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Exploration of the creative processes in animals, robots, and AI: who holds the authorship?

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Picture a simple scenario: a worm, in its modest way, traces a trail of paint as it moves across a sheet of paper. Now shift your imagination to a more complex scene, where a chimpanzee paints on another sheet of paper. A simple question arises: Do you perceive an identical creative process in these two animals? Can both of these animals be designated as authors of their creation? If only one, which one? This paper delves into the complexities of authorship, consciousness, and agency, unpacking the nuanced distinctions between such scenarios and exploring the underlying principles that define creative authorship across different forms of life. It becomes evident that attributing authorship to an animal hinges on its intention to create, an aspect intertwined with its agency and awareness of the creative act. These concepts are far from straightforward, as they traverse the complex landscapes of animal ethics and law. But our exploration does not stop there. Now imagine a robot, endowed with artificial intelligence, producing music. This prompts us to question how we should evaluate and perceive such creations. Is the creative process of a machine fundamentally different from that of an animal or a human? As we venture further into this realm of human-made intelligence, we confront an array of ethical, philosophical, and legal quandaries. This paper provides a platform for a reflective discussion: ethologists, neuroscientists, philosophers, and bioinformaticians converge in a multidisciplinary dialogue. Their insights provide valuable perspectives for establishing a foundation upon which to discuss the intricate concepts of authorship and appropriation concerning artistic works generated by non-human entities.

Foreword

In titling this article, we utilised the AI capabilities of ChatGPT, drawing upon our summary for guidance. This decision prompts a consideration of whether this AI ought to be acknowledged as one of the authors. Artistic authorship involves the recognition of an entity as the originator of a work that possesses aesthetic, cultural, or intellectual value. This concept is deeply rooted in philosophical debates about expression, identity, and the nature of art itself, while also engaging in legal discussions about copyright and ownership. The issues addressed in

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this context are poised to spark extensive debate in the future, bridging both artistic and scientific communities. This paper focuses on our research into the artistic output of non-human animals and machines, examining the extent to which their creations—ranging from pictures and paintings to music—are not acknowledged as their own work. Despite the evident capacity of these entities to produce what can be described as art, authorship is often not attributed to them. Instead, their creations are appropriated and monetised by humans, raising significant questions about the recognition of authorship and ownership in the context of non-human and artificial creators. For instance, in 2016, in Indonesia, a wild-crested macaque (later named Naruto) took a selfie with the camera of a professional photographer. This ‘selfie’ went viral worldwide and was quickly seen as a financial opportunity by the camera owner, who claimed the copyright. PETA (People for the Ethical Treatment of Animals) filed a lawsuit and initiated legal proceedings against the camera owner, seeking recognition of the sole monkey as the author of the photograph and demanding that copyright royalties be paid to Naruto if the image were to be used for commercial purposes. However, the legal vacuum surrounding non-human copyright and the fact that Naruto was not recognised as a legal person led the judge to reject PETA’s request (Guadamuz, 2016; Rosati, 2017).

This paper is the collaborative effort of a diverse team of researchers, including two ethologists, a neuroscientist, a philosopher, and a computer scientist. Our interdisciplinary approach is deliberate, reflecting our belief that the complex questions surrounding non-human authorship and rights in the context of animals, robots, and AI necessitate insights from multiple disciplines. Each author brings a unique perspective to the discussion, from the nuanced behaviours and cognitive abilities of animals to the ethical implications of emerging technologies and the philosophical underpinnings of creativity¹ and intelligence. Our collective expertise enables a comprehensive exploration of the subject matter, though it also means that our discussion flows through a wide range of arguments and disciplines. Recognising the importance of situatedness and positionality in scholarly work, we aim to locate our argumentation within the intersections of our respective fields, thereby providing a multifaceted view that enriches the debate on non-human entities’ potential for creativity and authorship. By clarifying our backgrounds and the intentional breadth of our perspectives, we hope to make explicit the relevance and intention behind our scholarly argumentation, ensuring our readers understand the foundation upon which our analysis is built.

Introduction

Just as toolmaking, sense of humour, or mathematics have been considered uniquely human activities, art has long been regarded as a distinctly human endeavour. However, without claiming to be Picasso or Mozart, some animals exhibit graphic or musical behaviours that we might classify as artistic (Watanabe, 2012). In Oceania, male bowerbirds build intricate structures from branches to attract females and secure opportunities for mating (Diamond, 1986). Pebbles, seeds, or leaves, often coloured, are placed by the birds at the entrance of the bower to master its symmetry, aesthetics, and perspective. Birds even adhere to a gradation of these different elements, from larger to smaller or from darker to lighter, to refine their decor. Also, in an effort to court females, male pufferfish sculpt rosettes in the sand with their mouths (Kawase et al., 2013). These sandy structures are likened to the lines and geoglyphs of Nazca, located in southern Peru and associated with the pre-Inca Nazca culture (Mujica, 2000). Another example of complex graphic compositions in

animals that we could appreciate as art is undoubtedly the structure of spider webs (Krink and Vollrath, 1997). On the musical side, it would be difficult not to mention the complexity of the songs of the animals around us. In many bird species, males use their most beautiful songs to attract females for reproduction. Others have mastered the art of imitation, such as the lyrebird (*Menura* sp.) (Dalziel and Magrath, 2012). Among primates, the communication of gibbons (*Hylobates* sp.) is entirely based on their vocalisations which even allow them to recognise each other individually (Terleph et al., 2015; Oyakawa et al., 2007; Geissmann, 2000). The same is true for cetaceans like whales and dolphins (Janik, 2014). The creation of these complex graphic or vocal compositions involves both elaborate learning processes and simple rules that enhance the desired effectiveness of the produced structure. Like with computational algorithms, natural selection and sexual selection have shaped the processes behind these animal creations, which sometimes emotionally touch us and move us. The creative aspect of these examples lies in the animals’ ability to produce and modify sounds in ways that serve both functional and expressive purposes. The complexity of the songs, the individual recognition through vocalisation, and their structured, evolving nature, all point to a process that involves learning, innovation, and even cultural transmission among these animals. Such behaviours mirror the human capacity for creating, involving not just the application of simple rules but also the expression of complex emotions, social connections, and cultural identities. This complexity and depth of animal vocalisations underscore their value as creative productions, inviting us to broaden our understanding of creativity beyond human artistic endeavours. Eventually, it is not uncommon for some of these animal productions to become sources of artistic inspiration for humans. The French Olivier Messiaen, for example, was one of the first contemporary music composers to incorporate bird songs into his works. Our focus on music and paintings stems from their prominence in both human and non-human artistic expression, as well as their significant development within machine and AI-generated art. These art forms are not only the most extensively studied in animal behaviour research but also represent the forefront of technological advancements in creative AI applications. By concentrating on music and paintings, we aim to explore the complexities of authorship in areas where the intersection of biological and technological creativity is most evident and advanced. This deliberate choice allows us to delve deeply into the implications of authorship across these two major domains of artistic expression, providing insights that are directly relevant to ongoing discussions in both animal studies and AI research.

The definition of art frequently hinges on the concept of the creator’s intentionality, such as the formation of a goal to be realised (Beardsley, 1970; Levinson, 1979; Bloom, 1996). A simple question then arises: do the above animal creations fall within the realm of art? Do these animal-creators become authors of their creations or even artists? The definition of art is often introduced by the notion of intentionality of its creator, e.g., the conception of a goal to be achieved. We can thus question the levels of intentionality and consciousness of action in these animals. This reflection can also extend to machines and artificial intelligences (AIs²) (Mikalonytė and Kneer, 2022) whose creations, sometimes indistinguishable from human ones, now fetch several hundred thousand euros (Doherty, 2019). In 2005, a captive chimpanzee named Barney was observed playing percussion on a plastic barrel (Dufour et al., 2015). An in-depth analysis of the recorded sound demonstrated rhythmicity, decontextualisation, and control of the gesture by this chimpanzee (Dufour et al., 2015). Prior to Barney, the bonobo Kanzi, trained in sign language, had also been observed playing percussion rhythmically (Kugler and



Fig. 1 Comparative illustrations of artistic expression across different 'creators'. This figure presents a diverse array of drawings originating from varied sources: **A** an adult chimpanzee, illustrating non-human animal creativity that challenges traditional notions of artistic authorship (drawing previously collected by Cédric Sueur in 2019 and extracted from Martinet et al. (2023) dataset, with the courtesy of Tetsuro Matsuzawa); **B** a 2-year-old human toddler, representing the nascent stages of human creativity and expression (drawing anonymously and previously collected by Marie Pelé in 2018 and extracted from Martinet et al. (2021) dataset); **C** an adult human professional artist (drawing anonymously and previously collected by Cédric Sueur in 2018 and extracted from Martinet et al. (2021) dataset); and **D** a visualisation generated by a simple random walk (Sueur, 2011) algorithm developed in NetLogo (Tissue and Wilensky, 2004), demonstrating how artificial intelligence can create patterns that mimic certain aspects of artistic creativity. Netlogo model available on Netlogo Community platform © Cédric Sueur.

Savage-Rumbaugh, 2002). Unfortunately, observations of such behaviours are extremely rare, and data are lacking.

