and 3.4.2 as a discursive artefact that provides a critical lens for audiences to reflect on the prevalence and evasiveness of the online algorithms it exposes. The motivation behind the custom web extension goes beyond the technical artefact and towards sensitising audiences and making abstract concepts related to data tracking more tangible, visceral, and embodied, through visualisation and sonification techniques. To this end, there is less concern for the code achieving a specific practical goal other than raising critical awareness.

In addition, we use a critical approach to design the participatory aspect of the performance, which consists of moments in which audience members respond to choreographic prompts with simple actions as a form of enactment of tracking strategies. These design decisions are described in Section 3.4.3.

3.4 Performance and System Design

In this Section, we provide a first-person account of designing HCCC from the perspective of the first author, who is both the performer and maker of the performance. As part of her autobiographical design process, she documented the performance-making process by keeping written notes of the steps she went through during creation. She also collected screenshots of visual experiments alongside saved versions of code. For this paper, we revisited all this material to retrace her journey of making this performance piece. In addition, all three public performances were video recorded, making it possible to rewatch and reflect on them afterwards.

3.4.1 Designing the Browser. My process for creating the piece started by investigating different web browsers (such as Chrome, Firefox, Tor) and how much information could be inferred in relation to tracking requests. In parallel, I investigated purpose-built tools, such as browser extensions, to enhance privacy while browsing online. I decided to work with the open-source DuckDuckGo privacy extension [30] in the Chrome browser as it seemed a malleable and well-maintained tool, providing more granular information on tracking requests compared to other choices. With the aim of exposing online tracking to audiences, I designed a custom version of the DuckDuckGo extension that maps each tracking request to audio and visual feedback in JavaScript. During the performance, I use this extension in combination with additional programming scripts, written in the same language as described next.

Additionally, I chose to use Google search engine because of its popularity with users in Europe and USA, where the performances took place. This means that audiences can immediately identify the interface and relate to its navigation gestures. In addition, Google corporation is at the forefront of the ad networks market which heavily uses tracking techniques to target users with personalised content [71] making it relevant for me to expose their strategies when addressing data tracking.

I divided the browser window into two: on the left side, I displayed the websites being navigated, and on the right side, the developer tools. I run and modify code on the browser developer tools which displays in real-time on the browser interface. While most code functions are pre-written and assigned to a specific section of the performance, some changes to the code are made live, for example, to highlight or change the scale of the visuals on the screen. My choice to display the console relates to the principle of algorithmic transparency advocated by the live-coding community. Although my practice consists of manipulating and parametrisating pre-written code instead of writing code from scratch, it qualifies as live-coding. As introduced in Section (2.1), there is no formal definition of live-coding nor a defined measure to how much coding needs to be written live to make a live-coding performance. One of the earliest definitions of this practice refers to ‘tweaking or writing the programs’ live [21, p. 321]. In fact Blackwell *et al.* resist claiming a particular definition as doing so would establish control over that which is an open and evolving practice [8]. In HCCC, live-coding consists of displaying the algorithms live to advocate for algorithmic transparency in response to the trend of hiding algorithms from users. The fact that the code is projected during HCCC allows me to perform impromptu modifications to it to better communicate the main aspects of online tracking to the audience.

I designed the browser to have overarching sonic and visual aesthetics, using the metronome as an ongoing sound and the pink-colour theme as a visual style. I chose the metronome’s sound as it is commonly used to set rhythm and synchronise dance movements. The idea behind it is to create a continuous rhythm that emphasises the concept of online tracking. The pink colour allows me to differentiate the custom code and the added content to the interface. For example, I applied a pink background to expose the tracker requests displayed in the browser console (as seen in Fig. 1). This allows people to notice the prevalence of third-party trackers from companies external to the webpage.

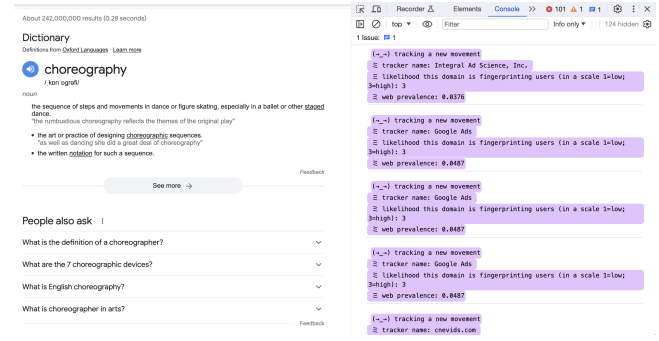


Figure 1: Screenshot of a webpage with the Chrome browser web console open on the right side, displaying the DuckDuckGo privacy extension adapted and developed by the first author to display tracking requests

Another visual aesthetic choice I made was to visually overlap elements in the browser to emphasise the cumulative aspect of the trackers. To do so, I drew inspiration from the choreographic concept of accumulation developed by Trisha Brown in her 1971 performance *Accumulation* [60]. In *Accumulation*, the American dancer and choreographer stands on stage and builds up a choreography, starting from the first step and adding one more step each time she repeats the choreography. Throughout HCCC, tracking accumulates, and such accumulation is visible both on the browser and in the long list of tracker requests in the console.

To emphasise the centrality of choreography in the piece, each of the JavaScript functions used in HCCC are named after choreographic concepts. For example, one of the code functions exemplified next is named after Brown’s ‘*Accumulation*’ concept. This practice of adding syntax and meaning to standard functional or procedural programming is called *Esoteric Programming* [67]. In HCCC the code vocabulary combines computer code and choreography as a means for exploring new aesthetic expressions outside the conventions established within computational systems. The added comments (‘//’) and the name of the code function help guide the audience to understand what the code does, both at a technical and conceptual level.

```
// function ‘accumulation’ lists data commonly extracted
// e.g. user's location, browser and operating system:
print[0]='location: ' + location;
print[1]='browser and operating system: ' +
navigator.userAgent;
// [...]
```

```
function accumulation (){
var fingerprinting = document.createElement("p");
document.getElementsByTagName('body')
[0].prepend(fingerprinting);
fingerprinting.innerHTML = print[count];
console.log('%c' + print[count], 'color: #9500ff;');
count++;
if(count==print.length){count='0';}
}
```

```
datapoints = setInterval(accumulation, 200);
```

The complete documentation of the code and adapted version of the browser extension are available in an online repository¹ and are open-source which is in line with views strongly present within live-coding community.

3.4.2 Visualising and Sonifying Online Tracking. I designed visualisations and sonification of three tracking techniques on the browser: 1) tracker requests, 2) fingerprinting, and 3) user interactions. I chose to add sound and visual feedback to reveal them and set a rhythm to the experience of being tracked for an audience.

First, to expose tracker requests, I mapped each request to the sound of a single metronome click. Depending on which page is visited and the corresponding amount of tracker requests, the sound plays repetitively. Tracker requests occur in various instances, such as when content is loaded or when interacting with content, depending on how much tracking is deployed on a website. The trackers are also printed at the same time that the metronome sound plays and a pink background flashes to allow the audience to follow which trackers are triggered each time. I expose these tracker requests by including their name, the likelihood of fingerprinting, and the tracker's prevalence on the web.

