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# Endemic Machines: Artificial Creativity in the Wild

David Kadish

# ABSTRACT

Artificial creativity is often applied in the production of artefacts and ideas for a human audience. However, as a creative force that is not bound to human experiences, it can act as a way of approaching nonhuman creative forces from a new perspective. This paper develops a concept of endemic machines to describe a process of engaging the creativity of an ecosystem through a machine that adapts with that ecosystem. A case study detailing the design and testing of an endemic machine called the Rowdy Krause helps to ground the concept of endemic machines in practice.

## **KEYWORDS**

endemic machines, artificial intelligence, soundscape ecology, creativity, eco-technogenesis

In the past half century, creative machines have produced paintings, music, and jokes (Boden, "Creativity and artificial intelligence"). They have rediscovered and refined basic scientific principles, including a range of principles such as Ohm's law, Coulomb's lay, and the Ideal gas law that form much of the basis of classical physics and chemistry (Langley; Boden, "Computer Models of Creativity"). And they have evolved new designs for objects from tables and optical lenses to robots (Lehman et al.). The paintings in question are enjoyed by human viewers; the scientific theories are deployed by human researchers; and the tables, robots, and lenses are used in a variety of daily human activities.

But creative artificial intelligences (AIs) – referring here to computer models producing results that are both new and valuable – also offer the opportunity for a different kind of exploration: the exploration of creative production for an audience that is not human. Artificial creativity can act as a lens through which to explore not creativity for humans, but other forms of creativity to which we have limited experiential access. In particular, this article focuses on nonhuman forms of biological creativity: the creativity of evolution and ecosystems.

The article outlines endemic machines, a set of practices and principles relating to machines that engage creatively with ecosystems through co-evolution. These are examined in greater depth through the presentation of a case study that details the design and testing of an endemic machine called the Rowdy Krause.

## Creativities

Margaret A. Boden defines computational creativity as the production of ideas that are "novel, surprising, and valuable" ("Creativity and Artificial Intelligence" 347) by computational models. In this view, creativity is an everyday activity, producing localised novelty that is new for the people or computers involved as well as global or "historical" novelty in the form of ideas that have never existed anywhere. Creative AIs have produced novel, surprising, and valuable ideas across a range of fields and localisations, from painting (Cohen) to musical composition (Carnovalini and Rodà) to scientific discovery (Boden, "Creativity and artificial intelligence").

These creative computational agents have engaged in a wide range of activities that were once considered the sole domain of human ingenuity and creative practice (Boden, "Computer Models of Creativity"; Jordanous). However, their creative strengths often differ from those of humans (Boden, "Computer Models of Creativity") and this has offered researchers the opportunity to use computational creativity as a sort of mirror with which to explore human creativity from novel perspectives (Gobet and Sala). As researchers have observed new modes of creativity in computers, it has led them to question and refine the existing models of human creativity (Gobet and Sala).

The distinctly nonhuman creativity of computational agents also offers another opportunity that has been less explored – to engage with and explore

other creative forces that are nonhuman and also non-machine (J. C. Kaufman and A. B. Kaufman; A. B. Kaufman et al.). The strangeness of computational creativity that has helped to shine new light on human creative processes can, in the same way, be deployed to study and engage with other biological creativities.

Examples of this can be found in recent efforts to interpret the communication of various animals using AI. An initiative called CETI [1] aims to use AI to better understand whale communication (Andreas et al.). Another research programme has produced promising results translating the ultrasonic vocalisations of rodents (Coffey et al.). These efforts make use of computational strength in exploratory creativity (Boden, "Computer Models of Creativity") – the exploration of the semantic space of another species in this case – as well as the ability to endow computational systems with sensory systems that can sense beyond the nominal ranges of human hearing.

In endemic machines, the domain of creative AI is further expanded, moving beyond engagement with a single individual or a small group towards an encounter with the creativity of an ecosystem. To engage with this creativity, it must first be defined. What is, exactly, the creativity of an ecosystem?

Researchers have long considered Darwinian evolution – in particular the process of natural selection – to be a creative process (Dobzbansky; Gould; Boden, "Computer Models of Creativity"; Beatty). Theodosius Dobzbansky points to the "absolute novelties" (63) produced by evolution while Stephen Jay Gould calls the creativity of natural selection "the essence of Darwinism" (44). Boden invokes the creativity of biological evolution to point to the tendency of evolutionary algorithms to generate transformational novelty ("Computer Models of Creativity"). McCormack goes a step further, hinting that biological ecosystems themselves might be considered creative ("Creative Systems: A Biological Perspective"). Evolution is not something that a species does on its own. Natural selection is a collective process, driven by predators and prey, mates and conspecifics. These processes of predation, mating, and co-operation occur in – and are a function of – the ecosystem.

