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### Playing with feedback

**Citation for published version:**

Mudd, T 2023, Playing with feedback: Unpredictability, immediacy, and entangled agency in the no-input mixing desk. in A Schmidt, K Väänänen, T Goyal, PO Kristensson, A Peters, S Mueller, JR Williamson & ML Wilson (eds), *CHI '23: Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems.*, 243, ACM, pp. 1-11. <https://doi.org/10.1145/3544548.3580662>

**Digital Object Identifier (DOI):**

[10.1145/3544548.3580662](https://doi.org/10.1145/3544548.3580662)

**Link:**

[Link to publication record in Edinburgh Research Explorer](#)

**Document Version:**

Peer reviewed version

**Published In:**

CHI '23

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# Playing with Feedback: Unpredictability, Immediacy, and Entangled Agency in the No-input Mixing Desk

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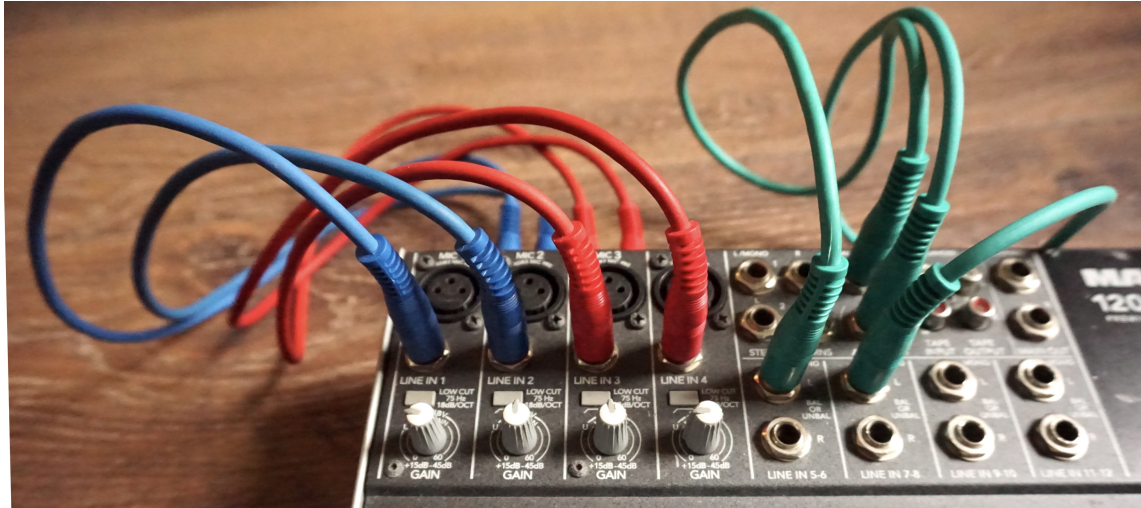


Fig. 1. A mixing desk with outputs routed back to inputs

Feedback is a process that is common in both acoustic and electronic musical instruments, but rare in digital musical tools or creative digital tools more generally. This paper examines the musical use of the 'no-input mixing desk'—or 'feedback mixer', a sound mixing desk fed back on itself—to explore how and why feedback is appealing for musicians. Twenty interviews were conducted with musicians who have used no-input mixing desk in their practice. Thematic analysis is used to explore the interview data. Results highlight the enjoyment and creative fulfilment of working with systems that can't be fully predicted or understood, a sense of gestural immediacy, sensitivity and tactility often perceived as lacking in digital instruments, and an affinity with acoustic instruments in terms of the scope for surprise and exploration.

Additional Key Words and Phrases: feedback, creative interaction, music technology, performance

## ACM Reference Format:

Tom Mudd. 2023. Playing with Feedback: Unpredictability, Immediacy, and Entangled Agency in the No-input Mixing Desk. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems (CHI '23)*, April 23–28, 2023, Hamburg, Germany. ACM, New York, NY, USA, 17 pages. <https://doi.org/10.1145/3544548.3580662>

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Manuscript submitted to ACM

## 1 INTRODUCTION

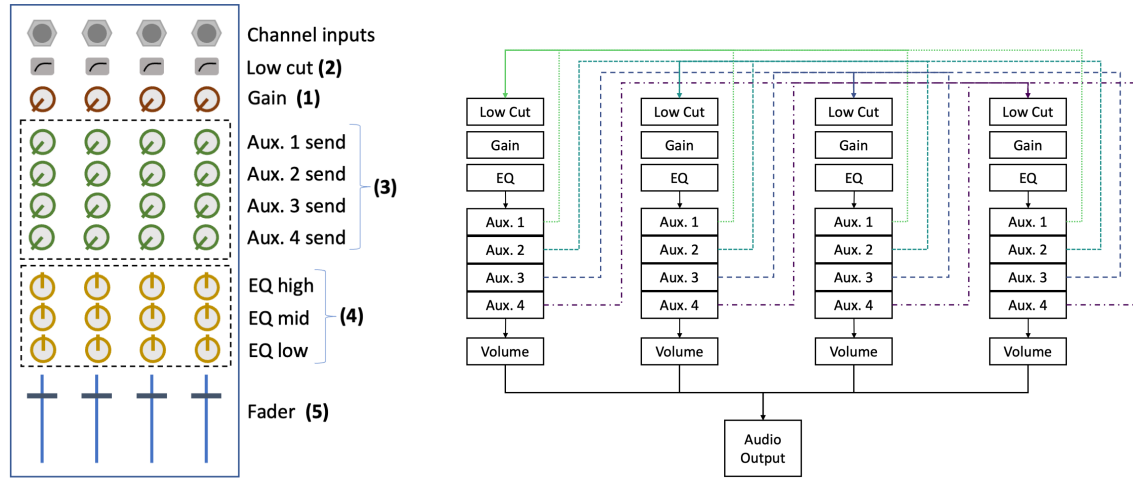
Considerations of interaction in music have a long history of making contributions to HCI research [8, 31]. This paper examines a discernible area of musical practice centered around feedback. Specifically, the use of the *no-input mixing desk*: feeding mixing desk channels back on themselves. The mixing desk—usually used for balancing external inputs in a performance or studio context—is thereby turned into a synthesizer, capable of creating a wide variety of tones, noises and behaviours with no external input.