Second, to expose fingerprinting, I collected and adapted JavaScript code that extracts information on the user's browser, operating system, and device. These include screen dimensions and resolution, time-zone and language preferences, and fonts installed, among others. The more information collected, the more precise the identification of the device. To emphasise this aspect of the accumulation of user's data, the text corresponding to each fingerprint item overlays the Google search engine displayed to the left of the screen. I set the font size to be large and with a level of transparency, so that audience members can clearly read the initial fingerprint values, but as the items stack on top of each other, they become unreadable (Fig. 2).

Lastly, to expose the user interactions commonly tracked by web analytics, I created a set of code functions, for example, a visual tail connected to the cursor that emphasises the monitoring that underlies user interactions with the mouse while browsing websites. As illustrated in Fig. 2, the tail is visible as a series of human fingerprints. Another example is the overlay of the scroll percentage onto the webpage. As seen in Fig. 3, the scroll value is updated as I 'move' vertically on the page.

3.4.3 Choreographing Audience Participation. Throughout the performance, I invite the audience to engage with choreographic prompts that introduce aspects of online tracking, such as fingerprinting and profiling through a series of physical enactments. As shown in Fig. 4, these prompts are overlaid on the webpage for the audience to read.

I designed the prompts following the given sequence: 'STAND UP if your age: 25–34'; 'STAND UP if your age: 35–44'; 'STAND UP if your age: Unknown'; 'STAND UP if you live in Italy'; 'STAND UP if you live in Italy and purchased 1–5 items in the last 7 days' and 'STAND UP if you live in Italy and purchased at least 3 items

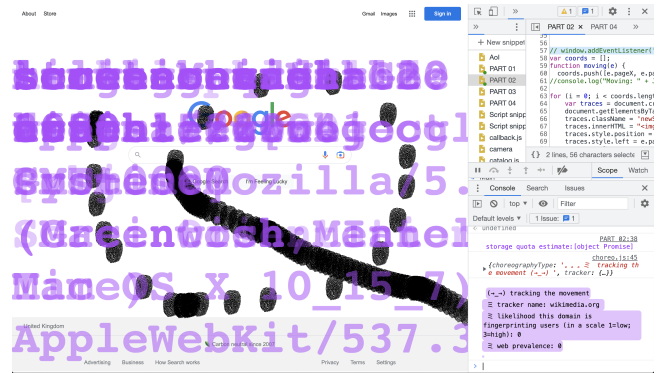


Figure 2: Screenshot detail of the interface with both user data fingerprint and a human fingerprint image trail overlaying the webpage.

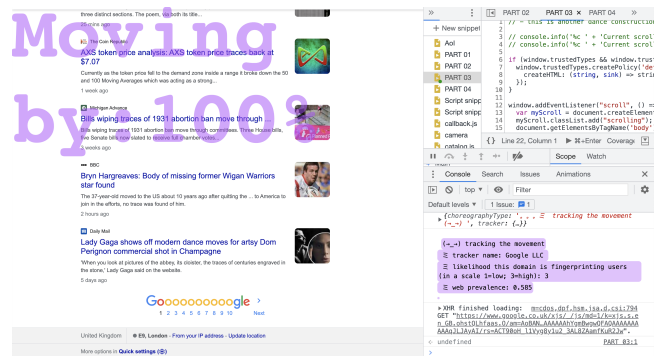


Figure 3: Screenshot displaying the current scroll percentage overlay on top of Google search results.

in the last 5 days and spent more than 50 euros'; 'thank you for all the movements performed'; 'please return to your initial positions'.

For each performance, the prompts are adaptable to the audience setup, for example, if people are seated or if there is space to move, the type of movement might change from 'stand up' to 'move to the left' or 'raise your hands'. The prompts also allow me to comment on people's responses, for example, by concluding: 'most likely someone sitting next to you is above 35 years old'. The latter emphasises the inferences that can be made from data extraction when employing online tracking algorithms.

I designed these prompts to choreograph the audience's participation using daily gestures. This choreographic approach is inspired by the method developed in the 1980s by Augusto Boal known as *Theatre of the Oppressed* (Teatro do Oprimido). Boal understood theatre as a rehearsal for everyday life. He did not see it as an end in itself, but as the beginning of a social transformation that supported the de-alienation of bodies and allowed the repetitiveness of daily tasks to be disrupted [9]. Another inspiration for my choreographic approach is the American choreographer Yvonne Rainer, who observed individual pedestrians and crowds in the streets of New York City and transposed the movement observed into the theatre. This

¹Link to repository available at: <https://gitlab.com/hc-cc/human-computer-counter-choreographies>.

opened up new possibilities for performing mundane daily gestures [73].

These references shaped the way I designed choreographic prompts using movement vocabulary that favoured daily gestures that are performed by people both offline such as standing and moving around, and online such as clicking or scrolling. The goal was to physically engage audience members in gaining an embodied understanding of online tracking technologies.

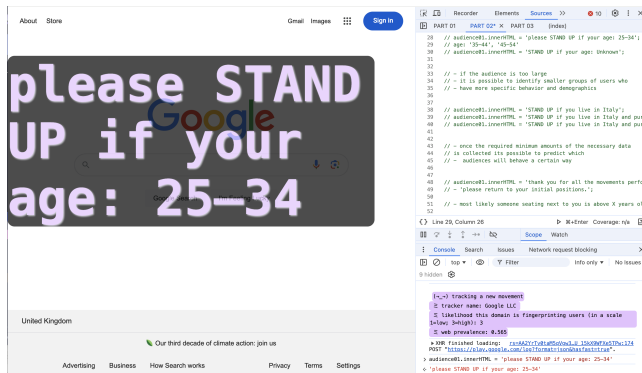


Figure 4: Screenshot of the choreographic prompts in large text on the screen for audience members to respond to.

3.4.4 Dramaturgy. The last step in the making of HCCC was bringing all the elements together in a live performance. The binding theme of the performance is the dramaturgic approach, which integrates the tracking visualisation and sonification with audience participation and with the overall design of the browser. Dramaturgy is approached here in line with Hanna Slättne's [65] view of it as a method of structuring an experience, a story, or a system. Slättne's dramaturgy provides a way of 'foregrounding, accentuating and drawing attention' [65, p. 515] to specific components, procedures, and information in HCCC following a given order.

The performance's total duration is approximately 20 minutes. In the accompanying video, the various parts that comprise the performance can be viewed. The performance starts with me walking on stage making an analogy between fingerprinting and the performance event. I list descriptive data out loud, such as the current date, time, location, language, dimensions of the space, and its capacity. I move back to my laptop, and a projection of a browser window appears divided into two (as illustrated in Fig. 5): on the left-hand side showing the website (Google search engine) and on the right-hand side the web developer tools.

In the first part of the performance, I introduce fingerprinting. After calling a function that prints commonly used fingerprinting parameters, I read out loud each parameter to the point of being unable to keep up with the speed of text being shown as it accumulates and overlays on the screen until it is illegible. This highlights the scale of tracking and how it supersedes human scale, as I am unable to keep up with the algorithm.

The second part of the performance focuses on audience participation: the audience is invited to move according to the on-screen prompts inspired by the web analytics data collection, as exemplified in Section 3.4.3.

