TRANSLATING THE WILD: AI, SEMIOTICS, AND THE FUTURE OF ANIMAL COMMUNICATION[1]

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Abstract

This article critically examines the recent rise of AI-based attempts to "translate" animal communication: with a specific focus on aquatic species such as dolphins and whales. Drawing on biosemiotics, ecosemiotics, and Umwelt theory, it argues that such projects, while technologically sophisticated, risk reducing animal semiosis to codifiable data structures and computational approximations of meaning. Through an analysis of DolphinGemma and CHAT, the article exposes the epistemological and semiotic limitations of current AI models, contrasting them with embodied, context-sensitive modes of communication in non-human species. Rather than serving as transparent translation tools, AI systems should be understood as technosemiotic infrastructures which may support new interspe-

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cies resonances, provided they are embedded within critical and relational frameworks. The analysis advocates for an ecotechnical semiotics which redefines intelligence and communication as emergent, situated, and materially grounded processes, resisting both symbolic reductionism and techno-utopianism.

Keywords: biosemiotics, zoosemiotics, artificial intelligence, dolphin communication, Umwelt

Introduction

In recent years, both media and scientific discourses have increasingly focused on the possibility of "translating" animal communication systems through the use of artificial intelligence (AI) technologies. Projects such as CETI (Cetacean Translation Initiative), DolphinGemma (developed in collaboration with Google), and the Wild Dolphin Project aim to decode acoustic signals and complex behaviors of species such as sperm whales and bottlenose dolphins, in the hope of extracting linguistic structures interpretable in a manner analogous to human language. These initiatives rest upon a strong epistemological premise, namely, that animal communicative patterns can be reduced to formal systems, amenable to computational and statistical modeling and translation.

This narrative, however, raises fundamental semiotic and philosophical questions. Reducing animal communication to a set of "decodable data" presupposes a referential and codifying model of semiosis in nature, in which meaning is conceived as a predefined and transferable amount of information and data. Such an approach risks obscuring the situated, embodied, and ecologically grounded nature of animal communication (Maran, Martinelli & Turovski 2011), the intelligibility of which cannot be separated from the perceptual, affective, and evolutionary conditions which give rise to it. As Thomas A. Sebeok already noted, animals do not possess language in the human sense, but communicate through a semiotic system which is simultaneously physiological, behavioral, and relational (Sebeok 1972, 2001). Each animal sign is thus part of an interpretive network internal to its Umwelt (Cerrone & Mäekivi 2021), according to the paradigm introduced by Jakob von Uexküll (1909), who conceived of every organism as an active interpreter of its own meaningful world.

From this perspective, biosemiotics offers a crucial contribution by reconfiguring the very questions which we pose about animal communica-

tion. The issue is not one of "translating" messages, but of understanding the embodied signification processes which make communication possible in the first place. The animal sign is not a mere computational code, but a relational, ecosystemic, and corporeal event. For this reason, its intelligibility cannot be disentangled from the ecosystemic context and the corporeal affordances that constitute its material basis. The recent AI-driven ambitions of translation, if not supplemented by a critical semiotic theory, risk reiterating an anthropocentric and logocentric paradigm, wherein communication becomes synonymous with symbolic language, and intelligence is assessed based on its compatibility with formalizable syntactic structures.

This article offers a critical reflection on such attempts to "decode the wild,"[2] drawing on a biosemiotic re-reading of a selected corpus of recent studies, with particular attention to the case of the Wild Dolphin Project. The aim is to show how the biosemiotic approach, which understands semiosis as an emergent, trans-categorical process inherent to all forms of life, can help reformulate the question of interspecific communication in less reductionist and more ecologically grounded terms. This reframing can offer important insights not only into animal communication, but also into our relationship with AI, and into how this technology might serve as a fruitful interface, providing a window into nonhuman worlds.