No-input mixing provides a specific example of a wider practice of engaging with feedback for musical purposes. Feedback can be unstable and unpredictable, but these aspects are often part of the appeal for musicians. As such, it has provided a productive area for investigating how entangled notions of interaction and agency manifest in creative engagements with technology [26, 38, 44].

Twenty artists that have used no-input mixer in their work were interviewed. Thematic analysis of the interview data is used to explore several important areas: (1) how and why musicians find it valuable to work with such unpredictable instruments, (2) how no-input mixing is likened to or distinguished from digital or acoustic instruments, and (3) how no-input mixing provides a space for understanding and exploring entangled agency.

No-input mixing is not examined here because it is markedly different from interactions with other instruments, but because it appears to present an *exaggerated* aspect of interaction present in many more conventional musical instruments: in violins, saxophones and most sustained tone instruments. Such instruments can also be viewed as complex feedback systems that need to be navigated by the performer [29, 40, 48]. Bowed strings, blown reeds, and circuit feedback are all nonlinear dynamical processes, where control is holistic. In a saxophone for example, pitch and volume are not controlled from single separate input controls, but emerge from the state of the acoustic system as guided by breath, embouchure and fingering [19]. Digital musical instruments and musical tools are typically linear and tend to be characterised by a one-to-one mapping, where a single input element such as a button, dial, slider, or number box controls a single, perceivable aspect of the output. For example, an audio synthesizer application may have individual dials for pitch, volume, or filter settings. While these controls are usefully simple and understandable, the parameterisation of music making can encourage an overly analytical approach to creative practice [32]. This paper argues that feedback can be a practical approach for engaging musically with nonlinear dynamical processes, helpful in achieving rich musical interactions that can be leveraged in digital musical instruments in ways that resist this parameterisation.

The unstable and unpredictable nature of interaction with no-input mixing is helpful for highlighting and therefore discussing questions of agency. This contributes to current discussions on *entanglement* and HCI [25, 30], particularly surrounding creative interactions [1, 51]. Eldridge [26] and Aufermann [5] link musical engagements with feedback process to a sense of “complexity literacy”, a practical understanding of nonlinear multi-agent interactions that can be otherwise difficult to communicate. Both authors point to the significance of this understanding not only for music, but for understanding complexity in areas such as chemistry (Aufermann), and in relation to wider social and ecological concerns (Eldridge).



(a) Simplified overview of the typical control layout of a four channel mixer. In this example, there are four auxiliary sends which can be used to send any individual channel audio to another place. In a no-input mixer, these auxiliaries are typically sent back to the channel inputs as shown in Fig. 2b

(b) An example layout of a four channel no-input mixer, where each channel can be sent to any of the others via the auxiliary sends. This example routing diagram is configured like a matrix mixer, with aux. 1 sending audio to the first channel input, aux 2. to the second channel input, and so on. On many mixers the auxiliaries can be switched from sending audio *after* the channel EQ (as shown here) to sending *before* the channel EQ, leading to very different results.

Fig. 2. An overview of a basic no-input mixer setup

## 2 BACKGROUND

### 2.1 Brief overview of a feedback mixer

While a full technical overview of feedback mixer configurations is beyond the scope of this paper <sup>1</sup>, a few basic elements are useful for understanding what follows. Mixer channels generally include at least the following elements (Fig 2a):

- (1) input gain dial,
- (2) low cut button that removes very low frequencies when toggled (e.g. < 75Hz),
- (3) auxiliary send dials, allowing the channel to be routed elsewhere (e.g. to other channel inputs as shown in Fig 2b),
- (4) EQ dials that allow more specific control over low, medium and high frequencies,
- (5) volume fader.

Feedback can be produced in a number of ways, for example, using a cable to connect an auxiliary send to the input for that channel, routing a direct channel output back to the input, taking one of the master outputs and sending that back to a channel input and so on. Analogue mixing desks are generally preferred, where noise in the circuit and the idiosyncrasies of any defects can become an important aspect of the process. From an interaction point of view, one of the most interesting aspects of feedback is that the controls on the mixer are transformed. For example, the channel gain changes from being a simple volume control to having a big influence on the actual pitch of the tone produced,

<sup>1</sup>See [4, 15, 35] for more on no-input mixing, and [16] for an auto-ethnographic account

and to a lesser extent, its timbre. The EQ dials that would normally boost or attenuate different frequency bands also change their function and become nonlinear: boosting the high frequencies may cause a tone to suddenly jump to a higher register, or may produce a continuous pitch bend or cause a pitch to emerge from silence or from noise; boosting the low frequencies may similarly cause a pitch bend, or may cause an abrupt transition to a rhythmic pulse instead of a consistent tone, and so on.