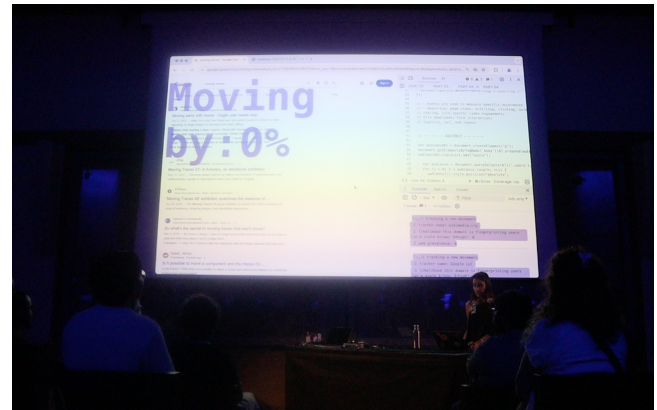


Figure 5: Photo of the performer on stage with a projection behind showing a split screen: on the left side the Google search engine results webpage with text overlay 'Moving by 0%' in colour pink and on the right side the web development tools.

The third part of the performance displays the traces left when interacting with the websites visited thus far. The sound of the metronome mapped to the trackers, as detailed in Section 3.4.2, plays as the tracking requests are triggered. I type 'tracing movement' into the search input field, in order to allude to how movement data is captured online. This search query leads to a list of Google search results on the left side of the screen which vary depending on the country of performance. I randomly click on 5-10 websites from the results aiming to choose different categories (e.g. news or e-commerce) for the audience to witness the contrast or similarities in the tracking requests triggered in each of them. Then, I scroll up the web console, on the right side of the screen, where the trackers have been listed throughout the performance and read out loud a short selection to emphasise the amount and diversity of the trackers that accumulated up until that moment of the performance.

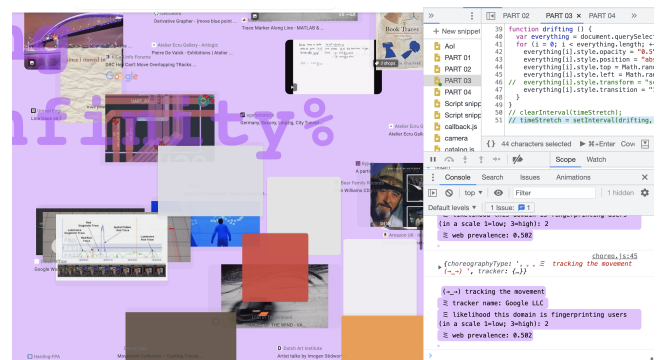


Figure 6: Screenshot of Google image search results showing images 'off-grid' overlaying each other after the performer manipulated code to change the style appearance.

Next, I click on the image search results and call a function that displays the scrolling percentage, as in Fig. 3 which changes to

‘infinite’, as it operates as an infinite scroll. Further alterations to the visual composition are improvised in the moment, making the interface morph dynamically and its original display become almost unrecognisable (as shown in Fig. 6). The sound of the metronome mapped to the trackers intensifies as tracking requests are triggered by more images loading and their display modified. The idea behind the intensification of the overlapping text elements, the chaotic morphing images and the metronome sound effects is to give the audience a feeling of overwhelmingness that reflects the ‘cumulative’ aspect of tracking.

In the final scene, I type commands to go back into the browser history. While each page loads, the tracking requests continue to trigger the metronome at different rhythms until I arrive back at the initial screen with the Google search landing page.

Overall, the dramaturgical choices of climaxing and calming down are geared towards progressively inviting the audience to feel overwhelmed by online tracking in order to develop resistance to it and imagine ways to move against it.

4 Performing HCCC and Probing Audience Members

4.1 Methods

4.1.1 Performance Setup and Audience Demographics. After an initial phase of design and production of the performance as described above, I presented the performance at three different events, the International Conference for Live Coding in The Netherlands in April 2023, HASTAC on Critical Making and Social Justice in the USA in June 2023, and xCoAx Conference on Computation, Communication, Aesthetics & X in Italy in July 2024.

Minor adjustments were made between performances to accommodate the feedback collected and to improve the experience of the audience. Changes between performances included presenting each tracking technique more clearly and making the visual display more legible.

Audience involvement has been crucial in understanding if our aim of raising critical awareness has been met and in collecting feedback on the performance. After each performance, a questionnaire was provided for audience members to share their experiences. We chose the questionnaire format rather than interviews, as it is more suitable for probing a larger number of people across all performances. A total of 43 responses were collected. The questionnaire included Likert scale questions, with seven options from ‘Strongly Disagree’ to ‘Strongly Agree’. The questions included: ‘The duration of the performance felt right’; ‘Before the performance, I had a good understanding of what online tracking algorithms are and how they work’; ‘After the performance, I had a good understanding of what online tracking algorithms are and how they work’; ‘The browser interface used in the performance clearly displayed what the algorithms were doing’; and ‘The movement tasks at the start of the performance were useful in creating a parallel with online tracking’.

The questionnaires also included open-ended questions: ‘What do you see as the main connections or parallels between the performance’s choreographic ideas and online tracking algorithms?’; ‘What was your favourite part of the performance?’; and ‘What

could be improved? Feel free to add suggestions for future iterations’.

In the first performance, we collected 18 responses to the questionnaire, respondents were between 24-63 years old, and half identified their gender as male and the other half as female. In the second performance, a total of 8 people responded to the questionnaire, ranging in age from 26-45, 6 of whom identified as female and 1 as male. In the last performance, a total of 17 people responded to the questionnaire, ranging in age from 25-59, 56% of whom identified as male and 44% as female.

We opted to share the performance during three conferences on live-coding, arts, and digital activism, which are communities the first author is part of. Although we might speculate that in these contexts, attendees had a level of technological literacy, we did not specifically collect data on their expertise in online tracking. In fact, responses to our questionnaires showed that their literacy levels were varied and not specific to online tracking. This is evidenced in the Likert Scale results described in Section 4.2, which states that audience members increased their understanding of what online tracking was and how it works. In Section 5.4 we further discuss our audience demographics and our aim to broaden it in future performances.

4.1.2 Data Collection and Analysis. The responses to the open-ended questions collected from the performance questionnaires were evaluated through a reflexive thematic analysis [15]. The thematic analysis process followed a six-phase structure of familiarisation, coding, theming, review, definition, and documentation [15]. These were not part of a linear trajectory but integrated a recursive process [14] in which the researchers returned to and revised the work done in the previous phases. For the initial phase of familiarisation, the data collected from research activities was printed out for note-making; for the next phases, a spreadsheet was used. Coding and analysis followed predominantly an inductive approach in which codes and themes were derived from the data. In addition, quantitative data analysis was employed, specifically a one-tailed Wilcoxon Test which is a commonly used statistical method to analyse Likert-scale responses [44].

Both qualitative and quantitative analysis aimed to capture a broad understanding of how audience members engaged with the performance and the connections they made between the choreographic approach and online tracking.

All audience members gave their consent to use their information for our research study, which was approved by the ethics committee at our academic institution. Audience members have been assigned unique IDs from A1 to A43 for anonymisation purposes.

4.2 Results

From the data analysis, three high-level themes were generated. The first focuses on how the performance revealed the prevalence of tracking algorithms online. It provides evidence of how the audience grew an understanding of online tracking after attending the performance. The second theme concerns how the choreographic aspect of the performance allowed audience members to critique data tracking online using their bodies. The third concerns how the performance allowed the audience to reflect on concepts related to

power and lack of agency online. Next, we expand on the themes and provide quotes from audience members.