Thus, the creativity of ecosystems resides in the complex web of relationships and dependencies that perpetuate the flow of materials and energies and drive the processes of evolution by natural selection within them. It is the combined creativity of the evolutionary processes shaping the species that compose the living community of the ecosystem (Gould). This is the creativity that results in Darwin's "endless forms" (490), the incredible diversity of the tree of life.

In this creativity of evolution and ecosystems lies an opportunity for artificial creativity. It is an opportunity to engage, as a nonhuman creativity with a creative force that is itself not human. A chance to engage ecosystems with an openness that pulls some focus from anthropocentric conceptions of what an ecosystem should be or what form it should take. There is the possibility of forming new types of relationships with plant, animal, and fungal inhabitants of an ecosystem that lie outside the realm of human sensory perception and human desire.

[1] The Cetacean Translation Initiative, <u>https://www.projectceti.org/</u>

## Trends in Robotics in Ecosystems

The aforementioned AI-based animal communication projects are just one way that researchers have attempted to develop machines that interact with nonhuman forms of biological creativity. Van Wynsberghe and Donhauser defined three categories to group different kinds of environmental robots: robots-in-ecology are general-use robots that are used for environmental purposes such as data collection or surveying; robots-for-ecology are robots designed specifically for use in ecology or by ecologists; and ecobots are robots that are "ecologically functional" – that is, they perform some ecosystem function as opposed to merely observing or collecting.

This last category, ecobots, is of particular relevance to the discussion here. The notion of functional implies an ecologically significant role. An ecobot, therefore, is active in "the cycling of materials and the flow of energy" (Odum) that shape the ecosystem. Note, however, that there is no requirement in Van Wynsberghe and Donhauser's conception of ecobots that the machines are artificially intelligent or necessarily creative. The two examples of digital ecobots that they give – they also discuss bio-tech hybrids such as genetically engineered plants and biofilms as potential ecobots – are autonomous underwater robots designed to hunt and kill predators that have become overabundant and are destabilising coral reefs.

These ecobots are interesting examples of robots performing an ecosystem function. They use AI systems to detect their targets and help conservation biologists to bring the ecosystem into a state of equilibrium. They are designed to address a situation where an apex predator has become successful beyond the carrying capacity of their environment. In that sense, they are indeed engaging the material and energetic flows of an ecosystem. But they are not designed to adapt their behaviours as the relative abundance of those target predators changes, for example. Their engagement and role with the ecosystem is static.

## Creativity and Endemism

Though the ecobots described in the previous section have an ecological mission, the complete terms of their operation are set by human designers. The concept of endemic machines proposed here is something more openended. It sets forth a paradigm for a type of digital engagement with ecosystems that seeks creative ways of contributing to the ecology of a place. It relies on the opacity of computational evolution – including the widespread ability of computationally evolved systems to produce results that confound their programmers (Lehman et al.) – as an entryway into the partially obscured world of biological evolution.

Endemic machines are grounded in the ecological concept of endemism. In ecology, endemism describes the relationship between a species and a particular place (Morrone). The singularity of the linkage between place and species signifies a special bond. An endemic robot, like an endemic species, is "produced in a specified place and nowhere else in the world" (Darwin).

Materially, this would seem antithetical to the way robots are produced. As artefacts of a globally connected system of trade, robots are conglomerations of standardised parts, each manufactured in a different, highly specialised factory from materials harvested from around the world. They are, in this sense, the very opposite of endemic.

While it is possible for robots to incorporate locally sourced materials, the discussion here focuses not on the production of the physical robot, but on the development of a robot's behaviour. The robot's physicality may be of a distributed origin, but for an endemic robot, its behaviour is learned, evolved, or otherwise produced in a specified place. Like evolution itself, the development of the robot's behaviour is uncharted; there is no defined destination.

As the endemic robot learns with the ecosystem, it engages in a process of ecotechnogenesis (Hines et al.). An ecological extension to the concept of technogenesis (Stiegler, expanded by Hayles), eco-technogenesis refers to a process of co-evolution whereby an ecosystem and a technology form a shared, entangled history. Each exists as it does because of the other.