When different channels are combined in different ways, the results can become increasingly complex, e.g. routing a small amount of a rhythmic pulse on one channel into another channel that is producing a constant tone may result in a more rhythmic version of that tone. The results are highly nonlinear however and it is not usually easy to predict what will happen when the signal routing becomes more complex.

## 2.2 Feedback Music

No-input mixing provides a specific example of a wider practice of engaging with feedback for music making, from Jimi Hendrix’s guitar and Eliane Radigue’s feedback compositions through to Hildur Guðnadóttir’s Oscar winning music made with the Halldorophone—a feedback cello-like instrument—and Cathy van Eck’s sonic art pieces. Feedback music has taken a wide variety of forms with artists using various methods such as synthesizers and circuitry [35, 50], microphones and speakers [23, 66], digital feedback at control rate for generating note-level events [54, 60] or at audio rate for synthesis [7, 17, 48, 61], or often combinations of these processes [2, 68]. One of the key appeals of feedback is that the technical apparatus can often be quite simple—basic circuits with few components, simple microphone-speaker combinations, minimal amounts of digital signal processing—but the results are emergent and can provide a significant level of depth and complexity that rewards exploration and experimentation [38, 44]. The description in the preceding section of how the mixer controls change when feedback is introduced from being simple, linear, one-to-one controls to being complex, contingent, nonlinear controls provides a typical example. More detailed accounts of feedback practice in music can be found in [3, 26, 38, 43, 58, 59, 66].

With no-input mixing the feedback is within the circuitry rather than emerging from a microphone-speaker coupling, and is therefore primarily a closed system<sup>2</sup>. The use of dials, buttons and faders contrasts with open feedback systems, where the positioning of speakers and microphones (or guitar pickups) in space, or the incidental sounds made by performers or audience members can become part of the performance. A really key aspect for no-input interaction is that there is generally very little delay in the feedback loop and the instrument is therefore very responsive; the system iterates rapidly and tends to spend less time on the transition between stable states when compared with microphone-speaker feedback. As the instrument doesn’t rely on sound reproduction through a speaker in the feedback loop, there is nothing to prevent very low frequencies, e.g. < 1Hz that manifest as rhythmic sounds, or very high frequencies, e.g. > 20kHz that are inaudible, but can still influence the behaviour of the system, or manifest as audible tones due to heterodyning, where the difference tone produced as the difference between the two frequencies is in the audible range.

## 2.3 Interactions with feedback

While feedback can be very attractive to musicians for sonic reasons, the nature of the interaction has been a key part of the appeal [27, 52, 59]. The complexity of control articulated in Section 2.1 connects with existing research into the control of digital musical instruments. Parameter cross-mappings have been highlighted as one way to create fun and

<sup>2</sup>excepting the potential influence of electrical and temperature variation

explorable musical interactions [32, 36]. These are mappings where there is not a one-to-one correspondence between input controls and perceivable features like pitch and volume, but where multiple inputs may affect an aspect like pitch, or a single input may affect multiple aspects simultaneously.

This research has been developed through considering both linear [45] and nonlinear control dynamics [34, 46]. The latter in particular brings the relationship between control inputs and perceptual outputs in digital musical systems closer to the highly nonlinear world of acoustic instruments [10, 29]. In both cases—as we see with feedback systems—perceivable sonic features are not generally controlled directly by the user input, but are emergent phenomena from the behaviour of a system that is being steered by user input.

Discussions of interactions with feedback often make more sense in the language of dynamical systems: attractors, trajectories, metastable states, oscillations, phase transitions, chaos, and so on [44, 58]. A feedback instrument can be thought of as an explorable landscape, where a particular trajectory is navigated between the push-pull of various attractors, in and out of stable states, into hidden niches that require careful timing to enter, and so on. This can make instruments interesting to explore and engage with over longer periods of time [48], and yet doesn't completely preclude the possibility of directing the instrument with a high degree of precision. This kind of interaction places a focus on listening and being attentive to how the instrument is behaving and responding.

Thinking through human-computer interaction in terms of nonlinear dynamics provides a useful perspective on creative interactions, and can support understandings of creativity in domains beyond music. Video feedback provides an example, having enjoying a parallel life to audio feedback [21, 39], and having also found new life in the digital domain [56], particularly in the realm of live coding visual performances [12]<sup>3</sup>. As we have seen above with sound and acoustic instruments, considering the use of feedback and nonlinear dynamics in a visual context can help us to think about the role these aspects play in non-digital practices, and hence what key differences there may be between digital and non-digital interactions. One example might be paint: interrelationships between the nonlinear, time-dependent behaviour of the paint, and the network of entangled spring-like elements that form the brush [69]. There are myriad ways of articulating a single brush stroke, just as there are myriad ways to articulate a single bowed gesture on a violin. In both cases, the nonlinear dynamical nature of the medium is a rich site for creative exploration. Paying attention to the material complexities at play in painting or in playing an acoustic instrument can help us see what may typically be different in a digital painting implementation or synthesizer, and how this may lead to a different kind of creative engagement.