4.2.1 Revealing and Raising Awareness of Data Tracking Algorithms Online. As one of our goals for the performance was to impact the audience's understanding of online tracking, we used data from the audience questionnaire to conduct a preliminary investigation of whether this was successful. Specifically, we used two of the 7-point Likert scale questions from the post-performance questionnaire: 'Before the performance, I had a good understanding of what online tracking algorithms are and how they work' and 'After the performance, I had a good understanding of what online tracking algorithms are and how they work'.

Audience members' Likert-scale responses to these questions were compared. On average, participants' scores indicated a higher understanding of online tracking (Mdn = 6) after the performance than before (Mdn = 5). A one-tailed Wilcoxon Test indicated this improvement was statistically significant ($W = 23.5$, $z = -3.6143$, $p = .00015$), allowing us to reject the null hypothesis ('the performance did not increase people's understanding'). This indicates that the performance increased people's self-reported understanding of what online tracking algorithms are and how they work.

From our analysis of the responses to the open-ended questions, a significant number of audience members highlighted the performance's revelation of tracking algorithms. Its revealing character refers both to the literal revelation of the tracking through the customisation of the web extension and the choreographic approach.

An audience member mentioned that the performance allowed them to see 'behind the browser' (A7), referring to the feeling of obfuscation of the algorithms that were brought to the 'surface' during the performance. Similarly, A32 highlights the code legibility and how the split screen layout 'was a resourceful way to show how the code impacted the website'.

The performer's intention to expose online tracking was reiterated by A17: 'the performance was very clear in its aim and really felt like it was making underlying web processes more exposed and explainable to an audience. The elements of humour and playfulness in engaging the audience were very useful in creating a dynamic performance about this topic'.

Audience members drew connections and even reappropriated the language of 'movement' and 'traces' in relation to the tracking of data as experienced during the performance. A36 referred to the realisation that 'our traces are recorded as we navigate the internet'. In a similar vein, A15 mentioned: 'I see that there is a connection between the ability to express user tracking and patterns obtained from the web through movement in a visual way. During the performance, I felt that this connection was further emphasised by the use of JavaScript commands to manipulate web components live, which highlights the relationship between choreography and web interface design'.

Finally, A16 highlighted the element of 'liveness of tracking processes' in the performance as an antithesis to their daily experience online in which data tracking is obfuscated. Live-coding as a format already focused on the presentation of algorithms in real-time was found to fit well with the aim of revealing tracking live, as it happens, to an audience.

4.2.2 Engaging the Body in Critically Reflecting on Online Tracking. The performance engaged audience members in reflecting and critiquing online tracking algorithms through an embodied and choreographic approach. Many audience members provided comments in response to open-ended questions about their embodied experience of online tracking during the performance.

In contrast to online tracking, which is often abstract and hidden from users, audience members found that the performance opened a space for it to be felt and for a connection to be established between digital and physical spaces. For example, A17 highlights the role of choreographic prompts and physical engagement during the performance to make tangible an abstract concept like online targeting: 'the parallel between creating segregation based on demographics like age and buying history was clear through its physicality in the audience participation'. A43 emphasised the embodied nature of the performance and how it helped to better understand tracking: 'I thought the standing up part was very illustrative (of) how tracking works'. Similarly, A33 referred to the embodied aspect of growing awareness: 'I was under the impression that it was a performance of movement and almost like a body awareness or somatic exercise but for our screen selves'.

The participants found that the choreographic exercises in the performance revealed how the online tracking strategies worked. A42 reflected on how the choreographic prompt in the performance is a metaphor for how online tracking conditions people's behaviours online. They said: 'your storytelling choreographed not only our behaviours (e.g. standing up), like a configuration we are meant to comply with, but you also guided the audience with your narrative, in the direction of your ultimate message. Similarly, these algorithms use our information as a means to an end, conditioning our online experience and, perhaps, our futures'. A17 also drew parallels between choreography and online tracking processes and strategies: 'the manipulation and the dancing elements of the webpage also helped metaphorically outline the tracking processes and decomposed the web into moving and traceable parts'.

Participants reflected on the value of experiencing the traces that are left online and that were made visible by the performance. Participant A10 highlighted that the performance helped 'situating the body within the technology - our actions online leave traces, as in life'. In a similar vein, A26: 'I enjoyed the parallel between physical and digital space and the way we leave our marks on both. The logic we use to move through space is also present on the web'. This means that the performance brought the body to the centre of the experience, acting as a common denominator across digital and physical spaces. It linked experiences commonly felt separate from each other; for example, being in a specific physical location influences the content we see online.

A8 mentioned that the choreographic approach to online tracking led them to reflect on their 'everyday "prosumer" choreographies'. They reflected on how they, as users, act as both consumers and producers of data, through daily actions and gestures performed online, which feed into the algorithmic systems in place. This aspect relates to the next theme, which focuses on the conditions within which users' movements online operate, particularly in relation to users' agency or lack thereof.

4.2.3 Online Power, Agency and Lack Thereof. One of the themes generated was the lack of agency regarding online tracking. Some participants found that the choreographic prompts in the performance led them to reflect on the concept of agency and how online services take control over personal data, not always with consent. These audience members provided comments on this matter, in the words of A11: ‘by coming to a performance, we as audience members inadvertently put ourselves in the position of giving power to you as presenter: when you asked us questions and asked us to (I can’t remember) put our hands up then, we all went along with it. In everyday use of a browser, we are similarly giving away our power to advertisers and other online actors, without realising it’.

The order of the choreographic prompts purposefully plays with power dynamics, for example, by first asking audience members to reveal aspects of their personal data and only at the end providing the chance to opt-out. A10 mentions that as a memorable moment: ‘The realisation that we do not have to supply data e.g. ‘age unknown’ was the last category after asking audience their age. This showed me how ready we are to give our data if asked’.

Due to the live nature of the performance, audience members witness how tracking is prevalent on various popular websites and how powerless one feels. A22 emphasises this: ‘the performance engaged us, the audience, in a kind of process of tracking and making meaning of the performer’s digital and physical movements and actions, which was an eerie echo of how companies track us. I felt odd but fascinated being a voyeur’.

Thus, the performance led participants to reflect on the powerlessness and the insidious lack of agency that online spaces impose on their users.

5 Discussion

In this paper, we illustrated how we designed our choreographic live-coding performance HCCC to reveal data-tracking algorithms in web environments. Our analyses of the audiences’ responses to HCCC (described in Section 4.2) showed that the performance supported them to: (1) increase awareness of online data tracking; (2) critique online data tracking through choreography and embodiment; and (3) reflect on concepts related to power and lack of agency online.

From our approach to live-coding with choreography combined with our empirical findings, we derive insights that can benefit the live-coding and HCI community at large. In the following sections, we present reflections, takeaways, and possible directions for future work.

5.1 Exposing and Embodying Data Tracking as New Approaches to Live-Coding

We contribute a new approach to live-coding that allows us to support audience members in gaining awareness of online tracking by exposing these mainstream algorithms and by using choreography and audience participation.