Simultaneously, other primates and great apes draw and paint when given the opportunity (Fig. 1A; for a review among non-human primates, see Martinet and Pelé, 2021). Their creations, often compared to children's scribbles (Fig. 1B), are exhibited, sold, or printed on accessories (Applegate and Grupper, 2013; Matsuzawa, 2017) without questioning their authorship as given to artists (Fig. 1C). Ownership of a scarf adorned with patterns by the female chimpanzee Ai, or a painting by the male chimpanzee Congo from the 1960s, introduces a dilemma regarding authorship. If a chimpanzee can be acknowledged as the creator of its work, the question extends to why a young child's scribbles, a worm's paint trail, or a machine's programmed drawing (Fig. 1D) should not receive similar recognition. This prompts a broader enquiry into how creation is defined across early, non-human, or even non-biological contexts. It also brings the concept of intelligence into the discussion, ranging from the cognitive capabilities necessary for the intention behind creation to those required for recognising a creation as such. From this concept of 'creative' intelligence, arise other ethical and legal concepts, notably at the origin of the question of legal personality. This paper will address these different notions in order to discuss authorship, considered as the act of characterising a full-fledged author and recognising them as such, and the appropriation of creation, whether it is auditory or graphic, created by an animal or a machine.

Of the intention to create...

Picture an earthworm traversing a sheet of paper, trailing paint in its wake, contrasted with a chimpanzee applying paint to paper with a brush. This juxtaposition raises the issue of whether the creative processes of these two animals are comparable and if

both can be deemed authors of their creations. Furthermore, it questions whether they should be regarded as equals in terms of authorship and what is behind this term. In the context of art and creativity, indexicality refers to the way in which a piece of art can act as a direct indicator or physical trace of its creator's actions or intentions. This concept is deeply intertwined with intentionality, especially when considering the creative outputs of animals like chimpanzees and the products of artificial intelligence (AI). In animal drawings, for example, the indexicality of a chimpanzee's artwork can be seen in the brush strokes, patterns, and choices of colour that directly relate to the animal's physical movements and decision-making processes at the moment of creation (Martinet et al., 2021, 2023). Similarly, in the realm of AI-generated art, indexicality manifests in the output of algorithms designed to create visual or auditory artworks. The ethics of virtue discussed by Aristotle or Kant (Betzler, 2008) focuses on the character and motivations of the individual, known as the agent, while consequentialism focuses on the consequences of the actions taken, without regard for the means employed and potential intentionality. Thus, virtue ethics allows us to consider art as the only intentional process, regardless of the final outcome. In contrast, consequentialism views art as a finished product, without considering the process of creation. Therefore, the intentionality of an animal artist or musician emerges as a key point in defining whether they are truly the author of their graphic production or musical composition. For some authors, intentionality even characterises art and the artist (Beardsley, 1970; Levinson, 1979; Bloom, 1996). For others, intentionality is defined by five elements: (i) a desire for a result, (ii) a belief about the action leading to that result, (iii) an intention to carry out the action, (iv) awareness of the accomplishment of the intention while executing the action, and (v) the ability to execute the action (Malle and Knobe, 1997).

In cognitive ethology, studies have shown that individuals of animal species such as pigeons, rats, or non-human primates are capable of anticipating their actions (Le Neindre et al., 2018). Individuals of most of these species are also aware of their decision-making and the consequences of these decisions. These degrees of action anticipation correspond to elements (i) and (ii) as defined by Malle and Knobe (1997), while the level of consciousness in these animals relates to elements (iii) and (iv) that define intentionality, again according to Malle and Knobe (1997). By applying these two capacities (anticipation and consciousness) to behaviours such as drawing, for example, consequentialism would qualify both the ape and the earthworm as authors of their drawings, while virtue ethics would consider the ape as the sole author, conscious of its actions. Consciousness is conceptualised as the awareness of oneself and one's surroundings, a state that encompasses the ability to experience sensations, thoughts, and emotions. From a neuroscientific perspective, consciousness is associated with specific patterns of brain activity and connectivity that denote an awareness of internal and external states. Ethological studies further validate these concepts by demonstrating instances of self-awareness and environmental responsiveness in non-human animals, indicating levels of consciousness that challenge the boundaries traditionally reserved for humans. Philosophically, this definition is accepted as it resonates with discussions on the nature of mind, self, and agency, bridging empirical observations with theoretical inquiries into the essence of sentient life.

Nevertheless, it is necessary to determine whether these capacities are genuinely underlying animal drawing. Some researchers argue that animal drawings are induced by experimenters who invite them to draw or even encourage them to do so (see Tomasello and Call, 2004 for cognitive tasks in general). For example, in Thailand, Asian elephants (*Elephas maximus*) create shapes that closely resemble self-portraits or bouquets of flowers, but the conditioning and latent mistreatment behind such productions lead researchers to doubt the pachyderm's understanding of its drawing (OneGreenPlanet, 2020). Moreover, in the wild, no spontaneous drawing behaviour has been reported to date in elephants or great apes. However, it is common for captive hominids to manipulate pencils and brushes on sheets of paper or even draw with their fingers on touchscreens (Martinet and Pelé, 2021). Thus, some chimpanzees maintain their graphic activity without any food reinforcement, indicating their interest in the action (Boysen et al., 1987). Beyond the sensation directly related to locomotor movement, visual feedback would also serve as reinforcement. Indeed, the drawing behaviour on a touchscreen decreases when the chimpanzee's trace becomes invisible (Tanaka et al., 2003). The various studies on chimpanzees, therefore, support the argument that the act of drawing itself has a reinforcing property for these animals. While drawings are not spontaneous in chimpanzees, the simple act of drawing and the properties of the drawing modify the subjects' future actions. However, if the earthworm leaves no trace behind, this absence of a trace will not impact its movements on the paper, unlike the hominid. Schiller (1951) went further and presented a young female chimpanzee named Alpha with blank sheets featuring geometric figures. She marked the sheets differently based on the stimuli presented, thus raising the question of intentionality behind these seemingly 'simplistic' 'scribbles' by animals. However, despite numerous studies on great apes, especially chimpanzees, no representative drawings have ever been observed, and researchers generally compare their productions to those of young human children (Martinet and Pelé, 2021). Using fractal mathematical indices to assess the representativeness of a drawing, Martinet et al. (2021) demonstrated that chimpanzee drawings, while not as proficient as those of children, are not random

either. The most common way to determine if a drawing is representative or not is to ask its author about its meaning. The question was posed to another sign-language-proficient female chimpanzee, and her response was 'bird' (Gardner and Gardner, 1978). However, this response does not prove the presence of intentionality in this individual; it could have been a random response, influenced by experimenters, or the sign may have been misinterpreted. All of these elements suggest that some individuals of certain species, especially great apes, appear to interact with their production (graphic or auditory) in the sense that what is created influences what will be. The concept of agency (McFarland and Hediger, 2009; Blattner et al., 2020; Sueur et al., 2023) can thus be attributed to these animals from a psychological perspective, for example, as actors in the world affecting their environment. It can also be attributed to a philosophical and ethological perspective if we consider great apes as capable of recognising themselves as individuals and having a certain sense of morality if these capacities define the very essence of personhood. Legal personhood refers to the recognition by the legal system of an entity as a subject that can bear rights and duties. Traditionally reserved for human beings, the concept's boundaries are being tested by advancements in AI and growing awareness of animal cognition and social complexity. This general definition of agency is accepted by biologists, psychologists as researchers in law and philosophers. In contemporary fields of art history, theory, and creative practices, the term 'agency' is employed to denote the capacity of individuals or entities to act autonomously and make independent choices within the creative process. Agency emphasises the role of the creator not just as a passive conduit for external influences but as an active participant with the power to shape the creative outcome. This perspective acknowledges the complexity of creative acts, recognising them as the result of deliberate choices, influences, and interactions between the creator's intentions and the medium's possibilities. A cross-disciplinary approach to agency enriches our understanding of art and creativity by challenging anthropocentric views and expanding the notion of who or what can be considered a creator. It encourages a re-evaluation of the criteria for authorship and creativity, pushing us to consider the ethical, philosophical, and practical implications of recognising agency in a broader spectrum of creative entities.

... to author recognition

Mylène Ferrand Lointier's doctoral thesis (2022) in Arts 'Le Tournant animal dans l'art contemporain (de 1960 à nos jours), approche écoféministe,' [The Animal Turn in Contemporary Art (from 1960 to today), an Ecofeminist Approach] delves into the increasingly significant role of the animal question in contemporary discourse, driven by evolving anthro-zoological relationships. Highlighting a shift in the portrayal of animals in art from mere objects or symbols to subjects with intrinsic value, this research examines a diverse international corpus of artworks and artists deeply engaged with animal issues from the 1960s to the present: Ijeia-Liisa Ahtila, Julie Andreyev, Banksy, Joseph Beuys, Sue Coe, Minerva Cuevas, Terike Haapoja, Jonathan Horowitz, Joan Jonas, Jenny Kendler, EvaMarie Lindahl, Isabella & Tiziana Pers, Araya Rasdjarmrearnsook, Rachel Rosenthal, Saeborg, Lin May Saeed, Sin Kabeza Productions, Bryndis Snæbjörnsdóttir & Mark Wilson, Diana Thater, and Robert Zhao Renhui. Through an ecofeminist lens, incorporating ethics of care and intersectionality, Ferrand explores an ecocritical territory intertwining art, emotion, animal ethics, and posthumanism. This thesis aims to chart a new eco- and zoo-poetic/political path towards an era termed the 'Ecocene', advocating for a reevaluation of human-animal relations within art as with *The Compassion*

Manifesto: An Ethics for Art + Design and Animals (Andreyev, 2016).