The unpredictable dimension to such complex interactions provides a useful site to examine entangled notions of agency between the artist and the artistic tool [38, 44]. Examining feedback provides an opportunity for understanding creative practice in terms of material engagement: how tools can play an active role and provide material to be creatively engaged with, collaborated with, and pushed back against [26, 38]. The analysis for this study draws on and contributes to ideas surrounding Entanglement HCI [30], picking up in particular on Karen Barad's ideas around agential realism [6, p 26] and intra-action [6, p 33]: examining how human and machine agency are not distinct and pre-given, but emerge through their engagement with each other.

### 3 METHOD

This section outlines the methods used for participant selection, interviews and data analysis.

<sup>3</sup>Participant Mira Martin Gray also mentions Chloe Alexander Thompson and Naomi Mitchell's work with video feedback, and Richard Knight describes his own work combining both audio and video feedback by mixing signals across audio and video mixers



### 3.1 Participants

Twenty participants were interviewed, identified through a mixture of existing researcher awareness, through reading and researching articles on the subject, and through exploring networks of practitioners (each participant was asked whether they knew of other practitioners). A range of levels of experience with no-input mixer were sought, with some participants having only started in the last two years, and some having decades of experience. Four were female and 16 were male. Participant data has not been anonymised, and excerpts presented here are attributed to named participants. This is in order to ensure that the artists receive credit for their insights, and to allow researchers to further explore work by these artists that might help to further develop this research. Participants were sent a draft of the paper to ensure they were comfortable with the way their words are being presented.

### 3.2 Interviews and Questions

All interviews were conducted remotely, with 17 via remote video connection and 3 via email. Interviews were semi-structured with pre-prepared questions focusing on how participants came to use the no-input mixing desk, what their motivations were for doing so, how they approached live performances and recordings with such an unstable instrument, how they conceived of control and intention, and about their awareness of others using a similar setup in the past and present<sup>4</sup>. Participants were also asked to describe a particular moment working with their instrument that made them happy.

Where possible, participants were presented with particular moments in video or audio recordings of their own work and asked to articulate what was happening and what their thoughts and intentions might have been at the time. This provided a particularly useful method for concentrating on the important details of interaction with the mixer. A full question list is provided in the supplementary material.

### 3.3 Data Collection and Analysis

The data analysis draws on Braun and Clarke's approach to reflexive thematic analysis [14]. The epistemological stance taken here is broadly realist, assuming a fairly direct relationship between language and reality. The author is nevertheless aware that their own presence in the interviews as a researcher and artist may have an influence on participant responses, and an influence on the subsequent analysis of the data set. This background is important in bringing an awareness of the wider artistic context of no-input mixing, and in being able to ask relevant questions. The analysis for this paper is generally deductive in that it is driven by specific questions about creative interactions in feedback systems.

Data familiarisation took place throughout the interview process, with interviews being transcribed and coded in an ongoing fashion. Three themes were developed of particular relevance for this paper. These themes are introduced in Section 4 below, then explored in the wider context of HCI and musical practice in Section 5.

## 4 RESULTS

Three key themes are developed here of particular relevance to interaction:

- (1) the joy of working with the unknown;
- (2) immediacy, rawness, and contrasts with digital tools;
- (3) favourable comparisons with acoustic instruments.

<sup>4</sup>this latter topic is omitted here, but will form the basis of a subsequent musicological study

Each theme will be detailed in the subsections below and discussed more widely in relation to each other and the wider literature in Section 5.

#### 4.1 Theme 1: The joy of the unknown

Positive sentiments were often attached to the fact that the no-input mixer—or specific routing configurations of the mixer—is not fully understood, and to the surprising and unpredictable things that emerged. This did not appear to be something that diminished over time, and still applied to artists who have worked with mixers for years or decades. Toshimaru Nakamura's response was typical of the participant response when asked to describe a happy moment with the mixer: "when I encounter a sound I would never have expected."

Surprise emerges from a system that is partially but not completely knowable: the instrument can be explored in an active way and driven into places that yield unexpected results. Even participants with a strong background in audio engineering can quickly create feedback routings whose behaviours are impossible to predict, meaning that it can be difficult to be sure exactly what will happen when a dial is turned. Metaphors relating to dealing with a separate agency were given by many participants, e.g. taming or riding: "I'm not playing it but I'm sort of taming [it]" (Simon Grab), or "no-input mixer is like a wild horse that you have to get intimate in order to be able to tame and ride it" (Saba Alizadeh).

No-input mixer can provide a music-making partner that is mysterious and unpredictable even when studied closely, as Richard Knight describes:

I have in the past spent quite a bit of time analyzing signals that have come from various mixers to understand further what's going on there, because obviously from a sort of component level we can make some assumptions about how the various components and various processes, sorts of filtering, do affect the nature of the feedback, [...] but there definitely are things that kind of happen beyond the remit of full accountability from a component-led perspective. So, for example, one of the things that I remember from when I did some analysis was that, I think it was about 40 to 60 kHz, the energy in some particular frequencies in that region was quiet far in excess of what was actually happening in the audible spectrum and it appeared as if there was some sort of heterodyning that was going on there. So it's possible that there are actually things going on at really high frequencies that are creating audible artefacts or you know things like that. But there's certainly some mystery in that respect, and to an extent I'm quite happy to persist that mystery. (Richard Knight)