#### Case Study: The Rowdy Krause

The concept of endemic robotics is explored in more depth through a case study of an embodied, artificially intelligent agent called the Rowdy Krause. The Rowdy Krause is an experiment in artificial niche construction in a biological ecosystem. The machine's goal is to create a space for itself, a niche within an existing ecosystem.

#### Niches and the Acoustic Niche Hypothesis

An ecological niche describes the collection of environments and resources that impact the lifecycle of an organism (McCormack, "Creative ecosystems"). It encompasses their food, shelter, predators, prey, symbionts, and waste streams (Pocheville). Niche construction recognises that, as an organism forms its own niche, it shifts the resource landscape such that the ecosystem itself changes form (Laland et al.). This opens space for new niches and shifts the adaptive pressures on other species. The act of a species inhabiting a space changes that space and has impacts that ripple through the ecosystem (McCormack, "Enhancing creativity with niche construction").

The Rowdy Krause engages an ecosystem and a specific part of its resource landscape: the soundscape. The soundscape is the collection of all the sounds in a particular environment (Schafer) and its study in the context of ecology is called soundscape ecology (Pijanowski et al.; Farina). Niche theory appears in soundscape ecology as the acoustic niche hypothesis (ANH), which treats the soundscape as a limited resource that ecosystem inhabitants can use (Krause). Much as plants compete for sunlight in a dense forest, species compete for sonic territory and construct niches in the acoustic spectrum.

The ANH hypothesises that different species try to minimise overlap in their use of sonic resources to not confuse signals. Partitioning can occur spectrally, by using different frequencies or tones; temporally, by vocalising at different times of the day or the year; or spatially, by moving to different locations. Of these, the Rowdy Krause focuses on spectral partitioning to find itself an acoustic niche.



Designing for Ecosystems

One of the central questions in the practice of endemic machines is how to design a machine for an ecosystem. Even the notion of what it means to contribute to an ecosystem seems to indicate that there is a correct trajectory for the development of an ecosystem. This is problematic; it implies a teleology to the dynamics of evolution.

Three ideas ultimately helped to address this question and served as guides in the design process for the Rowdy Krause: The first is the ANH, which helped to establish the intended sonic parameters for the new vocalisation. The second is Gregory Bateson's concept of ecological aesthetics and his notion of being "responsive to the pattern which connects" (8). Finally, there is Rafael Lozano-Hemmer's assertion that electronic art should have the ability to surprise the artist (Lozano-Hemmer and Ranzenbacher).

The use of the ANH helped to form a framework for what might be considered beneficial for an ecosystem without defining a specific sonic outcome. Bernie L. Krause (1987) posited that the partitioning of a soundscape is related to the age and maturity of an ecosystem. If the tendency is for an ecosystem's acoustic spectrum to be partitioned and filled over time, an

**Fig. 1** The Rowdy Krause, in development and initial testing. LEFT: The internal electronics. RIGHT: Testing at Byhaven på Sundholm.

endemic machine participating in the process of finding and occupying an acoustic niche can be understood as contributing to the maturation of the soundscape.

Ecological aesthetics helped to focus the process on the feedbacks and interactions that the Rowdy Krause would encounter. It drew attention to how current inhabitants of the ecosystem might perceive the sudden arrival of a new sonic agent. It focused the inquiry on to how to frame the process of listening within a soundscape and how to produce ecologically relevant sound to project back into that environment.

The idea of art surprising the artist helped to reinforce that the Rowdy Krause should not necessarily produce the sounds that met my own desires or expectations, but that its aim was to fit the fabric of the existing soundscape. Surprising vocalisations produced by the Rowdy Krause are acceptable and perhaps even valuable so long as they serve the purpose of establishing an acoustic niche. This prompt reinforced the idea that, in the process of building and programming the Rowdy Krause, it was important to be able to differentiate between something broken or not working and something not working as expected, but in a manner that is still in fulfilment of its overarching goal.

#### Prototype

The first task in the design of the Rowdy Krause was to design the mechanism for producing sound. The intent was for the Rowdy Krause to behave similarly to a novel animal in the soundscape, so it was important for it to have behaviours which responded to the ecosystem, but also for it to be able to evolve over time. Neuroevolution of augmenting topologies (NEAT) is a computational evolution algorithm that is well-suited to this task as it evolves a neural network structure, which can be used to drive specific behaviour. The algorithm adds complexity to the network as needed, meaning that the structure of the behaviour tends to move from relatively simple at the outset to more complex behaviours over time.