There is currently no research on the abilities of great apes to claim ownership of their creations, whether they are graphic or musical. Nevertheless, it becomes evident that consciousness and morality emerge as pivotal concepts in the realm of authorship. Morality is understood as a set of principles or guidelines that govern the behaviour of individuals within a social context, reflecting notions of right and wrong, justice, empathy, and welfare. Ethologically, the roots of moral behaviour are observed in the social interactions of non-human animals (e.g., great apes, elephants or even rats), where acts of altruism, cooperation, and fairness are not uncommon and serve to maintain social cohesion and mutual benefit (De Waal, 2016). Such behaviours suggest a biological underpinning for moral conduct, further supported by neuroscience, which identifies neural circuits and processes involved in empathetic responses, decision-making, and the evaluation of fairness and harm. Philosophically, these empirical findings are incorporated into broader discussions about the nature of morality as well as consciousness, their origin, and their applicability across different forms of life. By acknowledging the evidence of moral-like behaviours and consciousness in non-human animals, philosophy expands its enquiry into the moral agency, questioning the exclusivity of moral consideration and rights to humans and opening the door to a more inclusive understanding of moral subjects. These concepts enable individuals to achieve the status of a 'person', nothing more and nothing less, and subsequently, to acquire legal rights through their recognised personhood. Historically, this term 'person' has been exclusively applied to humans and is defined as 'an intelligent, thinking being, capable of reason and reflection, who can recognise themselves as the same thinking entity across different times and places' (Locke and Perry, 1975). Self-awareness and moral cognition thus play a significant role in the authorisation and appropriation of creative works, attributes currently ascribed solely to humans, who are deemed to possess 'a soul and consciousness' (Schrecker, 1938; Engels, 2009).

It is indeed in the field of metaphysics that are often grounded the basis for the attribution of rights for living beings, and more precisely in the question of the difference between humans and animals. Pivotal moments in philosophy engage in a significant debate regarding the anthropological question and the specific traits that distinguish humans from animals. A crucial argument for this discussion revolves around whether the differentiation is grounded in ontological terms, suggesting a fundamental disparity in nature or condition between humans and animals, or if it hinges on ontic qualities, indicating inherent, distinct characteristics between the two. Through the lens of an ontological distinction, numerous philosophers have constructed a recognised hierarchy within the spectrum of living beings, often based on universals (such as soul, conscience or reason). As an example, Aristotle considers that the human soul is the only one to demonstrate the dianoetic faculty, which means the 'power of thinking' (Aristotle, 1987, Book II, Chapter I, 412a) or the ability to exercise and apply reason. Descartes, by qualifying human beings as the only ones that possess the *cogitatio*, discloses a theory where animals are constituted as mere biological machines (Descartes, 1637/1937, p. 164), providing a landing mark for later theories on the mechanism and animal environment (Loeb, 1918). Malebranche (1997, book VI, part 2, chapter vii) argues that 'in animals, there is neither intelligence nor souls as ordinary meant'. And later, Marx (2022/1845, MEGA I, 5, p. 10; CW 5, p. 31) elaborates that 'men can be distinguished from animals by consciousness, by religion or anything else you like'.

By those few examples, we highlight that major authors in the philosophical tradition have influenced current interdisciplinary

discussions on animal rights, and the ethical and political treatment of non-human entities. Ontological attributes such as consciousness, morality, reason, intelligence and self-recognition have traditionally been used as a way to distinguish human beings from animals. The anthropological distinction between humans and animals ensues the possibility to acknowledge ontic differences and to ground them in a metaphysical perspective, giving them an axiological weight that easily leads to a hierarchy of living beings. Even though we will not tackle this issue in our article, this metaphysical debate is still widely discussed today and of major importance. But one of its many consequences is noteworthy: it impacted our ability to ground animal agency over a robust ontological status, which led to the denial of several categories of rights for animals, including the right to be acknowledged as authors (since, by definition, authorship has been attributed to individuals and people).

Even if ontological hierarchies have often been used as the groundwork on which are based distinct rights for human beings and animals, several contemporary debates explore the possibility that the possession of specific ontic, cognitive, or emotional attributes might entail the entitlement to certain rights, regardless of the inherent nature, status or condition of the subject. In short, the question of animal rights could be distinguished from the ontological question of the essence of animality, and more empirical ethological, bio-semiotic or zoological studies could lead to a better understanding of animal cognition, sociality and behaviour, leading to the establishment of grounded animal rights. From then on, numerous researchers, including Charles Darwin, who ascribed consciousness to individuals within social species, have probed the presence of intellect, self-awareness or autonomy in animals. Donald Griffin (2013) proposes that it is through the realms of communication, encompassing dialogues and negotiations, that we should investigate intentional behaviours and processes governed by consciousness. Research on great apes capable of using sign language or symbols has shown that they can speak about others and themselves as distinct and autonomous entities. Autobiographical self-awareness (Le Neindre et al., 2018) has also been found in many animal species (primates, cetaceans, birds) through the mirror test, demonstrating that subjects can identify and recognise themselves in it (Gallup et al., 2002). Likewise, metacognition, the ability by which an individual acquires knowledge of their own mental processes, or their ability to evaluate the state of what they know, has been verified in several animal species through tests assessing certainty or confidence (Le Neindre et al., 2018). Additionally, some social animals also display theory of mind, i.e., the capacity to impute a mental self to conspecifics or to understand what they are looking at, what they intend to do, or even to know their beliefs (Tomasello and Call, 1997). Finally, observations of chimpanzees and elephants, as well as experiments with rats, have shown that these animals possess a certain degree of empathy and morality (De Waal, 2006). From these new findings, the qualification of 'person' could be attributed to animals capable of self-recognition and demonstrating morality. By assigning legal personality, they could be granted ownership of their creations and recognised as genuine authors.

Legal personality

Therefore, some rights could be attributed to animals who possess capacities or qualities similar to those of human beings, beyond the ontological question of their essence, nature or condition. As highlighted by the example of marginal cases by Peter Singer and discussed by DeGrazia (1990), several categories of individuals—such as infants, adults with severe mental disabilities, or those in a coma—do not possess the cognitive, locomotor, or emotional

faculties usually attributed to an ideal type of human being. Nevertheless, these individuals do have legal personality. According to Peter Singer, if these individuals have legal personality, it could also be attributed to animals who have equal or sometimes more developed capabilities than these individuals. The young child or disabled adult who scribbles or drums has rights and will be recognised as the author of the drawing or sound they produce, regardless of the levels of intentionality and consciousness they put in their creation (in the process and towards its finality). By considering the complex philosophical question of the nature of the subject as a separate discussion from the legal rules that apply to them, animals could be granted legal personality based on certain faculties they possess, allowing them to hold rights and duties. This question entails difficult debates, and several actions that aim to grant rights to animals have already been initiated by animal protection associations. In particular, in the United States of America, the Non-Human Rights Project led by Steven Wise (Wise, 2010) relies on the legal concept of Habeas corpus, which states the fundamental freedom not to be imprisoned without trial, and aims to free several wild animals that are held captive despite possessing enough cognitive abilities to be aware of their deplorable living conditions.

As shown with the macaque Naruto (Guadamuz, 2016; Rosati, 2017), recognising animals with consciousness as legal persons appears to be a prerequisite for them to be truly and fully recognised as authors of their creations. In 2019, the Toulon Declaration reiterated the Cambridge Declaration on Consciousness (2012), stating that most animals with neurological substrates of consciousness should have legal personality (Regad and Riot, 2019). The theory of animal rights is increasingly discussed and formalised, allowing animals, depending on their species, agency, and interactions with humans, to have recognised rights (Donaldson and Kymlicka, 2011). The authorisation of animal artistic creations fits seamlessly into this theory.

What about artificial intelligence (AI)?

When highlighting the argument of authorship for non-human beings, an important discussion arises from the question of non-living or non-organic beings, such as machines, robots and AI. The philosophical considerations surrounding the attribution of rights to animals and machines or AI overlap in significant ways. By examining these questions in parallel, we gain insights into the principles that currently guide our interactions with non-human entities, whether biological or artificial. It helps us to reconsider our relationship with non-human entities and to reassess the values and norms that underpin our social and legal systems.

As such, our demonstration will mostly focus on the question regarding AI. Indeed, a proposition would be to consider that there could be a major distinction for authorship between machines themselves because the *embodiment* of a robot³ would have a huge impact on its perceived authorship compared to a non-embodied AI system. As such, a robot would be perceived as more susceptible to have rights than a non-embodied AI. In this case, embodiment itself would have a significant impact on whether or not something possesses rights and whether or not people believe that those rights are acceptable⁴. However, this thought experiment would be confronted with the fact that, currently, authorship is not attributed depending on their embodiment to living beings such as animals (which are by definition embodied). When determining authorship, embodiment appears to matter less than the legal personality we usually ascribe a being, and their status—be it human, animal, or machine, but also depending on if it is an adult or a child, or the degree of agency we ascribe to the animal in question. Therefore,

we chose to mostly focus this line of questioning on IA algorithms that could or could not be embodied.