1. Translating Dolphins? A Semiotic Critique of the Computational Rhetoric of Animal Communication

The idea of "talking to dolphins" is far from new in the landscape of anthropocentric speculations on animal communication (Mann et al. 2000), yet it has recently gained renewed vigor through the innovative rhetoric surrounding artificial intelligence (AI). Four recent articles, published respectively in *New Atlas*, *Times of Malta*, *ExtremeTech*, and Google's official

[2] This idea of translating the wild (apart from reintroducing a colonialist idea of translation), is inspired by Neil Savage's article entitled "AI decodes the calls of the wild", published in *Nature* on 10th December 2024. https://www.nature.com/immersive/d41586-024-04050-5/index.html (accessed 8 May 2025) At the same time, popularizer Philip Ball, echoing the words of Constantine Slobodchikoff, writes on 27 April 2021 in The New Yorker that "Computer technology is finally allowing us to see inside the world of animals...". https://www.newyorker.com/science/elements/the-challenges-of-animal-translation (accessed 8 May 2025). We are a long way from "seeing" into the animal Umwelt. From a semiotic point of view, we could (and perhaps should) ask what it means to "see" inside the animal world with technology. Is the subjective world of others something you can see? Can we see, as if it were something perpetually there waiting for our gaze, what a life form experiences in its ecologically, historically and corporeally situated existence?

blog, enthusiastically report on the DolphinGemma project, developed by Google DeepMind in collaboration with the Wild Dolphin Project. This initiative aims to construct a "language model" of dolphin vocalizations, in order to "decode" their language. The expressions used in these texts, while seemingly neutral or even celebratory of interspecies encounters, in fact reveal an interpretative paradigm heavily shaped by anthropomorphic projections and a reductionist conception of communication.

Phrases include such as: "allowing the researcher to "converse" with dolphins… Patterns allow DolphinGemma to predict what the dolphin is likely to "say" next, similar to how Google Search and generative AI predict the next fragment of a user's query" (*ExtremeTech*)[3]; "Researchers could also trigger artificial whistles using the interface, essentially "speaking" to the dolphins using sounds they could potentially learn to associate with specific objects" (*New Atlas*)[4]; "Before you scoff at this suggestion, consider that with its ability to analyze huge quantities of data, recognize patterns, and apply machine learning algorithms, AI is a powerful tool to decode the complex conversations of other species, whether underwater or intergalactic. Google translate is a fine example" (*Times of Malta*)[5]; to build an imaginary in which the acoustic behavior of bottlenose dolphins is construed as a language in the strict sense (with all the inverted commas put by the authors above words like speak or say). This can be seen as a structured symbolic system governed by syntactic rules and potentially translatable according to principles analogous to those of human languages. This use of linguistic terminology presupposes a correspondence between the clicks or whistles produced by dolphins and discrete units of meaning, capable of being transferred, processed, and ultimately translated through computational models. The Google blog, in particular, claims that deep learning models can identify patterns in dolphin vocalizations and attempt to associate them with known contexts and behaviors, offering a path toward this correlation. However, this computational framing introduces significant epistemological and semiotic limitations. Although deep learning mod-

[3] Nine, A. 2025. New Google LLM Aims to Translate Dolphin Language. *Extreme Tech, 16 April 2025.* Available at: https://www.extremetech.com/science/new-google-llm-aims-to-translate-dolphin-language (accessed 8 May 2025)

[4] Ghoshal, A. 2025. Google AI learns to speak dolphin. *New Atlas,* 15 April 2025. Available at: https://newatlas.com/biology/build-ai-translator-dolphins-dolphingemma/ (accessed 8 May 2025)

[5] Lafferty, E. 2025. On using Google Translate to speak 'Dolphin' to aliens. *Times of Malta,* 29 March 2025. Available at: https://x2.timesofmalta.com/20250329/opinion/how-google-translate-has-allowed-us-to-speak-dolphin/ (accessed 8 May 2025)

els can identify recurring acoustic patterns and statistically correlate them with observed dolphin behaviors, such as foraging, play, or social bonding, they do not access the meaning-making processes inherent to the dolphins themselves. For example, a particular whistle might occur both during cooperative hunting and during playful social interactions. The acoustic form remains constant, but its meaning shifts depending on the ecological context, group dynamics, and affective state of the animal. AI models, which rely on surface-level correlations, cannot discern this semiotic flexibility.

From a biosemiotic perspective, meaning is not an intrinsic property of a signal, but emerges from its embeddedness within the animal's Umwelt, a relational, embodied world of perception, need, and social interaction (Uexküll 1940; Sebeok 1977). Machine learning systems lack this Umwelt. They do not interpret signs which generate an interpretant shaped by lived experience. Instead, they simulate interpretation through probabilistic matching. As such, the "translation" offered by AI risks becoming a symbolic approximation, useful perhaps for human analysis, but disconnected from the intentional, adaptive, and affectively charged semiosis which characterizes dolphin communication. Without accounting for this contextual and embodied dimension, AI-driven models may not translate meaning, but instead transform it. They project computational structure onto a communicative process which is fundamentally ecological and relational.