However, an artificial neural network (ANN) itself does not produce sound. It merely maps inputs to outputs through a network of artificial neurons, analogous to a brain. That brain requires some form of instrument to turn its signals into sound. Recent research has used a range of different "instruments" for this task. Some ANNs generate raw audio waveforms that can be played directly on a speaker (van den Oord et al.). Others generate audio in the frequency domain, producing spectral representations that are then converted into sound (Engel et al.). Yet other attempts use a more symbolic approach, generating musical scores or MIDI instructions that can be played on real or electronic instruments (Huang et al.).

For the purposes of the Rowdy Krause these approaches all seemed either too limited or too open. The symbolic techniques are typically used to generate music or speech, both of which are rooted in human culture. If the project of endemic machines is based on using nonhuman intelligence to interact in new ways with the nonhuman ecosystem, it would seem antithetical to limit the range of sounds to those generated by human cultures. The raw waveforms and frequency domain representations pose almost the opposite challenge: they can create almost any sound imaginable, far beyond the range of what would be found in an ecosystem.



The task, then, was to identify a mechanism for generating sound that could produce a range of sounds that would not be out of place in an ecosystem, but that isn't limited to human semiosis. A search for a suitable mechanism led to the Pink Trombone (https://dood.al/pinktrombone/). Pink Trombone (fig. 2) is a vocal tract simulator made for touchscreen devices so that users can control a virtual tongue and palate as well as the voicebox to create human-like noises. However, it is also possible to re-code it so that the dimensions of the vocal tract can vary outside of the range of human anatomy and the tract can be controlled in ways that are not possible for a human to achieve. Together, these features formed an even balance between something that is based in biology, but not too specifically human.

To control Pink Trombone, the ANN's outputs were connected to the control points that determine the shape of the vocal tract's throat, tongue, and lips (see fig. 2). The ANN's outputs were calculated at every time step and the shape of the vocal tract was adjusted accordingly. This produced a unique vocalisation for each evolved iteration of the neural network structure.

In NEAT, the process used to evolve the ANN, a fitness is calculated for each of the individuals – the different neural network structures – in a generation (Stanley and Miikkulainen). The ANNs that produce the highest fitness levels in each generation are selected to reproduce and form the next generation, driving the population towards higher fitnesses. The design of an appropriate

Fig. 2. The Pink Trombone interface (© 2017 Neil Thapen, Used with permission). A video of the Rowdy Krause prototype evolving control of Pink Trombone in real time is available at https://vimeo.com/359044847. measurement of fitness is a key component in the success of an evolutionary algorithm.



The goal of the Rowdy Krause was to find an acoustic niche in an existing ecosystem. Thus, the fitness for an ANN controlling Pink Trombone was calculated as the uniqueness of the spectral composition of the sound that was produced. In practice, this involved sampling the soundscape of the ecosystem in question, performing a fast Fourier transform (FFT) to calculate its spectrum, and then creating a database of the spectral components of the soundscape samples. Sounds produced by the ANN and Pink Trombone were then compared to this database and those most different from the recorded sounds in the database were determined to be most ft. A full description of the soundscape analysis process is shown in Figure 3.

This system was demonstrated initially at a workshop in the summer of 2019, using recorded audio from a forest garden in southern Sweden as the soundscape. This proof-of-concept demonstration was entirely virtual and offline, but the sounds that were generated were interesting enough to warrant further exploration.

#### Embodied Implementation

The prototype demonstrated the efficacy of evolving a neural network to control the Pink Trombone. Missing, however, was the element of feedback from the ecosystem that is an essential component of an endemic machine. The Rowdy Krause could learn from the recorded audio in the virtual versions, but the ecosystems in question had no opportunity to respond to the Rowdy Krause.

The shift from a prototype to an embodied device prompted a miniaturisation of the computational components of the system. The code that had previously been executed on a laptop was now running on a Raspberry Pi - a singleboard, embedded computer with vastly less processing power. The consequence of this was that code that had run previously in realtime, a key

Fig. 3. Sounds are recorded as raw waveforms (a) during every other 10-minute period from the beginning of the Rowdy Krause's installation in a location. The silent parts of the recording are removed, and the remaining clips (b) are processed as individual samples. A 64-bin short-time Fourier transform (STFT) (c) is calculated for each clip. The average magnitude of the STFT for each bin forms a 64-element feature vector (d) for the clip. These feature vectors are added to the sample database (e) and the similarity between two audio clips is calculated as the Euclidean distance between their feature vectors. The representation of the sample database in (e) is a mapping of the 64-element feature vectors into dimensional space, such that similar sound samples are visually nearer to one another.

feature of a system that generates live audio, was now unable to do so. The process had to be reconsidered.