In 2018, an AI-created painting was auctioned for \$432,500, signed with a mathematical formula, developed by the Obvious research collective (Doherty, 2019; Vernier et al., 2020a, 2020b). This event raises the question of whether artificial intelligence could be acknowledged as the creator of its works and entitled to copyright rights. Additionally, platforms like Playform by Artrendex Inc. offer algorithms that replicate the style of renowned painters on any image. This situation poses a dilemma regarding the true authorship of the resulting artwork: Is it the AI (Davies, 2011; Abbott, 2016; Christie, 2018), the developers of the algorithm, or the original artists whose styles were emulated (Bridy, 2012; Hristov, 2016; McCormack et al., 2019), or another entity? The methodologies and debates surrounding animal intelligence and authorship could similarly be extended to the realm of artificial intelligence (Nguyen, 2019). In the case of the Obvious creation, the produced algorithm is not intelligent in the sense described above. It should be noted that the model used to create this painting was trained on existing paintings, which can be likened to the learning process present in humans. Capable of producing a specific act, this model is not, however, able to solve any problem, has no intentional acts, and is not self-aware. However, more complex robots capable of recognising themselves in a mirror could well be self-aware (Hart and Scassellati, 2012; Schneider et al., 2014; Meyer et al., 2020). New fields of research are thus created and developed to better understand the behaviour of machines and their emerging capabilities (Rahwan et al., 2019; Dorigo et al., 2020). Specific tests such as the Turing Test (Copeland, 2000) exist to precisely determine the capabilities of machines, especially in relation to artistic creation (Bishop and Boden, 2010). However, these tests are often criticised. On the one hand, because many humans do not pass them, and on the other hand, because they are conceptualised by humans with all the anthropomorphic biases that this presupposes (Sueur and Pelé, 2017; Sueur et al., 2020). However, even if some do not wish to recognise machines as artists, it is important to note the difficulty for a human to distinguish computer-generated creations from human creations (Mikalonytė and Kneer, 2022).

Consequently, the question of authorship and AI plays a key role in better understanding the issues of authorship and agency themselves. As regarding animals, this very specific issue depends on many factors such as the nature of the agents involved (weak AI or strong AI⁵), the degree of intentionality of the creation (intentional or accidental), and the content or nature of the graphical creation itself (abstract or representational) (Mikalonytė and Kneer, 2022). However, as the attribution of agency and personhood are a crucial issue both for AI and animals, the question of authorship for machines often ends with a much clearer conclusion than that of animal authorship. Indeed, as a machine is created by humans, it is usually considered devoid of all rights in favour of its creator or user. For instance, the authorship of an AI-generated artwork is commonly attributed to the human artist behind the machine (when there is no copyright issues...), whereas it is much more complicated to consider that the human who gave a pencil to an animal is the author of the resulting canvas. Therefore, by considering through an experiment of thought that authorship for a machine or AI is a real issue, and as it may indeed soon become a crucial one, we may better uncover what is usually the basis for authorship in a broader sense.

Photons be free

To tackle this complicated issue, we decided to incorporate and decipher a science fictional case study in our analysis. It serves as

a valuable methodological tool allowing us to explore the potential futures shaped by current technological advancements and ethical considerations. Science fiction, often regarded as a form of speculative methodology, enables us to envision the societal, legal, and ethical implications of technology before they fully manifest in reality. This approach is particularly relevant when discussing the rights and authorship of non-human entities, as it provides a narrative framework to examine complex issues that might not yet be fully realised or understood within our current legal and ethical systems. To further ground our use of sci-fi examples, we draw upon the concept of technological imaginaries (Sartori and Bocca, 2023; Jasanoff and Kim, 2015), which is extensively used to describe modern societies in which technology plays a key role in shaping both our understanding of them and our way to envision their evolution. This critical theoretical framework investigates how collective visions of technological futures influence current technological development and societal norms. Technological imaginaries help us understand how our expectations, fears, and hopes for technology shape the way we interact with and conceptualise emerging technologies. By examining these imaginaries, we aim to unpack the cultural and social underpinnings of our assumptions about non-human authorship and the rights of artificial entities, offering insights that are accessible to readers from a broad range of disciplinary backgrounds. In the scope of this article, engaging with fictional narratives urges us to envision new possibilities and challenge conventional thinking about the role of machines in creative processes and intellectual endeavours, and the evolving concept of authorship in the digital age.

In this context, a specific example issued from science fiction helps us better understand this evolving aspect of our technological imaginaries and the various dimensions of authorisation that can apply to artificial or non-human entities. The episode 'Author, Author' (2001, Season 7, Episode 20) of the series *Star Trek: Voyager* questions the situation of the Doctor, a hologram (with a strong AI⁵) that has exceeded its initial programming's limits over the years, and developed behavioural and emotional characteristics usually seen only in living beings. The Doctor is confronted with the controversial question of his own copyright when he writes a holoprogram and sells the rights to a publishing house. The editor published it without his consent while he still had major modifications to make. The stakes that this episode highlights mirror the famous debate about the rights of the android Data in the well-known episode 'Measure of a Man' (1989, Season 2, Episode 9) of *Star Trek: The Next Generation*. In both episodes, the question aims to determine to what extent Data and the Doctor are individuals because a certain number of rights will depend on their identity, status, and the legal personality that will be granted to them. If Data is not a person, then he is the property of Starfleet, much like any toaster or computer. If the Doctor is not a person, then he cannot be considered an artist and has as many rights over his holoprogram as a coffee machine has over the coffee it produces.

For the Doctor, as Data before, this debate unfolds in the legal framework of a trial whose decision will be a legal action: 'A Federation Arbitrator has been assigned to determine whether the Doctor has the right to control his artistic creation.' ('Author, Author', 00:32:13). The first session aims to outline the scope of the debate and raises the question of the Doctor's personhood, rather than his rights as an artist. Indeed, Starfleet defines an artist as 'a person who creates an original artistic work.' ('Author, Author', 00:34:36). While the Doctor has indeed created an original artistic work, he is not considered a full person and, therefore, cannot claim authorship of his work of art.

This episode delves into a crucial aspect of our discussion: the notion that an individual must belong to a specific category to

access certain rights, such as those allowing humans exclusively to be recognised as authors or artists. It proposes an alternative perspective where rights could be allocated with respect to the subject's category, enabling entities—whether human, non-human, animal, or artificial—to be acknowledged as authors or artists. This perspective raises the possibility of recognising an animal or an AI as an artist without necessarily classifying them as persons. However, it also suggests that affirming an entity's status as an artist might require expanding the definition of personhood. Legal decisions and efforts to establish precedents are currently addressing these considerations, bringing theoretical debates into the realm of practical applications. Last year, the United States Copyright Office (USPTO) reversed its decision to grant copyright protection to a comic book whose images were generated by AI (Ostrow and Dengel, 2022). The fundamental element in this latter case is that the USPTO's revocation is based on the 'Human Authorship Requirement',⁶ which means the necessity for the author of a work to be ... a human being. Here, we find thirty years later the stake that was raised by *Star Trek* about the relevance of encompassing authorship in a category: be it a strictly human definition for the USPTO's Human Authorship Requirement or, more broadly, the status of personhood or individual, in *Star Trek* series.

By trying to avoid the strict question of copyright and to focus on the legal personality of the Doctor, the episode 'Author, Author' explicitly reminds us that the question still exists today for other individuals within the human species. For example, the tendency to invisibilize female authors in artistic fields is still a contemporary issue (Rollet, 2007; Nochlin, 1971/ 2021), which questions the way we structure our understanding of creation by highlighting mechanisms that delegitimise certain individuals based on their gender or origin. This example illustrates the painstaking evolution of authorisation norms even within the human species. In this regard, the question of the right to be called an 'author' still arises from identity premises (the subject's status—male or female, human or non-human, etc.) rather than from the artistic production itself. If an animal cannot be an artist, it is not because it has not created a work of art, but because it is not considered as an operating subject. And it is not the work of the non-human artificial entity that is judged, but the AI's status within humanity, as demonstrated by the USPTO, when it first recognised the artistic value of an AI work before retracting its decision.

In the series episode 'Author, Author', as it is the question of personhood that is at stake through the issue of authorisation, the trial's witnesses emphasise the importance of the Doctor's experiences, by highlighting his ability to evolve beyond his programming, to think for himself, and even, to disobey orders. However, when he returns with his decision, the Arbitrator instructs a judgement similar to the one that granted the android Data free will in 'Measure of a Man', but without changing his status. The Arbitrator is not willing to declare the Doctor a 'person' per se. However, the legal definition of the term 'artist' can and will be expanded to include his creations. Therefore, the Doctor holds the copyright on his artwork and can intervene in the distribution of his holoprogram. This conclusion underlines that the status of an artist is generally deemed more flexible than the definition of personhood; and that expanding the sphere of authorship and its associated rights raises fewer challenges than to extend the concept of personhood. As such, it is easier to imagine that the USPTO could remove the Human Authorship Requirement to include non-human individuals like AI or animals in copyright protection, rather than to extend the human status to animals or AI. In other words, the legal personality is more flexible and plastic than the natural personality, understood as the nature or condition of the subject (human, non-human).