5.1.1 Exposing Mainstream Algorithms. While live-coding traditionally exposes the algorithms that performers manipulate, these tend to be within custom-made programs that the performers develop and use, but may not be familiar to audience members. Additionally, the performances rarely explicitly point to the impact of

the algorithms they display. While a critique of algorithmic opacity and data extractivism is implicit in the foundations of live-coding—live-coding’s first principle is algorithmic transparency—most performances focus on audiovisual composition or other forms of collaborative work. It is thus uncommon for live coders to reappropriate familiar mainstream tools and systems, and even less common for them to reveal their impact on people. The specificity of our approach in HCCC was to manipulate mainstream algorithms and to display these manipulations in front of audience members to open a space for them to critique them and reflect on their impact in their lives. Our findings show that our approach was effective in critically engaging the audience members in reflecting on the presence of extractivist technologies. Our findings showed, for example, that exposing mainstream algorithms helped participants question how their actions online are used as data to profile them.

Thus, even though the underlying discourse in the live-coding community is political, supportive of open-source technologies, and regularly contributes to those efforts, the performances are rarely explicitly political. Instead, most live-coding performances are aesthetic audio-visual experiences. HCCC distinguishes itself from these by providing an experience that focuses on the exposure and critique of extractivist technologies, thus extending the scope of the current literature on live-coding performances. Our paper contributes to the live-coding community by illustrating an approach that live coders can appropriate in their work to explicitly display the algorithms that they manipulate with the aim of fostering critique and advocating for activism among audience members.

5.1.2 Choreography and Audience Participation for Increased Digital Awareness. Our approach focuses on involving audience members in performing physical tasks. Instead of presenting data tracking as a distant phenomenon (confined to a screen), we bring it closer to people’s embodied experiences. This allows them to make connections between what they witness on the screen and their own bodies. As reported in Section 4.2.2 we weave together both physical and digital aspects of tracking and audience members perceived it as we intended. These findings connect to previous live-coding performances that involve audience members in various aspects of the performances.

One example is *CrowdPatching* [6], a system for audience participation that allows the audience to change the performance’s visual and audio parameters in real-time by connecting to a web interface through their mobile phones. Although this participatory approach focused on interaction with the live-coding systems in place, the audience participation did not extend to physical tasks.

On the other hand, live-coding pieces such as *Codes for a Dance* by Sicchio *et al.* [63], *CO/DA* by Fdili Alaoui *et al.* [28] and *MosAIck* by Wilson *et al.* [72] focused on designing systems to choreograph and facilitate physical engagement of the performers themselves.

HCCC combined both approaches, using live-coding to choreograph audiences and choreographing audiences to engage with the live-coding piece. Our embodied and choreographic approach supported audience members in understanding how tracking works and critiquing it. As we demonstrated, live-coders can explore new forms of prompting audience members and break the ‘fourth-wall’ separating performers from their audience. We showed that including physical and embodied participation of the audience offers a

more direct connection between the audience and the topic of the performance. Thus, our work contributes to live-coding by demonstrating the effectiveness of embodied and participatory approaches to foster the audience's interest in digital matters, with the aim of growing their digital awareness.

5.2 Exposing and Embodying Data Tracking as New Approaches to HCI

HCCC contributes to HCI by demonstrating a live setup that engages audience members critically with tracking algorithms by both witnessing them on stage and embodying them.

5.2.1 Benefits of 'Liveness' for HCI. Our results show the potential of live-coding in exposing the prevalence of social control in algorithms and inviting audience members to reflect on them. Foucault developed the concept of social control, which refers to rules and restrictions that shape, supervise, and regulate the behaviour of individuals in societies [27]. We believe that the first stage for resisting the mechanisms of social control is to expose them. Our piece illustrates how we used the liveness of live-coding to expose the mechanisms of online tracking on stage in order to make explicit how they shape and control users, echoing Li *et al.*'s argument [47]. HCCC displayed live the everyday interactions people have with data tracking and, by doing so, opened a space for imagining how else these systems might operate and how users can subvert their usual ways of working. While audience members were not explicitly asked to reflect on forms of countering online tracking during the performance, some of the actions taken by the performer were perceived as opposing or resisting tracking. In our findings, we describe how A4 made a parallel between the choreographic approach proposed in HCCC and what they perceived as forms of countering 'tracking requests and measurements.' Another audience member, A15, understood the live-coding in the browser as 'JavaScript hacking'. The concept of hacking is inherently subversive and attempts to disrupt existing systems. Thus, our work contributes to HCI by demonstrating the effectiveness of exposing the mechanism of tracking algorithms to foster the audience's awareness and criticality, and inspire forms of emancipation.

5.2.2 Benefits of Embodied Participation for HCI. Additionally, our piece illustrates how we utilised audience participation and embodiment as an effective means to involve people in critically reflecting on data tracking. Our results show that embodiment and choreography contributed to engaging the audience in reflecting more intimately and viscerally on the algorithms' impacts. The audience went beyond witnessing the effects of online tracking: HCCC created a shared experience that involved the audience physically-individually and collectively. Instead of tracking being an external phenomenon, including embodiment and audience participation in our approach emphasised the entanglement between people's actions and the extractivist technologies that choreograph them online. Similar performances developed in HCI have used audience participation to foster critical reflection of engagement-based algorithms [3] or peoples' dependence on mobile technologies [2]. We contribute to this line of work by advocating for audience participation alongside clear demonstrations of the mechanisms behind the algorithms critiqued in the performances. Our approach aims

to reveal how these algorithms shape users while enabling a more direct and embodied form of critical engagement with them.

Building a performance that is physically engaging while being critical, political, and entertaining at the same time is a challenging endeavour. As pointed out by Skirpan *et al.*, 'even if we know fiction and enactments have the potential for reflection and inquiry by participants, it is not easy or obvious how these efforts could be formatted for broad accessibility. That is, we consider the balance between engagement and entertainment, detailed technical content and artistic simplification as well as audience interaction and narrative structure' [64, p. 2]. Our paper contributes to these efforts by detailing how we designed, performed, and analysed audience responses to a performance that both exposes online tracking and engages people in enacting it.

Our dual approach to 'liveness' from live-coding (e.g., manipulating and displaying) the algorithms on stage combined with audience participation through the enactment of these algorithms, contributes to HCI with two complementary entry points to allow people to grow their understanding and critique of data tracking. We see a potential for our dual approach to be appropriated by HCI researchers outside the confines of theatres to grow awareness of a large number of malicious algorithmic practices online, reach a large audience and impact more general users.

5.3 Insights Gained from a Personal Artistic Project

Artistic Research is a method that gives space to the artist's voice. HCCC is an artistic research project (as detailed in 3.3.1), deeply grounded in the choreographic and live-coding practice of the first author. The artist brings her own experiences but also biases, which shape the scope of the project and the communities it involves, as mentioned in Section 3.2. For instance, the choreographic references influencing HCCC reflect the dance trajectory and interests of the first-author. The concept of 'Accumulation' (3.4.4), for example, shaped HCCC at conceptual, technical, and aesthetic levels, which has proven effective in engaging audiences. Another example is the use of the browser's developer tools within the performance which reflects the first-author's practice as a live coder. Although these design choices were shaped by the first author's personal background and experiences, the paper offers larger insights that come from an authentic and reflexive understanding of these decisions.