Knight has also created software models of the no-input mixer to aid his understanding, but is clear that "there's always going to be a bit of mystery to it, which is one of the things that makes it so fascinating to work with". No-input mixing is an instrument that can be studied for long periods of time without exhausting the mystery and the potential for unexpected things to occur. Simon Weins articulates similar sentiments:

It's kind of unexpected and there was a logic to it, but it was a logic that you couldn't really wrap your head around intellectually. And I thought it was very appealing. (Simon Weins)

As with the Nakamura quote above, this sense of working with the unknown was often invoked when participants were asked to describe a particular moment working with their instrument that had made them happy:

Sometimes, sometimes the sounds are so sweet [...] because you never can expect the sound, [...] this kind of moment comes. It comes: just, it comes. You have to you just play then, it's a gift from the room, the speakers, the audience, everything. But you have a feeling: it might come, it might happen today. (Yan Jun)



This sense of discovery can be seen as an integral part of using a no-input mixer for some.

that's why it's interesting [...] because I'm not designing it you know, I'm not designing sound, I'm just searching for it. (Emilia Wysocka)

This gives some idea of the depth of a system like this. The mixer was not designed to work in this way, but the simple process of feeding channels back on themselves presents a seemingly infinite labyrinth of sounds and behaviours that can be explored by musicians. The points of discovery seem to be all the more special and enjoyable when participants weren't able to later retrace their steps.

[working with a particular setup] it was definitely different and surprising and I've never really produced any sound quite like that, and I was kind of pleased with that. I couldn't get it to stick, couldn't ever recreate that type of stuff [...] You know feedback is a very touchy thing. It does what it wants and you can't always get to where you want to go. (David Lee Myers)

For some, these moments are also important because the mixer is revealing something new to understand, and learning is seen as important.

For me, whenever I hear something that's slightly new it's just 'wow that's so cool,' you know, the instrument is deepening and broadening for me and I'm learning more about it. (Sarah Belle Reid)

Even then however, this is not necessarily directed towards a notion of mastery in a conventional sense:

I do feel like you can get better at playing them, and this, this is not so much having more control but it's more having a better intuition (Tijs Ham)

A further important part of these unpredictable aspects for some was that they could be developed. A new sound is also a new behaviour and an area to engage with on the mixer, rather than an unexpected event that does not have consequences.

No-input mixing is the gift that keeps on giving because you just basically change one minor aspect of it, and instead of being a slight variation [...] it becomes this whole new world that you can explore again. (Tijs Ham)

## 4.2 Theme 2: Immediacy, Rawness, and Contrasts with Digital Tools

Several participants highlighted the importance of *immediacy* in working with their no-input mixer. There were several overlapping aspects to this immediacy. First, a temporal dimension: the instrument responds immediately to dial, fader and button movements. Secondly, sensitivity: the instrument can be responsive to delicate movements leading to a very tactile experience. Finally, some participants expressed a sense of immediacy in working directly with electrical current as the sound generator: a sense of *rawness* where the artist is not at a remove from the actual sonic material.

### 4.2.1 Temporal Immediacy.

What I always appreciated about the no-input mixer is that it's, generally speaking, as fast as an acoustic instrument. Whereas the problem with laptops was that often we have some delay until a certain result is achieved, and that always felt more time consuming than when playing on the no-input mixer, so in a way the spontaneity and fast reaction time you have on a mixer, that was something that brought it very close to acoustic instruments. (Marko Ciciliani)

This rapid response seemed to provide a refreshing contrast with digital instruments, often appearing to be a key motivator for using the no-input mixer.

I'd been generally focusing on computer composition or on the computer as an instrument and that kind of leaves a bit to be desired with gestural interaction [...] there was a distinct lack of immediacy I suppose in my life. [...] The immediate responsiveness of using [no-input mixer] as an instrument is so engaging as to make it quite a stimulating thing. (Richard Knight)

I like the fact that you can articulate things really quickly on an analog mixer too. That's the thing with anything [digital], there's always that sort of latency between the the human movement and the sort of zeros and ones catching up you know, whereas the Allen and Heath or any analog mixer [...] you can really sort of jab that fader and have almost staccato notes. (Christian Carrière)

**4.2.2 Sensitivity and physicality.** A connected but distinct aspect of this immediacy relates to the sensitivity of the mixer: a very small amount of physical change can be perceived audibly. Lucia H Chung describes working with dials and buttons that are sensitive to being touched without needing to be actually turned or fully depressed.

it's a very wobbly gain dial, so you can just like kind of press it slightly, like you know... rattle it. [...] For mixer feedback, the looser the dial, the better. It's the same with the low cut [button]. Lots of times it's more utilizing it not completely, it's more like in between the space of it being pressed. So that can create lots of different textures or disturbances of the current. (Lucia H Chung)

While this is true to an extent in most analog instruments, the sensitivity is amplified in a no-input mixer, as the result of that tiny movement may be highly significant.

It can be really interesting and expressive to just touch the knobs with your finger, just like not even turning anything but just sort of tapping the top of a mixer or some other system, just to see if the little tiny touches already derail whatever is happening, and in some significant way. (Tijs Ham)

**4.2.3 Rawness.** The sense of immediacy also seems to connect to the fact that there is a directness to working with electricity in this way, creating a sense of "rawness". As with the sensitivity, this can give the mixer a tactile quality and a sense of physicality.