That being said, *Star Trek* highlights the important point that the definition of what constitutes a person itself has continued to evolve. The episode presents the important issue that conceding certain rights to certain entities (such as copyright and artistic authorship to an AI or an animal) implies, in fact, an evolution of their natural status. Moreover, these legal changes could lead to changes in ethical frameworks. In essence, granting copyright to the Doctor, then other rights to other holograms, and so on, brings closer to a legal decision in which a hologram's personhood could no longer be questioned. To consider that personhood alone grants access to certain rights may imply that gaining these rights is the first step towards the modification of a non-human entity's status. *Star Trek* offers us the following alternative: perhaps the access to certain rights should not depend on the subject's status. Perhaps human imaginaries must reconcile with emerging realities, driven by the evolution of our technological landscapes, and acknowledge the necessity of granting rights and protections to non-human entities. In fact, it is no coincidence that the Doctor's holoprogram, duly entitled 'Photons Be Free', revolves around the struggle for equality of hologram populations.

What about digital tools in musical creations?

Science fiction is often considered as a literature of ideas that allows for thought experiments in hypothetical or speculative scenarios that may not yet have real-world manifestations, but will or could have important implications for our societies. Consequently, it is now of major importance to apply the questioning that arose from this example to a more grounded debate regarding AI-generated artworks and the use of machines and algorithms in artistic practices.

Nowadays, with technological advancements and the rise of digital equipment, the issue of authorship is increasingly relevant in live performances, particularly in music (see seminal works of Reeves et al., 2005; Berthaut, 2015; Capra et al., 2020). The intense experience of creation 'in the making' can be disrupted by the presence of machines if the audience begins to believe that the machines, rather than the artists, are producing the artistic work. Unless the contributions are shared? For the artists themselves, there may be a challenge in distinguishing what is produced by their exclusive actions from what is produced by the accompanying machines (Rimoldi and Manzolli, 2016). Here, the question is no longer about determining whether the artist is an author or not, but to what extent, and from which perspective, that of the author or the audience.

In music, the sophistication and apparent autonomy of digital instruments raise questions that are nearly absent in the case of analogue instruments such as the violin or drums. When a machine is capable of playing autonomously—whether in a rudimentary manner, as with an MP3 player, or more adaptively, through generative algorithms and artificial intelligence—the role of the artist-author in music production no longer appears as evident, at least not exclusively. From a cognitive perspective, this dilution of the artist's contribution due to digital assistance is partly explained by the close connection between movement and perception (Rizzolatti et al., 1996; Jeannerod, 2001). In traditional music performances where instruments have almost no autonomy, the perception of the link between the musicians' gestures and the produced sounds is clear (these are referred to as 'transparent instruments' Fels et al., 2002). The brain's constant simulation of perceived gestures to predict their consequences is the basis for integrating this link (Zatorre et al., 2007; Salimpour et al., 2015). From this simulation emerges the sense of understanding what is happening, perceiving what the artist controls, their intention, and virtuosity, all of which are components of authorship.

In electronic music, a single gesture can generate a multitude of different sounds depending on machine settings. AI and digital technology blur the traditional link between a musician's actions and the resulting sounds, raising questions about authorship. The causal link between gesture and sound can thus disappear, leading to a loss of interest for the audience and doubt regarding the artist's involvement (Schloss, 2003; Stuart, 2003; Huron, 2008). Indeed, the audience may struggle to attribute authorship due to the obscured causal relationship between gesture and sound. As AI plays a significant role in generating music, it necessitates re-evaluating how we define and recognise the creative contributions of human artists and the extent to which AI systems can be considered co-creators in the artistic process.

Towards shared authorship: from human-machine interaction to human-animal-machine collaboration?

Recent studies (Capra et al., 2020) have shown that the audience's sense of understanding a digital music interaction leads them to consider the artist as more contributory than the machine in performances with digital instruments or computers. These findings not only emphasise the crucial role of the sense of understanding in the judgement of authorship but also highlight the gradual nature of this judgement. Furthermore, the 'evidence' of a machine's involvement in the artistic process is not always obvious; computers can be hidden backstage, and artists can pretend to play live while everything is pre-recorded. One might have images of musicians with their hands in the air, clapping while the music continues, or, conversely, focused on their instruments without it is possible to see what they are doing or even distinguish which sound they are working on. This perceptual deficiency and its consequences on the audience's experience have led the Human-Computer Interaction (HCI) community to propose new evaluation criteria for digital devices (Berthaut et al., 2013; Berthaut et al., 2015; Bin 2018; see an extended review in Capra, 2020), including the Association (Capra et al., 2020), which designates the capacity of a device to expose to the audience the respective contributions of artists and machines in electronic performances. This human-machine collaboration in artistic creation can also occur in other disciplines, such as cinema, again in various and graduated forms. In the film *Attack the Sun* by Gwendal Sartre and Fabien Zocco (2019), the dialogues are generated by processing content from social networks and communicated to the actors by an artificial intelligence. The artists remain in control of the overall framework and many production elements, but by letting an AI drive something as structurally significant as the dialogues, are we witnessing a strictly human production or a human-machine collaboration with a shared degree of authorship?

Thus, authorship in digital creation can be refined with more gradual notions of the level of control by the artist and the varying degree of their contribution to artistic production compared to that of machines. Additionally, as we have seen, authorship can be understood here from a dual perspective: that of the artist and their agency, and that attributed to them by the audience, referred to as attributed agency (Berthaut, 2015; Capra, 2020). This dual consideration highlights technology not only as a medium for creation but also for its mediation to make digital interactions perceptible and to reveal them (Berthaut et al., 2013), thus allowing authors to assert their desired level of authorship.

Delving deeper into the realm of human-animal-machine collaboration, we explore an innovative paradigm of authorship that transcends traditional species boundaries. This interdisciplinary nexus is exemplified by initiatives such as the Interspecies Internet (Dolgin, 2019; Jones, 2019) and the use of environmental sensing technologies (Gabrys and Pritchard,

2018), which are pioneering the way for a new form of artistic expression and communication across species and technologies. This blending of human creativity, animal behaviour, and technological intervention serves as a powerful testament to the potential of collective intelligence and creativity (Bonnet et al., 2019; Wang et al., 2023). It suggests that authorship can extend beyond the confines of human endeavour, encompassing the contributions of non-human participants whose interactions with technology provide a unique perspective to transcend creativity. The exchange of learning and behaviours between humans and animals (Sueur and Huffman, 2024), becomes a fundamental element of this co-creative process. This mutual adaptation and shared understanding facilitate a form of artistic creation that is truly collaborative, allowing for the emergence of novel expressions.

The outcomes of such partnerships—be it in the form of music that incorporates animal sounds interpreted through AI algorithms, or visual art that visualises the migratory patterns of birds captured via satellite technology, shapes of ants or termite colonies to co-create sculptures—enrich our artistic vocabulary.

In a mesmerising fusion of human movement and natural spectacle, choreographer Sadeck Berrabah's *Murmuration*⁷ stands as a profound example of interspecies inspiration in contemporary art. Drawing from the breathtaking phenomenon of murmuration—where thousands of birds, typically starlings, move in unison through the sky, creating fluid, dynamic shapes—Sadeck Berrabah captures the essence of this natural wonder through human bodies in motion. This performance blurs the lines between human and animal realms, redefining artistic authorship as a shared, interspecies endeavour.

Björk, through her innovative use of technology and nature in music, exemplifies shared authorship by integrating animal sounds and digital manipulation, blurring the lines between human, non-human, and technological creativity. Her project *Biophilia*⁸ showcases this symbiosis, treating natural sounds not merely as inspirations but as co-creators, challenging traditional notions of creative agency. Björk's approach, where machines serve as bridges between human creativity and the natural world, contributes to redefining authorship as a collective effort that transcends species boundaries. This perspective enriches discussions on the creative participation of non-human entities, urging a broader recognition of diverse contributions within the creative process.

Chris Jordan, Oliver Beer and Richard Mankin each uniquely engage with the natural world through their art, exploring the interplay between human activity, wildlife, and the environment. Jordan's digital photography, especially in *Midway: Message from the Gyre*⁹, reveals the dire effects of plastic pollution on seabirds, offering a stark visual commentary on environmental degradation. Beer merges art with ecology, using animal sounds in installations to examine space's acoustic qualities, connecting architectural and natural harmonies. Mankin, blending entomology with artistry, transforms insect acoustics into music, highlighting their ecological significance and challenging our perceptions of natural soundscapes. Together, these artists contribute to a broader dialogue on environmental awareness and interspecies relationships through innovative artistic practices.

In conclusion

We acknowledge the complexity inherent in discussing authorship across a spectrum of entities, ranging from animals to various forms of technology such as machines, robots, computers, and artificial intelligence (AI). We recognise that each of these entities possesses distinct levels of consciousness, intentionality, and embodiment, which significantly impact their perceived and

potential authorship. To clarify, our argument is rooted in the notion that authorship should not be considered a binary attribute but rather as existing on a continuum that reflects the degree of consciousness and intentionality of the creator, whether animal or artificial. This approach allows us to critically examine the prevailing norms of personhood and human-centric authorship, while also addressing the significant impact of embodiment on the perception of authorship. Specifically, the physical presence or absence of a robot, as opposed to the disembodied nature of an AI system, influences how authorship is ascribed and perceived. We have to embrace a nuanced understanding of these differences and propose a framework for degrees of authorship, based on the capacities of both biological and technological entities. This stance not only enriches the dialogue around the intersection of ethics, law, and technology but also ensures that our discussion remains relevant and adaptable to the evolving landscape of intelligent and creative beings.