We believe that the insights into the artistic research process and the analysis of the performance's impact on the audience will resonate with readers. Describing both our design process of HCCC and our empirical findings of how the audience members experienced it should inform future works in HCI about combining choreography, live-coding, and audience participation to encourage critical engagement with technology.

Our design process, empirical results, and discussion provide concrete takeaways that can inspire novel design directions beyond our specific use and that HCI researchers can learn from.

5.4 Limitations and Future Work

Our approach certainly presents limitations. We see these limitations as opening opportunities for future work.

As mentioned in Section 4.1.1 our audience members were mainly drawn from people who attend live-coding, digital arts and activist events. This might not reflect how a general audience might perceive the performance. We are interested in further exploring the impact of the performance in events and venues that host a broad audience, one less familiar with online technologies. For that, the performance design might need to be adapted, for example, by adding a more detailed introduction to online tracking at the start of the performance or by drawing attention to each aspect of tracking through more explicit connections between the data collected and the visual and sound clues on the screen. Performing the piece in a broader context would be possible since our design emphasises portability (the technology operates within a web browser that can be adapted to a variety of contexts). This would allow HCCC to be presented, for example, in public spaces or streamed online to reach larger audiences. We see a potential for our approach to live outside of the confines of theatres or conference venues to impact the general public.

While this paper covers a series of three performances with no follow-up afterwards, we are interested in developing further work that will investigate longer-term engagement with choreographic prompts and visualisation or sonification of online tracking. This will allow us to investigate whether our approach can lead people to long-term behavioural change and can provide strategies for them to counter online tracking.

Moreover, HCCC focused on exposing online tracking algorithms and prompting audience members to embody such algorithms so they could relate more meaningfully and deeply to them. In the current version of HCCC, we do not feed the performance's real-time tracking system with personal data from audience participants. We are interested in further exploring how our embodied approach can be combined with other forms of data capture from the audience integrating, for example, sensor data or mobile interactions. Capturing various personal data from the audience exposes them to different forms of data tracking in daily life, which are often obfuscated. Growing awareness of these would allow audiences to expand on the critique of surveillance capitalism [75] and the prevalence of data extractivism in our societies.

Finally, our strategy in problematising data extraction through participation and a sense of embodied engagement supports sense-making and critical reflection, which drive change. The live algorithmic aspect of the performance combined a 'real scenario' (that of data tracking) with an imaginative one (that of 'counter-choreographies') opening space for new and emerging emancipation strategies. While the concept of 'counter-choreographies' is not explicitly addressed during the performance, it is an invitation to take the next step in resisting or countering online tracking. Our future work will explicitly explore the engagement of participants in imagining forms of countering and data advocacy.

6 Conclusion

In this paper, we describe the making of HCCC from the first-person perspective of the first author. HCCC is a live-coding performance that reveals the algorithms tracking users in web interfaces. Our findings, derived from analysing the audience responses to the performance, demonstrate how the performance revealed and grew

the audience's understanding of the prevalence of online tracking algorithms. In addition, the embodied and choreographic aspects of the performance allowed audience members to critique data tracking and reflect on power issues and lack of agency online.

Our contribution is twofold: (1) we present a novel approach to live-coding that combines choreography with online tracking and (2) we share insights on the performance's effectiveness in engaging audiences to reflect on and critique data tracking. Our contribution benefits the live-coding community as our piece illustrates the impact of exposing mainstream algorithms and the use of choreography and audience participation to increase their awareness of these algorithms. It also benefits the HCI research community as our approach shows the potential of live-coding and the benefit of using choreography and audience participation to expose the prevalence of data tracking and involve audiences physically in reflecting on these issues.

We believe that the insights from our study inspire new embodied and algorithmic approaches to both live-coding and HCI that enhance audiences' awareness of online tracking and have the potential to empower them to imagine meaningful alternatives.

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References

- [1] Philip E. Agre. 1997. *Computation and Human Experience* (1 ed.). Cambridge University Press. <https://doi.org/10.1017/CBO9780511571169>
- [2] Sarah Fdili Alaoui and Jean-Marc Matos. 2021. RCO : Investigating Social and Technological Constraints through Interactive Dance. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. ACM, Yokohama Japan, 1–13. <https://doi.org/10.1145/3411764.3445513>
- [3] Chriszine Backhouse, Sarah Robinson, and Claudia Barton. 2023. Making the Invisible Visible: How Forum Theatre Can Reveal the Impact of Social Media Algorithms on Local and Global Justice Issues. *Policy and Practice* 37, A Development Education Review (2023), 90–112. <https://www.developmenteducationreview.com/issue/issue-37/making-invisible-visible-how-forum-theatre-can-reveal-impact-social-media-algorithms>
- [4] Rafael Bastide. 2021. Cascade. <https://raphaelbastide.com/cascade/>
- [5] Francisco Bernardo, Chris Kiefer, and Thor Magnusson. 2019. Sema. <https://github.com/mimic-sussex/sema>
- [6] Jamie Beverley and David Ogborn. 2017. CrowdPatching: a system for audience participation in algoraves. Morelia México. <https://iclc.toplap.org/2017/cameraReady/shortpaper-beverley-crowdpatching.pdf>
- [7] Rahul Bhargava, Amanda Brea, Victoria Palacin, Laura Perovich, and Jesse Hinson. 2022. Data Theatre as an Entry Point to Data Literacy. *INTERNATIONAL FORUM OF EDUCATIONAL TECHNOLOGY & SOCIETY* 25, 4 (2022), 93–108.
- [8] Alan F. Blackwell, Emma Cocker, Geoff Cox, Alex McLean, and Thor Magnusson. 2022. *Live Coding: A User's Manual*. The MIT Press. <https://doi.org/10.7551/mitpress/13770.001.0001>
- [9] Augusto Boal. 2019. *Teatro do oprimido: e outras poéticas políticas* (1ª edição ed.). Editora 34, São Paulo. OCLC: 1137218643.
- [10] Loes Bogers and Letizia Chiappini (Eds.). 2019. *The critical makers reader: (un)learning technology*. Number 12 in INC reader. Institute of Network Cultures, Amsterdam.
- [11] bolwerK, Goldjian, Karine Rathle, Ellen Foster, and Margaret Westby. 2016. Cryptodance. <http://www.ooooo.be/cryptodance/references.html>
- [12] Kerstin Bongard-Blanchy, Arianna Rossi, Salvador Rivas, Sophie Doublet, Vincent Koenig, and Gabriele Lenzini. 2021. "I am Definitely Manipulated, Even When I am Aware of it. It's Ridiculous!" - Dark Patterns from the End-User Perspective. In