The prototype system shown in fig. 4 had three subsystems: the Pink Trombone, the evolutionary system (NEAT), and a control system that linked the evolved ANNs to the Pink Trombone's interface. The combination of these three elements in this way was convenient, but highly inefficient. To enable the software to run on the embedded computer, the Pink Trombone was recoded into Python and better integrated into the rest of the software.

The system worked – the embodied the Rowdy Krause was able to evolve a vocalisation – but minor changes in the new implementation of the process meant that the sounds it produced were quite different from those of the virtual prototype. In place of the types of vocalisations produced by the prototype – a sort of rhythmic blooping that sounded vaguely like it could have come from an undiscovered primate – the sounds were often longer and droning. This veered occasionally into an unpleasant high-pitched whine.



Consideration of the structure of the fitness function revealed the likely reason for this. The fittest sounds – those most spectrally different from the set of sounds heard in the soundscape – are likely to be pure tones on frequencies that have minimal usage (see fig. 5 for sample spectrograms). The structure of the virtual system had constrained the Rowdy Krause from finding these sounds but the implementation in the embodied version of the Rowdy Krause made it possible. The fitness function now had to be adjusted to account for the change in capability of the instrument.

Fig. 4. Evolving a sound in the prototype. The evolutionary neural network generates control signals (a) which direct the vocal tract parameters in the Pink Trombone using Open Sound Control (b). The resulting sounds are stored (c) in an audio file which is analysed (d). The spectral components of the generated sound are compared (e) to those in the database that were recorded from the soundscape. The fitness of that particular neural network is calculated based on how different the generated sound is to the recorded sounds and drives (f) selection in the evolutionary process (NEAT).

**Fig. 5.** Sample spectrograms showing the frequency components of a pure 4 kHz tone (left), the call of a crane (centre), and white noise (right). The horizontal axis is time and the vertical axis is frequency, with the darkness of the image at a point indicating the intensity of that frequency component of the sound at a given point in time.

From a biosemiotic perspective, the problem with droning vocalisations and pure tones is that they are informationally poor. A source that produces only tonal sounds tends to have low Shannon entropy which, from the perspective of information theory, means that it has low information content. A tonal vocalisation might be appropriate as signal of alarm, but not for general communication.

The other challenge is that, in this configuration, the Rowdy Krause tended to become trapped in an evolutionary dead end. As the evolving population of neural networks found these tonal vocalisations, the populations converged towards these types of highly fit solutions. They ceased to explore the evolutionary landscape of possible vocalisations.

To address these two problems, two modifications were made to the structure of the neuroevolutionary process: The fitness function was adjusted to reward sounds with greater spectral entropy; and the vocalisations produced by the various evolved neural networks were added to the database of sounds alongside those recorded from the soundscape. The first modification encouraged the pursuit of a more temporally varied vocalisation. The addition of evolved vocalisations to the database meant that the populations were encouraged to create sounds different from those they had created in the past in addition to being different from sounds recorded from the soundscape. The effect of this was to create a sort of novelty search, driving the evolutionary neural networks toward new configurations and helping them to avoid becoming stuck in a particular type of vocalisation.

With these modifications, the Rowdy Krause was deployed virtually once again as an art installation at the Artificial Life virtual conference in the summer of 2020. For this version, titled Virtual Rowdy Krause - Point Pelee, vocalisations were evolved using streaming audio from a Point Pelee National Park near Windsor, Canada. A recording of that work is available online. [2]

The embodied version of the Rowdy Krause was also tested in the field in Malmö, Sweden in October 2020. Due to travel restrictions related to the COVID-19 pandemic, the field site was moved from a community garden in Copenhagen to the balcony of my apartment in Malmö, where it overlooked a small park and playground, a busy urban road, and an active construction site for the regional hospital. A short video recording of the field experiment can be viewed online. [3]

#### Vocalisations

The two iterations of the final version of the Rowdy Krause – one evolving in a virtual soundscape from Point Pelee and the other in the real soundscape on my apartment balcony – were able to produce vocalisations. Those vocalisations were varied, occasionally sounding like a strange frog and other times more like the wind whistling over a pipe without quite producing resonance.