The concepts related to authorship and ownership of creation are those that define a person: a conscious entity with rights. The scientific approach to applying copyright involves various steps to assess the intentionality of an act and its awareness of it. Therefore, machines cannot currently be recognised as authors of their creations. However, if one considers that an artist is less of an author when accompanied by a machine whose contribution to the work is evident, or even superior, this illustrates the gradual nature of authorship. From the artist's perspective, in a context where they are both the public performer and the programmer of the software used to create, they have a legitimate claim to authorship to a higher degree than if they were using prebuilt algorithms. This is a higher level of authorship than that perceived by a novice audience incapable of distinguishing the artist-computer scientist's contribution from the presence of machines. It results in a subjective notion, nonetheless linked to objective technical knowledge of the attributed agency. In the context of collaboration between human artists and machines, and from the perspective of spectators, the notion of authorship would not necessarily imply the existence of consciousness.

However, this conclusion appears different regarding conscious animals. In the case of great apes, even though only captive individuals seem to enjoy drawing, this enculturation (Tomasello and Call, 2004) should not prevent us from recognising their authorship and ownership of their creations, since a similar learning process is observed in humans. Drawing or playing an instrument is a skill that develops through observation and learning in *Homo sapiens*, similar to other hominids, including young children who undergo a lengthy process to acquire these abilities. Mozart's composition of musical works at the age of six illustrates that age or species does not constrain creativity. Some primatologists recognise the primates they study as co-authors in their research, publications, or productions, acknowledging their contributions (Savage-Rumbaugh et al., 2007; Applegate and Grupper, 2013; Matsuzawa, 2017). However, granting authorship to animals raises concerns about potentially undermining their agency (McFarland and Hediger, 2009; Blattner et al., 2020). Similarly, this article's title, derived from the AI of ChatGPT, prompts a reflection on its authorship status. These considerations are likely to spark extensive debate within both the artistic and scientific communities in the future.

Furthermore, our exploration into the realms of authorship and creativity among non-human entities prompts a consideration of the concepts of transhumanism and transanimalism, especially in relation to the use of assisted technologies and robotics within contemporary art (Burgat, 2015; Delfin, 2019; Grundmann, 2007; Someşan, 2022; Vita-More, 2013). Transhumanist and metahumanist (Sorgner and Deretic, 2015) movements that advocate for the evolution of the human condition

through advanced technologies, offer compelling lenses through which to view the integration of AI and robotics in artistic creation. These movements question the plasticity of the human condition and envision political and practical possibilities where the boundaries between human and machine, organic and artificial, are increasingly blurred, suggesting a new paradigm of creativity that is collaborative, hybrid, and expansive in its potential. Additionally, the concept of transanimalism (Cayol et al., 2024)—extending transhumanist ideas to include non-human animals in the technological enhancement narrative—further enriches this discourse. It invites us to reimagine the creative capacities of animals when augmented by technology, thus opening up new avenues for artistic expression that transcend traditional species boundaries. By integrating these considerations into our discussion, we acknowledge the evolving landscape of contemporary art, where assisted technologies not only redefine the parameters of human creativity but also challenge us to envisage a future where diverse forms of intelligence, both human and non-human, contribute to the tapestry of artistic expression in unprecedented ways.

Data availability

Data sharing is not applicable to this article as no datasets were generated or analysed during the current study.

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Notes

- 1 From an ethological perspective, creativity may be observed in animal behaviour that solves new problems or adapts in novel ways. In AI research, creativity is often demonstrated through the ability to produce work that is indistinguishable from or surpasses human-created art, challenging our understanding of creativity's origins and manifestations. Philosophically, creativity involves the exploration of the bounds of imagination and the capacity for conceptual expansion, inviting a re-evaluation of creative agency across different forms of consciousness.
- 2 Just as there are multiple forms and instances of intelligence across different animal species, with varied structures and supports for intelligence, the same reasoning can apply to AI. The term 'artificial intelligences' acknowledges the diversity and multiplicity of AI systems, frameworks, and applications. Each AI system can be designed with unique capabilities, purposes, and underlying algorithms, thus representing distinct 'intelligences' in the artificial realm. This pluralisation can emphasise the variety and specificity of AI entities, recognising their individual characteristics and contributions to the broader landscape of technology and society.
- 3 A robot is typically defined as a machine that is capable of carrying out complex actions automatically, especially when programmed to do so by a computer. Not all robots necessarily incorporate AI technologies and some robots may operate based on pre-programmed instructions or simple rule-based systems without the need for sophisticated AI algorithms. But many robots can be considered embodiments of AI because they incorporate AI algorithms to interact with the physical world through sensors and actuators, process sensory information and make decisions about how to act in their environment.
- 4 The question regarding agency and IA embodiment itself is an important discussion that is notably addressed by phenomenology and cognitive phenomenology (Buongiorno, 2023; Corti, 2022; Turner, 2020).
- 5 Strong AI, also known as Artificial General Intelligence (AGI), refers to a type of artificial intelligence that has the ability to understand, learn, and apply its intelligence to solve any problem, similarly to how a human would. It possesses the capacity for conscious thought, understanding, judgement and self-awareness, allowing it to perform tasks requiring human-like cognitive abilities and to adapt to new situations without human intervention. Strong AI aims to replicate the multifaceted intelligence of human beings but is still a theoretical object that only exists in cultural items such as movies or video games, with famous characters such as Data (*Star Trek: The Next Generation*). Weak AI, also known as Narrow AI, is designed and trained for a specific task as or a simple computer, an articulated robot or a machine. Unlike Strong AI, it operates under a limited pre-defined range or context and does not possess consciousness or self-awareness. Weak AI is focused on executing specific applications such as voice recognition, image analysis, or executing specific functions within a

software environment. Examples include virtual assistants, chatbots, and recommendation systems. While it can exhibit some level of learning and adaptation within its narrow domain, it does not have the capability to generalise its intelligence to the broad spectrum of tasks that a human or Strong AI can perform.

- 6 The U.S. Copyright Office will register an original work of authorship, provided that the work was created by a human being." (U.S. Copyright, 2021, Compendium (Third) § 306) This regulation was renewed in March 2023 in the legal text Copyright Registration Guidance: Works Containing Material Generated by Artificial Intelligence (U.S. Copyright, 2023, Copyright Registration Guidance).
- 7 <https://murmuration-lespectacle.com/en/murmuration-the-show/>.
- 8 <https://www.bjork.fr/-Biophilia-special->.
- 9 <https://www.aa13.fr/photographie/midway-message-from-the-gyre-chris-jordan-16430>.

References

- Abbott R (2016) I think, therefore I invent: creative computers and the future of patent law. *BCL Rev* 57:1079. <https://doi.org/10.2139/ssrn.2727884>
- Andreyev J (2016) The compassion manifesto: an ethics for art+ design and animals. In: Castricano J, Simonsen RR (eds). *Critical perspectives on veganism*. The Palgrave Macmillan Animal Ethics Series, pp. 155–180
- Applegate K, Grupper A (2013) *The one and only Ivan*. Recorded Books, United States of America
- Aristotle (1987) *De Anima (On the Soul)*, translated by Hugh Lawson-Tancred, Penguin Classics, London
- Beardsley MC (1970) The aesthetic point of view. *Metaphilosophy* 1(1):39–58
- Berthaut F, Marshall MT, Subramanian S, Hachet M (2013) Rouages: revealing the mechanisms of digital musical instruments to the audience. In: *Proceedings of the International Conference on New Interfaces for Musical Expression (NIME)*, May 2013, pp. 164–169
- Berthaut F, Coyle D, Moore J, Limerick H (2015) Liveness through the lens of agency and causality. In: *Proceedings of the International Conference on New Interfaces for Musical Expression (NIME)*, May 2015, pp. 382–386
- Betzler M ed (2008) *Kant's ethics of virtue*. de Gruyter, Berlin, Germany
- Bin SA (2018) *The show must go wrong: towards an understanding of audience perception of error in digital musical instrument performance*. Dissertation, Queen Mary University of London, England
- Boden MA (2010) The Turing test and artistic creativity. *Kybernetes* 39(3):409–413. <https://doi.org/10.1108/03684921011036132>
- Bonnet F, Mills R, Szopek M et al. (2019) Robots mediating interactions between animals for interspecies collective behaviours. *Sci Robot* 4(28):eaau7897. <https://doi.org/10.1126/scirobotics.aau7897>
- Blattner CE, Donaldson S, Wilcox R (2020) Animal agency in community. *Pol Anim* 6(1):1–22
- Bloom P (1996) Intention, history, and artifact concepts. *Cogn* 60(1):1–29. [https://doi.org/10.1016/0010-0277\(95\)00699-0](https://doi.org/10.1016/0010-0277(95)00699-0)
- Boysen ST, Berntson GG, Prentice J (1987) Simian scribbles: a reappraisal of drawing in the chimpanzee (*Pan troglodytes*). *J Comp Psychol* 101(1):82. <https://doi.org/10.1037/0735-7036.101.1.82>
- Bridy A (2012) Coding creativity: copyright and the artificially intelligent author. *Stan Tech L Rev* 5. <https://doi.org/10.31235/osf.io/5ru6m>
- Buongiorno F (2023) Can algorithms be embodied? A phenomenological perspective on the relationship between algorithmic thinking and the life-world. *Found Sci* 28(4):1035–1045. <https://doi.org/10.1007/s10699-022-09855-z>
- Burgat F (2015) *Improving animals, improving humans: transpositions and comparisons*. In: Bateman S, Allouche S, Gayon J, Marzano M, Gofette J (eds). *Inquiring into animal enhancement: model or countermodel of human enhancement?* Palgrave Macmillan, London, United Kingdom, pp. 34–48
- The Cambridge Declaration on Consciousness (2012) *Proceedings of the Francis Crick Memorial Conference*, Churchill College, Cambridge University, United-Kingdom
- Capra O, Berthaut F, Grisoni L (2020) Have a seat on stage: Restoring trust with spectator experience augmentation techniques. In: *Proceedings of the 2020 ACM Designing Interactive Systems Conference*, July 2020, Royal Birmingham Conservatoire, pp. 695–707
- Capra O (2020) *The experience of spectators of digital interactions: Benefits of visual augmentations and the role of attributed agency in electronic music performances*. Dissertation, Lille University, France
- Cayol A, Bévière-Boyer B, Gaillard E (2024) *Transanimalisme. L'animal augmenté, entre exploitations et protections*. Mare&Martin, Paris
- Christie's (2018) *Is artificial intelligence set to become art's next medium*. <https://www.christies.com/features/A-collaboration-between-two-artists-one-human-one-a-machine-9332-1.aspx>
- Copeland BJ (2000) The turing test. *Mind Mach* 10(4):519–539. <https://doi.org/10.1023/A:1011285919106>
- Corti L (2022) Robot as embodied agent. A phenomenological critique. In: *Software engineering and formal methods, SEFM 2022 Collocated Workshops: AI4EA F-IDE CoSim-CPS CIFMA*, September 2022, pp. 302–312