- Designing Interactive Systems Conference 2021*. ACM, Virtual Event USA, 763–776. <https://doi.org/10.1145/3461778.3462086>
- [13] Henk Borgdorff. 2010. The Production of Knowledge in Artistic Research. In *The Routledge companion to research in the arts* (1st ed ed.). Routledge, New York, 44–63. <https://www.taylorfrancis.com/chapters/edit/10.4324/9780203841327-4/production-knowledge-artistic-research-henk-borgdorff>
 - [14] Virginia Braun and Victoria Clarke. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology* 3, 2 (Jan. 2006), 77–101. <https://doi.org/10.1191/1478088706qp0630a>
 - [15] Virginia Braun and Victoria Clarke. 2022. *Thematic analysis: a practical guide*. SAGE, London ; Thousand Oaks, California. OCLC: on1247204005.
 - [16] Renee Carmichael. 2016. Care to Dance? <https://fleeimmediately.com/02-danceandcode/dancefloor.html>
 - [17] Renee Carmichael. 2016. Flee Immediately. <https://fleeimmediately.com>
 - [18] Joana Chicau. 2016. A WebPage in III Acts. In *Interface Politics, 1st International Conference*. Gredits, BAU Editions, Barcelona, Spain. <http://www.gredits.org/interfacepolitics/class/a-webpage-in-iii-acts-performance/>
 - [19] Joana Chicau and Renick Bell. 2018. Transdisciplinary Tools for Collaborative, Choreographed, and Embodied Audio-Visual Live Coding. In *4th International Conference on Live Interfaces*. Porto, Portugal. <https://live-interfaces.github.io/2018/pdf/ICLI2018-Bell.pdf>
 - [20] Joana Chicau and Jonathan Reus. 2023. Anatomical Intelligence: Live coding as performative dissection. *Org. Sound* 28, 2 (Aug. 2023), 290–304. <https://doi.org/10.1017/S1355771823000481>
 - [21] Nick Collins, Alex McLEAN, Julian Rohrerhuber, and Adrian Ward. 2003. Live coding in laptop performance. *Org. Sound* 8, 3 (Dec. 2003), 321–330. <https://doi.org/10.1017/S135577180300030X>
 - [22] Ted Davis. 2019. P5JS Live. <https://teddavis.org/p5live/>
 - [23] Lins Derry. 2023. Data embodiment: approaching the body as a choreographic medium for performing abstract data. *International Journal of Performance Arts and Digital Media* 19, 1 (Jan. 2023), 60–82. <https://doi.org/10.1080/14794713.2023.2175105>
 - [24] Audrey Desjardins, Oscar Tomico, Andrés Lucero, Marta E. Cecchinato, and Carman Neustaedter. 2021. Introduction to the Special Issue on First-Person Methods in HCI. *ACM Trans. Comput.-Hum. Interact.* 28, 6 (Dec. 2021), 1–12. <https://doi.org/10.1145/3492342>
 - [25] Paul Dourish, Janet Finlay, Phoebe Sengers, and Peter Wright. 2004. Reflective HCI: towards a critical technical practice. In *CHI '04 Extended Abstracts on Human Factors in Computing Systems*. ACM, Vienna Austria, 1727–1728. <https://doi.org/10.1145/985921.986203>
 - [26] Anthony Dunne. 2008. *Hertzian tales: electronic products, aesthetic experience, and critical design* (1. mit press paperback ed ed.). MIT Press, Cambridge, Mass. London.
 - [27] Michel Foucault and Michel Foucault. 2020. *Power*. Number 3 in Essential works of Foucault. Penguin Books, New York.
 - [28] Jules Françoise, Sarah Fdili Alaoui, and Yves Candau. 2022. CO/DA: Live-Coding Movement-Sound Interactions for Dance Improvisation. In *CHI Conference on Human Factors in Computing Systems*. ACM, New Orleans LA USA, 1–13. <https://doi.org/10.1145/3491102.3501916>
 - [29] Alistair Gentry. 2018. The DoxBox Trustbot. <https://alistairgentry.net/performance/doxbox-trustbot-2019/>
 - [30] Duck Duck Go. [n. d.]. DuckDuckGo Browser Extension. <https://github.com/duckduckgo/duckduckgo-privacy-extension>
 - [31] Colin M. Gray, Yubo Kou, Bryan Battles, Joseph Hoggatt, and Austin L. Toombs. 2018. The Dark (Patterns) Side of UX Design. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. ACM, Montreal QC Canada, 1–14. <https://doi.org/10.1145/3173574.3174108>
 - [32] Ben Grosser. 2017. Demetricator. <https://bengrosser.com/projects/twitter-demetricator/>
 - [33] Ben Grosser. 2019. Safebook. <https://bengrosser.com/projects/safebook/>
 - [34] Jasmine Guffond. 2019. Listening Back. <https://jasmineguffond.com/art/Listening+Back>
 - [35] Drew Hemment, Ruth Aylett, Vaishak Belle, Dave Murray-Rust, Ewa Luger, Jane Hillston, Michael Rovatsos, and Frank Broz. 2019. Experiential AI. *AI Matters* 5, 1 (April 2019), 25–31. <https://doi.org/10.1145/3320254.3320264>
 - [36] Kristina Hook. 2018. *Designing with the Body: Somaesthetic Interaction Design* (1 ed.). MIT Press, Cambridge.
 - [37] Bert Hubert. 2022. GoogleTeller. <https://github.com/berthubert/googerteller>
 - [38] Olivia Jack. 2017. Hydra. <https://hydra.ojack.xyz/>
 - [39] Guy John and Davide Della Casa. 2014. LiveCode Lab. <https://livecodelab.net/>
 - [40] Mirabelle Jones, Christina Neumayer, and Irina Shklovski. 2023. Embodying the Algorithm: Exploring Relationships with Large Language Models Through Artistic Performance. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*. ACM, Hamburg Germany, 1–24. <https://doi.org/10.1145/3544548.3580885>
 - [41] Harmanpreet Kaur, Eytan Adar, Eric Gilbert, and Cliff Lampe. 2022. Sensible AI: Re-imagining Interpretability and Explainability using Sensemaking Theory. In *2022 ACM Conference on Fairness, Accountability, and Transparency*. ACM, Seoul Republic of Korea, 702–714. <https://doi.org/10.1145/3531146.3533135>
 - [42] Goda Klumbyte, Phillip Lücking, and Claude Draude. 2020. Reframing AX with Critical Design: The Potentials and Limits of Algorithmic Experience as a Critical Design Concept. In *Proceedings of the 11th Nordic Conference on Human-Computer Interaction: Shaping Experiences, Shaping Society*. ACM, Tallinn Estonia, 1–12. <https://doi.org/10.1145/3419249.3420120>
 - [43] Michael Kretschmer, Jan Pennekamp, and Klaus Wehrle. 2021. Cookie Banners and Privacy Policies: Measuring the Impact of the GDPR on the Web. *ACM Trans. Web* 15, 4 (July 2021), 1–42. <https://doi.org/10.1145/3466722>
 - [44] Jonathan Lazar, Jinjuan Heidi Feng, and Harry Hochheiser. 2017. *Research Methods in Human Computer Interaction* (second ed.). Morgan Kaufmann.
 - [45] Sang Won Lee, Jungho Bang, and Georg Essl. 2018. Live Coding YouTube. In *Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems*. ACM, Montreal QC Canada, 1–6. <https://doi.org/10.1145/3170427.3177759>
 - [46] André Lepecki. 2015. The Choreopolitical: Agency in the Age of Control. In *The Routledge Companion to Art and Politics*, Randy Martin (Ed.). Routledge, Taylor & Francis Group, London ; New York, 44–52.
 - [47] Jingyi Li, Eric Rawn, Jacob Ritchie, Jasper Tran O’Leary, and Sean Follmer. 2023. Beyond the Artifact: Power as a Lens for Creativity Support Tools. In *Proceedings of the 36th Annual ACM Symposium on User Interface Software and Technology*. ACM, San Francisco CA USA, 1–15. <https://doi.org/10.1145/3586183.3606831>
 - [48] Lian Loke and Thecla Schiphorst. 2018. The somatic turn in human-computer interaction. *interactions* 25, 5 (Aug. 2018), 54–5863. <https://doi.org/10.1145/3236675>
 - [49] Duri Long, Sophie Rollins, Jasmin Ali-Diaz, Katherine Hancock, Samnang Nuonsinoeun, Jessica Roberts, and Brian Magerko. 2023. Fostering AI Literacy with Embodiment & Creativity: From Activity Boxes to Museum Exhibits. In *Proceedings of the 22nd Annual ACM Interaction Design and Children Conference*. ACM, Chicago IL USA, 727–731. <https://doi.org/10.1145/3585088.3594495>
 - [50] Andrés Lucero, Audrey Desjardins, Carman Neustaedter, Kristina Höök, Marc Hassenzahl, and Marta E. Cecchinato. 2019. A Sample of One: First-Person Research Methods in HCI. In *Companion Publication of the 2019 on Designing Interactive Systems Conference 2019 Companion*. ACM, San Diego CA USA, 385–388. <https://doi.org/10.1145/3301019.3319996>
 - [51] Alan F. Newell, Margaret E. Morgan, Lorna Gibson, and Paula Forbes. 2011. Experiences with professional theatre for awareness raising. *Interacting with Computers* 23, 6 (Nov. 2011), 594–603. <https://doi.org/10.1016/j.intcom.2011.08.002>
 - [52] David Ogborn, Jamie Beverley, Luis Navarro del Angel, Eldad Tsabary, and Alex McLean. 2017. Estuary: Browser-based Collaborative Projectional Live Coding of Musical Patterns.
 - [53] Søren Bro Pold. 2019. New ways of hiding: towards metainterface realism. *Artnodes*, 2019 Num. 24 (2019), pp. 72–82. <https://doi.org/10.7238/a.v0i24.3283>
 - [54] Ulysses Pople. 2021. Nodysseus. <https://nodysseus.io>
 - [55] Kruakae Pothong, Larissa Pschetz, Ruth Catlow, and Sarah Meiklejohn. 2021. Problematising Transparency Through LARP And Deliberation. In *Designing Interactive Systems Conference 2021*. ACM, Virtual Event USA, 1682–1694. <https://doi.org/10.1145/3461778.3462120>
 - [56] Arrian Purcell, Henry Gardner, and Ben Swift. 2014. Visualising a live coding arts process. In *Proceedings of the 26th Australian Computer-Human Interaction Conference on Designing Futures: the Future of Design*. ACM, Sydney New South Wales Australia, 141–144. <https://doi.org/10.1145/2686612.2686634>
 - [57] Charlie Roberts. 2012. Gibber. <https://gibber.cc/>
 - [58] Charlie Roberts and Mariana Pachon-Puentes. 2019. Bringing the TidalCycles Mini-Notation to the Browser. Trondheim, Norway.
 - [59] Felix Roos and Alex McLean. 2022. Strudel. <https://strudel.tidalcycles.org/learn/getting-started/>
 - [60] Susan Rosenberg. 2012. Trisha Brown: Choreography as Visual Art. *October* 140 (May 2012), 18–44. https://doi.org/10.1162/OCTO_a_00087
 - [61] Ana Selvaraj, Eda Zhang, Leo Porter, and Adalbert Gerald Soosai Raj. 2021. Live Coding: A Review of the Literature. In *Proceedings of the 26th ACM Conference on Innovation and Technology in Computer Science Education V. 1*. ACM, Virtual Event Germany, 164–170. <https://doi.org/10.1145/3430665.3456382>
 - [62] Kate Sicchio. 2016. Untitled Algorithmic Dance. <https://www.sicchio.com/work-1/untitled-algorithmic-dance>
 - [63] Kate Sicchio and Alex McLean. 2023. Codes for a Dance. <https://iclc.toplap.org/2023/catalogue/performance/codes-for-a-dance.html>
 - [64] Michael Warren Skirpan, Jacqueline Cameron, and Tom Yeh. 2018. More Than a Show: Using Personalized Immersive Theater to Educate and Engage the Public in Technology Ethics. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. ACM, Montreal QC Canada, 1–13. <https://doi.org/10.1145/3173574.3174038>
 - [65] Hanna Slättne. 2022. Navigating the Unknown. In *The Routledge international handbook of practice-based research*, Craig Vear (Ed.). Routledge, Abingdon, Oxon ; New York, NY.
 - [66] Ben Swift, Andrew Sorensen, Michael Martin, and Henry Gardner. 2014. Coding livecoding. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, Toronto Ontario Canada, 1021–1024. <https://doi.org/10.1145/2555854.2555854>