I think there's something about the rawness and the... it's like starting with bare electricity, you know, in a way it's sort of like the sonic version of bare electricity and then, you know carving it into something or wrestling it into something. (Christian Carrière)

One of the first things that I love is just the actual, like the physicality of it, you know. [...] John Bischoff had a really great thing in an interview he did with Doug Kahn [33] where he was talking about the old days of the KIM1 computers, it was like they were programming the speaker, you know, like they're saying "push out this much". So that's like what the mixer feels like, right, it's like you're just like using the electricity to play the speakers. (Philip White)

Again, while this is technically true with any analog synth or even digital musical system, there appear to be fewer perceived layers of mediation between the musician and the current in the speakers in the case of no-input mixing, contributing to this sense of immediate, direct, rawness.

### 4.3 Theme 3: Favourable Comparisons with Acoustic Instruments

Participants often compared the no-input mixer to acoustic instruments. This is a theme of particular interest in this research as it articulates aspects that are perceived as missing or limiting in digital musical instruments. One aspect relates to the immediacy presented in the previous theme as can be seen in the extract from Marko Ciciliani in Section 4.2.1. However, other more subtle similarities were highlighted. In the extract below, Tijs Ham describes the appeal of the chaotic turbulence found in a saxophone and how this was a key influence on him in beginning to work with feedback and no-input mixer:

I went to this concert, which for me was very formative. Not an electronics concert, but a concert by a saxophonist called Colin Stetson and I was really blown away by the overblown sound of his saxophone and the intensity of it and the richness of the sound and I was just like, what's happening here? What is this? And I'm not a saxophonist at all, I was working with live electronics [...] but I was thinking like, how can I get to this kind of rich sound world within my field of live electronics? So my first realization was that this overblowing of the saxophone is actually creating turbulence within the tube of the saxophone and it's basically turning the saxophone from a stable instrument into a chaotic system. (Tijs Ham)

Ham points to a difference between acoustic instruments and no-input feedback instruments as being how central the stable and unstable aspects of the instrument are to performing with that instrument:

So whereas a lot of acoustic instruments are designed to be used in their stable states and their unstable states are kind of in the peripheries I designed my instrument in such a way that the unstable states are in the middle. that's the difference to me. (Tijs Ham)

This is notable in that the no-input mixer is not perceived as similar to acoustic instruments *despite* its chaotic nature, but *because* of it, and that the distinction is instead one of degree. Saba Alizadeh also focuses in on the unpredictable aspect in making this comparison:

Coming from an acoustic performer background, for me no-input mixer is the closest thing to that experience in the electronic world, since it could always have a surprise element. A no-input mixer is like a wild horse that you have to get intimate in order to be able to tame and ride it, I would have to say I find it very similar to my main instrument Kamancheh [a bowed string instrument], since Kamancheh is also fretless it is also very hard to get a grip on compared to other instruments. (Saba Alizadeh)

This perspective on acoustic instruments as being surprising and chaotic is important for thinking about digital instruments, and is developed further in the discussion in Section 5.

Most of the participants have used their no-input mixer in improvised settings alongside acoustic musicians, with several participants noting a good fit with the mixer and saxophones in particular:

"I find it blends really well in a room with with a saxophone or percussion" (Mira Martin Gray)

"It works actually really well with certain instruments. I've noticed it works well with saxophone. In fact, one of my ambitions, was to try to sound like [saxophonist] Peter Brotzmann in a way." (Andrew Leslie Hooker).

Sarah Belle Reid talks about how no-input mixing feeds back into her trumpet playing, particularly a terms of being more open to unpredictability and chaotic aspects:

I think working with a no-input mixer and working with feedback instruments has helped me approach my acoustic trumpet playing in a different way, where I am more open to embracing and seeing where

things go rather than always being in control. Like, for example, perhaps your lip vibrates in a strange way and you create a double buzz that maybe you were intending, or maybe you weren't, and then you've got this new physical variable at play because things are vibrating in a weird way. The training that I had as a classical trumpet player was to immediately try to correct that and get back into the mode of playing in which I am in control. But I think working with feedback instruments and generally my interest in that way of making music has led me to linger there a little bit longer, and ask myself, "I wonder what will happen if I let that condensation accumulate in the horn, as opposed to emptying it out, or if I let that weird extra vibration happen and I explore it further". And when I do that it feels more like the no-input mixer because I'm a little less certain at any moment what will happen when I input a new gesture. (Sarah Belle Reid)

This echoes Ham's point that the difference between feedback systems like the no-input mixer and many acoustic instruments is to do with where the focus is placed in playing the instrument. The no-input mixer easily affords leaning into the chaotic aspects. Similar engagements can be had with acoustic instruments, but these are either less obvious, or they are studiously avoided, with instrumental training tending to focus on the reproduction of stable tones and clean transitions between tones, bringing the complexity to heel.

## 5 DISCUSSION

The themes articulated above are discussed here from three perspectives:

- (1) how complicated interactions can be useful, and how feedback is a means to achieve this;
- (2) feedback's potential role in digital musical interactions;
- (3) how entanglement notions of agency in no-input mixing can be useful for thinking about interaction more generally.

### 5.1 Feedback can create usefully complicated interactions

The themes above highlight several important aspects in relation to interaction. Firstly that it can be creatively rewarding to work with instruments that are complicated, confusing, and unpredictable. Secondly that direct or complete control is not always desirable. Thirdly that feedback processes can be a useful mechanism to transform a traditionally straightforward situation into a more mysterious, engaging, and potentially fun creative situation.