[2] https://soundcloud.com/davidkadish/virtual-rowdy-krausepoint-pelee-alife2020

[3] https://vimeo.com/542298317 The embodied version of the Rowdy Krause inhabited the balcony for approximately two weeks. About a week into its residency, I heard a sound from outside and found myself unsure of whether it was coming from the Krause. Whether it was the Rowdy Krause or a bird or something else entirely, I found myself paying more attention to the soundscape outside my workspace than I had previously.

# Niche Construction and Endemism

It is possible to determine more precisely whether the Rowdy Krause was able to construct a niche in the two ecosystems that it inhabited. Figure 6 visualises the results of the two experiments. The plots are two-dimensional representations of the spectral components of sounds created using a process called t-distributed Stochastic Neighbour Embedding (t-SNE). Each point represents a recorded or evolved sound and the proximity of two points reflects their similarity.

The darkness of the points representing evolved sounds shows when in the evolutionary process that sound was produced, with sounds from early in the evolutionary process appearing lighter. Figure 6a shows the evolved sounds from the balcony experiment in blue and the recorded sounds from the soundscape in green. There is very little overlap between the clusters of evolved and recorded points, indicating that, for the most part, the evolved sounds were spectrally different from the recorded soundscape. The Rowdy Krause appears to have been successful in constructing an acoustic niche – represented by the cluster of blue points – that is distinct within the soundscape. A similar pattern is seen in the evolved (orange) and recorded (purple) sounds from Point Pelee in Figure 6c.

**Fig. 6.** Plots of the recorded and evolved sounds from the experiments at Point Pelee (virtual) and the balcony (embodied).

a) Audio from the embodied (balcony) version

b) Evolved sounds from both experiments

c) All sounds from the balcony and Point Pelee.

Sounds that were evolved later are shown in darker shades. The plots use t-SNE to visualize high-dimensional data (the frequency components of each sound) on a two-dimensional plane. The space between points relates to the similarity between the sounds with sounds that are more alike being clustered together.



The plots can also help to address the question of whether the Rowdy Krause was able to become endemic to these two soundscapes. One of the features of endemism is particularity to a place.

Figure 6b shows the evolved vocalisations from the two experiments. The points have some overlap towards the centre of the plot, but for the most part are found in two distinctive clusters. This indicates that the evolutionary processes proceeded differently in the two soundscapes. However, it is difficult to discern the degree to which this is due to the different soundscapes or different random initial conditions for the evolutionary process. It does mean that it is possible that the Rowdy Krause demonstrated a degree of endemism.

## Reflections

There is a point in the description of the design process in the previous section that illustrates a central issue in the design of endemic machines. After the redesign of the Rowdy Krause's software to work on an embedded system, it was not performing in the same way it had been in the initial prototype. Moreover, the change in performance produced a result that was not in line with my expectations of what the Rowdy Krause should sound like. As a result, adjustments were made to the code.

In retrospect, however, there is a question as to whether those adjustments should have been made. It is not clear that the changes improved the ability of the Rowdy Krause to find an acoustic niche in the soundscape. While the vocalisations did not meet my expectations, that version may still have fulfilled the goal of constructing an acoustic niche. Without installing that version in an ecosystem and completing a full assessment of the resulting vocalisations, it is impossible to know. Was that version of the Rowdy Krause broken or merely being creative in a manner that was inaccessible to me? In the design of endemic machines, this is often unclear. This tension between the designer's instinct and the ecological intent of an endemic machine points to another framework for considering the design of endemic machines that should prove fruitful moving forward. While the design process for the Rowdy Krause was framed as attempting to dismiss the agency and desires of the designer, perhaps a more appropriate view is that of the designer, creative AI, and ecosystem as co-designers. This recalls the types of multispecies co-designing described by Westerlaken or Fabrício et al. and the human-computer co-creativity detailed by Jordanous.

In this view, the particular ecosystem informs the design cycles as its responses and reactions to various prototypes shape future design iterations. The designer's perspective is not an outside influence to be shunned, but a valuable asset coming from a member of the ecosystem and an empathetic contributor to the design process. The creative AI's strength as an explorer of a design space (Boden, "Computer Models of Creativity") generates new possibilities that feed back into the design cycle.

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