- 2556288.2557049
- [67] Daniel Temkin. 2022. Code-Poetics X Esolangs. In *The Book of X: 10 years of Computation, Communication, Aesthetics & X*, Miguel Carvalhais, Mario Verdicchio, Luisa Ribas, and André Rangel (Eds.). i2ADS/CITTAR, 193–206. <https://doi.org/10.24840/978-989-9049-26-0>
 - [68] Martino Trevisan, Stefano Traverso, Eleonora Bassi, and Marco Mellia. 2019. 4 Years of EU Cookie Law: Results and Lessons Learned. *Proceedings on Privacy Enhancing Technologies* 2019, 2 (April 2019), 126–145. <https://doi.org/10.2478/popets-2019-0023>
 - [69] Mauricio Verano Merino and Juan Pablo Sáenz. 2023. The Art of Creating Code-Based Artworks. In *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems*. ACM, Hamburg Germany, 1–7. <https://doi.org/10.1145/3544549.3585743>
 - [70] Adrian Ward, Julian Rohrerhuber, Fredrik Olofsson, Dave Griffiths, Amy Alexander, Nick Collins, and Alex McLean. 2004. Live Algorithm Programming and a Temporary Organisation for its Promotion. In *Read_me - Software Art and Cultures*. Aarhus University Press, 242–261.
 - [71] James Williams. 2018. *Stand out of our Light: Freedom and Resistance in the Attention Economy* (1 ed.). Cambridge University Press. <https://doi.org/10.1017/9781108453004>
 - [72] Elizabeth Wilson, Deva Schubert, Mika Satomi, Alex McLean, and Juan Felipe Amaya Gozalez. 2023. MosAIck: Staging Contemporary AI Performance - Connecting Live Coding, E-Textiles and Movement. (April 2023). <https://doi.org/10.5281/ZENODO.7843540> Publisher: Zenodo.
 - [73] Catherine Wood. 2007. *Yvonne Rainer: the mind is a muscle*. Afterall, London. OCLC: ocn153578140.
 - [74] John Zimmerman, Jodi Forlizzi, and Shelley Evenson. 2007. Research through design as a method for interaction design research in HCI. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, San Jose California USA, 493–502. <https://doi.org/10.1145/1240624.1240704>
 - [75] Shoshana Zuboff. 2015. Big other: Surveillance Capitalism and the Prospects of an Information Civilization. *Journal of Information Technology* 30, 1 (March 2015), 75–89. <https://doi.org/10.1057/jit.2015.5>