An important distinction for HCI is that the unpredictability is not arbitrary or random. When something unexpected occurs, it can usually be engaged with and explored further. For example, an unpredictable outcome may involve the discovery of a new metastable state that an artist can probe and experiment with, engaging with new sounds and behaviours, and learning about an aspect of their instrument. As theme 1 articulates, the discovery of a new sound, behaviour, or area of interaction was associated with joy, and this sense of possibility appears to motivate the exploration of the instrument: there is a depth of possibility.

A study with improvising musicians highlighted similar perspectives on working with the unknown [48]. Beauty was ascribed to being in a musical situation that can never be fully understood. The study similarly found a focus on learning that is not necessarily about mastering an instrument, but as an end in itself. This connects to Eldridge's notion of "complexity literacy", where again, the learning that takes place in engaging with feedback systems is not focused on mastery but encourages a letting go of intention, embracing an entangled agency, that for Eldridge "borders on the blissful" [26].

Theme 3 highlights that the interactions associated with feedback have close parallels with interactions with acoustic instruments. Even if these aspects of the interaction are exaggerated in no-input mixers, they are present in more traditional instruments, and can be explored and exploited in very similar ways. Acoustic instruments often come equipped by default with some sense of mystery due to the complexity of bowed string interactions [24], hydrodynamics [28], or reed behaviour [22]. They are also frequently described as collaborators [13, 55, 64], mirroring the kinds of co-creation and mingling of agency presented in Section 4.3.

By contrast, digital musical instruments are generally built from comparatively straightforward elements. Although these may be sometimes be difficult to use and learning will play an important part, these aspects don't necessarily manifest in the *interaction* with the tool, and don't allow for analogous approaches to exploration. This supports the notion that the nonlinear feedback processes present in instruments like the saxophone or violin may be an integral part of what makes these instruments engaging and explorable over long periods of time. Feedback processes provide a means by which to leverage this kind of interaction in digital instruments and interfaces.

Such perspectives on creative engagement can also offer important insights into how and why artists may want to engage with artificial intelligence processes for creative outcomes (e.g. a text prompt-based image generator): the unpredictability and unknowable nature of the machine learning systems being dealt with can be part of their appeal, rather than a hindrance.

## 5.2 Digital feedback instruments

Several of the study participants described digital feedback systems that are either self-contained or that interface with their analog feedback processes (Marko Ciciliani, Tijs Ham, Richard Knight, Simon Weins, Philip White)<sup>5</sup>. This hybridity is something that can be seen in a range of other feedback instruments that seek to blend the potential of digital control, with the complex properties of acoustic feedback. Instruments like the feedback cello, bass and viola [27] and resonator piano [41] draw on this approach, as do feedback compositions experiments by composers such as Cathy van Eck [67], Nicolas Collins [20] and Agostino Di Scipio [59].

The immediacy and perceived “rawness” of no-input mixing detailed above in Section 4.2 are two elements that are difficult to achieve in digital systems. Several participants placed the experience closer to playing an acoustic instrument than a digital interfaces, suggesting that the time delay when using digital interfaces such as MIDI reduced that sense of immediacy. A useful future study might test whether ultra low latency systems like the Bela board [42] might be able to recreate this sense of immediacy in the digital domain. Participant Philip White suggests that “rawness” is not unique to analog systems, discussing John Bischoff's use of the KIM1 computer as a similarly raw engagement with sound and electricity.

Feedback can exist in digital musical tools in less obvious ways. Physical modelling—digital synthesis processes based on physical simulations of acoustic or electronic instruments—inevitably relies on nonlinear feedback mechanisms to successfully model acoustic instruments [9, 65]. It's notable in this context that one of the outstanding concerns in physical modelling research is one of control [11]: a digital simulation of a trumpet is difficult to control, comparable to the complexity of a real trumpet. The fact that feedback is essential in modelling acoustic musical instruments, but generally not harnessed in other digital musical tools presents a gap in this domain that could be usefully explored.

<sup>5</sup>see also [53, 62]

### 5.3 Entangled Agency

The negotiations of agency being described by artists using no-input mixer can be connected to recent discussions in HCI on *entangled* perspectives [25, 30]. Barad’s notion of intra-action [6, p 33] avoids locating agency as pre-existing within either the artist or the instrument, and instead suggests that it is negotiated in their encounter with each other. Barad describes writing a book as a “mutually constitutive working out, and reworking, of “book” and “author”” [6, p X]. Devendorf and Rosner use the term “coproduction” to describe this hybridity [25], a concept that allies closely to some of the participant descriptions of no-input mixer.

In her participant interview, Sarah Belle Reid uses the term “co-creation” to describe her relationship with her instrument (as well as the wider set of entanglements such as the audience and the larger musical community surrounding any given performance). This idea can be seen reflected in many of the participant data excerpts reported above, and is embedded into some of the earliest examples of the practice. David Tudor described himself as an “interpreter and performer acting within an interactive situation created collaboratively” in relation to his feedback mixer work in the 1960s [35]. Similarly, Toshimaru Nakamura’s earliest work with no-input mixer alongside Sachiko M in the late 1990s engaged with similar ideas, where “non-human bodies, forces and media [...] contribute to the ‘organisation of sound’” [63, p 161]. The fact that no-input mixer can be so difficult to predict can force a reappraisal of the nature of interaction, making it difficult to maintain a “communication-oriented” view of instrumental interaction [47], where the instrument is “a passive agent in a unidirectional flow of sonic information travelling unchanged from sender to receiver” [44].