- Davies CR (2011) An evolutionary step in intellectual property rights—Artificial intelligence and intellectual property. *Comp Law Secur Rev* 27(6):601–619. <https://doi.org/10.1016/j.clsr.2011.09.006>
- Dalziel AH, Magrath RD (2012) Fooling the experts: accurate vocal mimicry in the song of the superb lyrebird, *Menura novaehollandiae*. *Anim Behav* 83(6):1401–1410. <https://doi.org/10.1016/j.anbehav.2012.03.009>
- DeGrazia D (1990) On singer: more argument, less prescriptivism. *Behav Brain Sci* 13(1):18–18
- Descartes R (1937) *Discours de la méthode*. La Pléiade, Paris
- De Waal F (2006) *Primates and philosophers: how morality evolved*. Princeton University Press, Princeton
- De Waal F (2016) Are we smart enough to know how smart animals are? WW Norton & Company, New-York
- Diamond J (1986) Animal art: variation in bower decorating style among male bowerbirds *Amblyornis inornatus*. *Proc Natl Acad Sci USA* 83(9):3042–3046. <https://doi.org/10.1073/pnas.83.9.3042>
- Delfin D (2019) An Artist's creative process: a model for conscious evolution. In: Lee N (ed.). *The transhumanism handbook*, Springer Verlag, pp. 587–602
- Doherty SJ (2019) ART in the age of artificial intelligence. *Esse* 97:30–41
- Dolgin E (2019) Elephants, Dolphins, and Chimps need the Internet, too: a new initiative promotes Internet communication among smart animals. *IEEE Spectr* 56(09):6–7
- Donaldson S, Kymlicka W (2011) *Zoopolis: a political theory of animal rights*. Oxford University Press, Oxford
- Dorigo M, Théraulaz G, Trianni V (2020) Reflections on the future of swarm robotics. *Sci Robot* 5(49):eabe4385. <https://doi.org/10.1126/scirobotics.abe4385>
- Dufour V, Poulin N, Curé C, Sterck EH (2015) Chimpanzee drumming: a spontaneous performance with characteristics of human musical drumming. *Sci Rep* 5(1):1–6. <https://doi.org/10.1038/srep11320>
- Engels F (2009) *Feuerbach—the roots of the socialist philosophy*. Forgotten Books, London
- Fels S, Gadd A, Mulder A (2002) Mapping transparency through metaphor: towards more expressive musical instruments. *Organ Sound* 7(2):109–126. <https://doi.org/10.1017/S1355771802002042>
- Ferrand Lointier M (2022) *Le tournant animal dans l'art contemporain (de 1960 à nos jours): approche écoféministe*. Dissertation, University Bordeaux 3, France
- Gabrys J, Pritchard H (2018) Just good enough data and environmental sensing: moving beyond regulatory benchmarks toward citizen action. *Int J Spat Data Infr Res* 13:4–14. <https://doi.org/10.1177/2053951716679677>
- Gallup Jr GG, Anderson JR, Shillito DJ (2002) The mirror test. In: Bekoff M, Allen C, Burghardt G (eds). *The cognitive animal: Empirical and theoretical perspectives on animal cognition*, Bradford Books, pp. 325–333
- Gardner R, Gardner BT (1978) Comparative psychology and language acquisition. In: Sebeok TA, Umiker-Sebeok J (eds). *Speaking of apes: a critical anthology of two-way communication with man*, Springer US, pp. 287–330
- Geissmann T (2000) Gibbon songs and human music from an evolutionary perspective. In: Wallin NL, Merker B, Brown S (eds). *The origins of music*, The MIT Press, pp. 103–123
- Griffin DR (2013) *Animal minds: beyond cognition to consciousness*. University of Chicago Press
- Guadamuz A (2016) The monkey selfie: copyright lessons for originality in photographs and internet jurisdiction. *Internet Policy Rev* 5:1. <https://doi.org/10.14763/2016.1.398>
- Grundmann M (2007) Transhumanist arts. Aesthetics of the future? Parallels to 19th century Dandyism. In: Heil R, Kaminski A, Stippak M, Unger A, Ziegler M (eds). *Tensions and convergences: technological and aesthetic transformations of society*, Transcript Verlag, pp. 83–92
- Hart J, Scassellati B (2012) Mirror perspective-taking with a humanoid robot. *Proc AAAI Conf Artif Intell* 26(1):1990–1996. <https://doi.org/10.1609/aaai.v26i1.8389>
- Hristov K (2016) Artificial intelligence and the copyright dilemma. *Idea* 57:431
- Huron D (2008) *Sweet anticipation: music and the psychology of expectation*. The MIT Press
- Janik VM (2014) Cetacean vocal learning and communication. *Curr Opin Neurobiol* 28:60–65. <https://doi.org/10.1016/j.conb.2014.06.010>
- Jasanoff S, Kim SH (2015) *Dreamscapes of modernity. Sociotechnical imaginaries and the fabrication of power*. The University of Chicago Press
- Jeannerod M (2001) Neural simulation of action: a unifying mechanism for motor cognition. *Neuroimage* 14(1):S103–S109. <https://doi.org/10.1006/nimg.2001.0832>
- Jones R (2019) An interspecies internet? Thinking and acting feminist-animal rights discourse online. *for(e)dialogue* 3(1):1–20
- Kawase H, Okata Y, Ito K (2013) Role of huge geometric circular structures in the reproduction of a marine pufferfish. *Sci Rep* 3(1):1–5. <https://doi.org/10.1038/srep02106>
- Krink T, Vollrath F (1997) Analysing spider web-building behaviour with rule-based simulations and genetic algorithms. *J Theor Biol* 185(3):321–331. <https://doi.org/10.1006/jtbi.1996.0306>
- Kugler K, Savage Rumbaugh S (2002) Rhythmic drumming by Kanzi an adult male bonobo (*Pan Paniscus*) at the language research centre. *Am J Primatol* 57:62
- Le Neindre P, Dunier M, Larrère R, Prunet P (2018) *La conscience des animaux*, Éditions Quae
- Levinson J (1979) Defining art historically. *Br J Aesthet* 19:232–250
- Locke J, Perry J (1975) Of identity and diversity. In: Perry J (ed.). *Essay concerning human understanding*, Berkeley, University of California Press
- Loeb J (1918) *Forced movements, tropisms, and animal conduct*. Philadelphia and London, J. B. Lippincott Company
- Malebranche N (1997/1674) *The search after truth: with elucidations of the search after truth*. The Cambridge University Press
- Malle BF, Knobe J (1997) The folk concept of intentionality. *J Exp Soc Psychol* 33:101–121
- Martinet L, Pelé M (2021) Drawing in nonhuman primates: what we know and what remains to be investigated. *J Comp Psychol* 135(2):176. <https://psycnet.apa.org/doi/10.1037/com0000251>
- Martinet L, Sueur C, Hirata S, Hosselet J, Matsuzawa T, Pelé M (2021) New indices to characterize drawing behaviour in humans (*Homo sapiens*) and chimpanzees (*Pan troglodytes*). *Sci Rep* 11(1):3860. <https://doi.org/10.1038/s41598-021-83043-0>
- Martinet L, Sueur C, Matsuzawa T, Hirata S, Morimura N, Pelé M (2023) Tool assisted task on touchscreen: a case study on drawing behaviour in chimpanzees (*Pan troglodytes*). *Folia Primatol* 94(2–3):111–127. <https://doi.org/10.1163/14219980-bja10008>
- Marx K, Engels F (2022) *The German ideology*. Foreign Languages Press, Paris, /1845
- Matsuzawa T (2017) The 40th anniversary of the Ai Project: the commemorative gift is a silk scarf painted by Ai the chimpanzee. *Primates* 58(2):261–265. <https://doi.org/10.1007/s10329-017-0604-0>
- McCormack J, Gifford T, Hutchings P (2019) Autonomy, authenticity, authorship and intention in computer generated art. In: *International conference on computational intelligence in music, sound, Art and design*. Cham, Springer International Publishing, pp. 35–50
- McFarland SE, Hediger R (2009) *Animals and agency: an interdisciplinary exploration*. Brill, Boston
- Meyer HG, Klimeck D, Paskarbeit J, Rückert U, Egelhaaf M, Pormann M, Schneider A (2020) Resource-efficient bio-inspired visual processing on the hexapod walking robot HECTOR. *PLoS ONE* 15(4):e0230620. <https://doi.org/10.1371/journal.pone.0230620>
- Mikalonytė ES, Kneer M (2022) Can artificial intelligence make art? Folk intuitions as to whether AI-driven robots can be viewed as artists and produce art. *ACM Trans Hum-Robot Interact (THRI)* 11(4):1–19. <https://doi.org/10.1145/3530875>
- Mujica E (2000) *Nazca: lignes et géoglyphes du désert*. La Rev du Patrim Mond 15:42–49
- Nguyen P (2019) The monkey selfie, artificial intelligence and authorship in copyright: The limits of human rights. *Pub Int LJNZ* 6:121
- Nochlin L (2021/1971) *Why have there been no great women artists?* Thames & Hudson, London
- OneGreenPlanet (2020) *Elephant artists? Here's why making an elephant paint is cruel, not cute*. <https://www.onegreenplanet.org/animalsandnature/why-making-an-elephant-paint-is-cruel-not-cute/>
- Ostrow M, Dengel C (2022) *United States: art and artificial intelligence collide with copyright law*. Romano Law Blog. <https://www.romanolaw.com/art-and-artificial-intelligence-collide-with-copyright-law/>
- Oyakawa C, Koda H, Sugiura H (2007) Acoustic features contributing to the individuality of wild agile gibbon (*Hylobates agilis agilis*) songs. *Am J Primatol* 69(7):777–790. <https://doi.org/10.1002/ajp.20390>
- Rahwan I, Cebrian M, Obradovich N et al. (2019) Machine behaviour. *Nature* 568(7753):477–486. <https://doi.org/10.1038/s41586-019-1138-y>
- Reeves S, Benford S, O'Malley C, Fraser M (2005) *Designing the spectator experience*. In: *Proceedings of the SIGCHI conference on Human factors in computing systems, July 2005*, Association for Computing Machinery, pp. 741–750
- Regad C, Riot C (2019) *La Déclaration de Toulon du 29 mars 2019 sur la personnalité juridique de l'animal: pourquoi? quelle potentialité juridique?* Démocratie et Justice
- Rimoldi G, Manzollì J (2016) *Enactive framework for design of digital music interfaces*. In: *Proceedings of the 2nd International Conference on New Music Concepts-ICNMC, March 2016*, Corpus ID: 207815887
- Rizzolatti G, Fadiga L, Gallese V, Fogassi L (1996) Premotor cortex and the recognition of motor actions. *Cogn Brain Res* 3(2):131–141. [https://doi.org/10.1016/0926-6410\(95\)00038-0](https://doi.org/10.1016/0926-6410(95)00038-0)
- Naudier D, Rollet B (2007) *Genre et légitimité culturelle: quelle reconnaissance pour les femmes?* Genre et Légitimité Culturelle 1:172
- Rosati E (2017) *The Monkey Selfie case and the concept of authorship: an EU perspective*. *J Intellect Prop Law Pr* 12(12):973–977. <https://doi.org/10.1093/jiplp/jpx199>