I argue here that this co-creation is present in any instrumental interaction, but that it is much more explicit in feedback music and particularly no-input mixing, making it easier to articulate and describe as seen in some of the extracts above. The comparisons above with acoustic instruments in Section 4.3 provide links between intra-acting with the no-input mixer and with acoustic instruments. Eldridge articulates the way that feedback instruments defy “wilful imposition” [26], but the same could be said of a brass, reed or bowed instrument. A musician encountering a trumpet for the first time will likely feel that the instrument resists wilful imposition as they struggle to produce or maintain a stable tone, or articulate a particular melody or timbral gesture, and they will need to negotiate the unruly behaviours of the instrument. Again, the language of dynamical systems becomes relevant as the player encounters metastable states, oscillations, and abrupt phase transitions.

### 5.4 Considerations for other HCI domains

The no-input mixer provides a usefully exaggerated example of an interaction with feedback. The properties of feedback are front and centre in the creative work. This is interesting in itself and for understandings of musical practice, but as Section 4.3 shows it also helps to explore more subtle examples of similar interactions, e.g. helping to articulate how the nonlinear dynamical aspects of many acoustic musical instruments may be fundamental to the practices that build up around them. This in turn helps to articulate what can be different in the digital domain, where nonlinear dynamical properties are no longer the default as they are in the physical world, and would need to be consciously considered in the design process. As noted in Section 2.3, the nonlinear dynamical complexity of paint and paintbrushes provides an analogous situation in the visual domain as can be seen in digital models of paintbrushes [18, 69].

A feedback perspective changes the perspective on what is being controlled: the perceptual aspects of the output are emergent phenomena rather than aspects that can be controlled directly. In a musical context, this might mean pitch, volume or timbre. In a visual domain, this might be the brightness or colour of a set of pixels, or particular changes in gradient with space and/or time. In animation or gaming, this might be the position and momentum of a character or



vehicle. The notions of control expressed by participants using the no-input mixer contrast with typical digital approach to controlling sound. The MIDI protocol [57] which conceives of sound as a series of discrete note events is ubiquitous in music technologies, stemming from the use of the keyboard as the default way to engage with synthesizer. While the default in the digital realm, the keyboard is often an outlier in terms of how acoustic musical instruments are controlled, as it separates the musician from a direct engagement with the acoustic complexity of a vibrating string, or a column of air. In non-keyboard instruments, as in the feedback mixer, notes are usually emergent properties: metastable entities that can be pushed into and out of, and where there can be a lot of creative interest in exploring the boundaries [49].

We can take this concept of emergent, metastable situations into other domains beyond sound and image. Considering again the control of a virtual vehicle: an outcome such as ‘moving to the left’ may often be less interesting if it can be done directly. If the player of a driving game presses a ‘left’ button and their vehicle immediately moves to the left, this may be less satisfying as an interactive experience than having to manage the dynamics of the vehicle. Pressing ‘left’ may begin to shift the car to the left, but there may be interesting complications. The car may skid and keep moving in a direction different to the direction the tyres are facing, or the may flip and begin to roll. A lot of the fun and creativity in a driving game can come from play and exploration with the dynamics of the vehicle regardless of the goals of the game [37]: managing the momentum, balance, rotation, etc. Just as there are endless ways to articulate a violin note, so there are endless ways to drive over a ramp in a virtual vehicle, even with relatively simple models of vehicle dynamics.

A feedback interaction perspective provides a particular practical method for creative interactions with digital technologies, but also a framework for understanding and articulating creative explorations that already exist, whether in sound and music, visual image creation or animation, video game control, or beyond.

## 6 CONCLUSION

This paper has explored no-input mixing as a creative engagement with feedback. Thematic analysis of artist interviews provides insights into how people value working with an unpredictable and often incomprehensible instrument. While no-input mixing provides an extreme example of interacting with feedback, this can help us understand creative interactions where the feedback element is more subtle. A focus on feedback also helps us to understand our existing engagements with the physical world, and to develop more nuanced understandings of how creative practices connect to the specific material properties of our tools and technologies. The complexity and unpredictability of feedback can be allied with acoustic instruments that rely on acoustic feedback mechanisms such as reed-bore couplings and bowed-string interactions. By default these kinds of feedback interactions are absent from digital technologies, but forays into digital feedback process suggest a practical way to open up usefully different ways of engaging creatively with computers. Ultra low latency audio systems may be helpful for fostering a sense of immediacy and directness.

## ACKNOWLEDGMENTS

Many thanks to the artists who generously contributed their time to discuss their practice in the research interviews: Saba Alizadeh, Knut Aufermann, Christian Carrière, Lucia H Chung, Marko Ciciliani, Jez Riley French, Simon Grab, Tijs Ham, Andrew Leslie Hooker, Yan Jun, Richard Knight, Mira Martin-Gray, Andreas Mangweth, David Lee Myers, Toshimaru Nakamura, Sarah Belle Reid, Frans de Waard, Simon Weins, Philip White and Emilia Wysocka.

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