- Salimpoor VN, Zald DH, Zatorre RJ, Dagher A, McIntosh AR (2015) Predictions and the brain: How musical sounds become rewarding. *Trends Cogn Sci* 19(2):86–91. <https://doi.org/10.1016/j.tics.2014.12.001>
- Sartori L, Bocca G (2023) Minding the gap (s): public perceptions of AI and socio-technical imaginaries. *AI Soc* 38(2):443–458. <https://doi.org/10.1007/s00146-022-01422-1>
- Sartre G, Zocco F (2019) Attack the Sun [62 min] Nuit Blanche Productions
- Savage-Rumbaugh S, Wamba K, Wamba P, Wamba N (2007) Welfare of apes in captive environments: comments on, and by, a specific group of apes. *J Appl Anim Welf Sci* 10(1):7–19. <https://doi.org/10.1080/10888700701277261>
- Schiller PH (1951) Figural preferences in the drawings of a chimpanzee. *J Comp Phys Psychol* 44(2):101–111. <https://psycnet.apa.org/doi/10.1037/h0053604>
- Schloss WA (2003) Using contemporary technology in live performance: The dilemma of the performer. *J New Music Res* 32(3):239–242
- Schneider A, Paskarbit J, Schilling M, Schmitz J (2014) HECTOR, a bio-inspired and compliant hexapod robot. In: *Biomimetic and Biohybrid Systems: Third International Conference, Living Machines Proceedings 3*, Springer International Publishing, pp. 427–429
- Schrecker P (1938) Malebranche et le préformisme biologique. *Revue Internationale de Philosophie*. pp. 77–97
- Someşan AI (2022) Transhumanism in performance art. *J Intercult Manag Ethics* 5(4):51–57. <https://doi.org/10.35478/jime.2022.4.06>
- Star Trek: Voyager (2001) Author, Author, Season 7, episode 20. United States
- Sorgner SL, Deretic I (2015) From humanism to meta-, post- and transhumanism? Peter Lang GmbH, Internationaler Verlag der Wissenschaften
- Sueur C (2011) A non-Lévy random walk in chacma baboons: what does it mean? *PLoS ONE* 6(1):e16131. <https://doi.org/10.1371/journal.pone.0016131>
- Sueur C, Forin-Wiart MA, Pelé M (2020) Are they really trying to save their buddy? The anthropomorphism of animal epimeletic behaviours. *Anim* 10(12):2323. <https://doi.org/10.3390/ani10122323>
- Sueur C, Pelé M (2017) Editorial: Anthropomorphism, between merits and demerits. *Lett du CEERE* 107:1
- Sueur C, Zanaz S, Pelé M (2023) Incorporating animal agency into research design could improve behavioural and neuroscience research. *J Comp Psychol* 137(2):129–143. <https://doi.org/10.1037/com0000335>
- Sueur C, Huffman MA. Co-cultures: exploring interspecies culture among humans and other animals. Preprint on <https://hal.science/hal-04368545/document>
- Tanaka M, Tomonaga M, Matsuzawa T (2003) Finger drawing by infant chimpanzees (*Pan troglodytes*). *Anim Cogn* 6:245–251. <https://doi.org/10.1007/s10071-003-0198-3>
- Terleph TA, Malaivijitnond S, Reichard UH (2015) Lar gibbon (*Hylobates lar*) great call reveals individual caller identity. *Am J Primatol* 77(7):811–821. <https://doi.org/10.1002/ajp.22406>
- Tissue S, Wilensky U (2004) Netlogo: a simple environment for modeling complexity. *Int Conf Complex Syst* 2:16–21
- Tomasello M, Call J (2004) The role of humans in the cognitive development of apes revisited. *Anim Cogn* 7:213–215. <https://doi.org/10.1007/s10071-004-0227-x>
- Tomasello M, Call J (1997) *Primate cognition*. The Oxford University Press, USA
- Turner C (2020) The cognitive phenomenology argument for disembodied AI consciousness. In: Gouveia S (ed.). *The age of artificial intelligence: an exploration*. Vernon Press. pp. 111–132
- U.S. Copyright Office (2021) *Compendium of U.S. Copyright Office Practices* § 101, 3rd edn. U.S. Copyright Office
- U.S. Copyright Office (2023) *Copyright Registration Guidance: Works Containing Material Generated by Artificial Intelligence*, Library of Congress. U.S. Copyright Office
- Vernier G, Caselles-Dupré H, Fautrel P (2020) Electric dreams of Ukiyo: a series of Japanese artworks created by an artificial intelligence. *Patterns* 1(2):1–2
- Vernier G, Caselles-Dupré H, Fautrel P (2020) Facets of AGI: where science meets spirituality. *Patterns* 1(8). <https://doi.org/10.1016/j.patter.2020.100026>
- Vita-More N (2013) Aesthetics: bringing the arts & design into the discussion of transhumanism. In: More M, Vita-More N (eds). *The transhumanist reader: classical and contemporary essays on the science, technology, and philosophy of the human future*, John Wiley and Sons. pp. 18–27
- Wang GY, Cheng DD, Xia DY, Jiang HH (2023) Swarm intelligence research: From bio-inspired single-population swarm intelligence to human-machine hybrid swarm intelligence. *Mach Intell Res* 20(1):121–144. <https://doi.org/10.1007/s11633-022-1367-7>
- Watanabe S (2012) Animal aesthetics from the perspective of comparative cognition. In: Watanabe S, Kuczaj S (eds). *Emotions of animals and humans: comparative perspectives*. Springer, Tokyo, Japan. pp. 129–162
- Wise SM (2010) Legal personhood and the nonhuman rights project. *Anim L* 17:1
- Zatorre RJ, Chen JL, Penhune VB (2007) When the brain plays music: auditory-motor interactions in music perception and production. *Nat Rev Neurosci* 8(7):547–558. <https://doi.org/10.1038/nrn2152>

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Additional information

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