This implicit semiotic operation entails two major distortions. First, it reduces the animal sign to a decontextualized acoustic input, treated as raw data to be extracted and modeled; while secondly, it flattens meaning into its referential and behavioral correlate. Both strategies reveal a model of semiosis which is rigidly codified and grounded in the information theory of Shannon and Weaver (1948). Here communication is equated with the transmission of data through a channel. However, as the biosemiotic tradition has long argued, this model proves inadequate when it comes to understanding the processes of signification in non-human species.

The perspective of biosemiotics proposes a radically different conception of sign and communication (Zengiaro 2023a). The issue is not to identify "units of meaning" which can be translated between different codes, but to understand semiosis as a dynamic, embodied process emerging from a triadic relation (sign, object, interpretant) which always takes place within a situated context. According to Thomas A. Sebeok (1972), animals do not possess "language" in the human sense of the term, but rather species-specific semiotic systems rooted in their morphology and ecology (primarily iconic and indexical in nature) the primary function of which is to orient action, rather than to transmit propositional content. According to Sebeok,

it is misleading to speak of "language" in reference to animal communication, except in a metaphorical sense (Sebeok 1990: 106). Similarly, Jakob von Uexküll (1909) conceived every organism as immersed in an Umwelt, a meaningful world emerging from the interplay between its perceptual capabilities and the landscape it inhabits. The meaning of a dolphin's vocalization cannot be grasped, if it is isolated from the ecological, affective, and corporeal conditions which generate it.

The articles under analysis, however, tend to abstract the dolphin vocalization from its ecological and behavioral grounding, treating the sign as a discrete and computable unit. Nevertheless, empirical research in dolphin cognition and communication, such as the work by Smith et al. (1995) demonstrates that interpreting vocal signals is inextricably tied to understanding the behavioral responses which follow. Their study showed that dolphins are capable of complex auditory comprehension, responding to syntactically ordered human-generated acoustic signals (Smith et al. 1997). Crucially, however, these responses were shaped not only by the acoustic form of the stimulus but by contextual cues, prior training, and motivational states. This underscores the challenge of interpreting vocalizations through AI: meaning is not inherent in the signal itself but arises through a situated interpretive process.

In this light, the assumption that we can straightforwardly "break down what dolphins are saying, and even respond in kind," as some popular articles suggest, misrepresents the asymmetry between machine processing and biological semiosis. Dolphins do not "respond" in a symbolic, dialogic sense, as humans might in linguistic conversation. They respond through embodied and context-sensitive behaviors: orienting their echolocation beam, altering swimming patterns, or emitting socially nuanced clicks and whistles. These behaviors are not mere outputs to be decoded: they are affective, ecological expressions embedded in a social Umwelt (Martinelli 2011). Attempting to isolate "messages" from these behaviors for the purpose of symbolic translation ignores the co-emergent nature of communication within relational and environmental feedback loops. Without access to the interpretive ground which motivates and gives sense to the sign, a capacity rooted in embodied cognition, AI systems risk misattributing functional equivalence where there is only statistical correlation.

In a semiotic framework, Machine Learning (ML) can be interpreted as a set of algorithmic processes aimed at modeling sign relations between data inputs and decision outputs through iterative refinement. Rather than simply processing "information," ML systems operate as translation machines which extract, transform, and abstract patterns from empirical data,

thereby producing new layers of operational meaning. This dynamic of semiosis is particularly evident in the three main paradigms of ML (Bermant et al. 2019): supervised, unsupervised, and reinforcement learning.

1. Supervised learning functions through a logic of indexical anchoring: it operates on pre-labeled data where the referent (ground truth) is explicitly known, allowing the algorithm to learn correspondences between signifiers and predetermined classes. The system builds a predictive model through repeated exposure to these labeled signs, effectively emulating a Peircean interpretant guided by externally imposed norms.
2. Unsupervised learning, in contrast, explores the internal structure of sign systems without predefined classifications. It searches for clusters, associations, or latent variables, operating through abductive inference, it attempts to uncover implicit relations between signs, modeling semiosis as the discovery of emergent regularities within undifferentiated signal spaces.
3. Reinforcement learning situates semiosis within a feedback loop of action and consequence. Here, the algorithm-agent engages with an environment, receiving reward signals which function as pragmatic indices of interpretive success. The meaning of a sign (e.g., an action) is determined retrospectively, through its contribution to an outcome, a model of semiosis akin to trial-and-error learning in animals.

These paradigms converge in Deep Learning (DL), a subfield of ML which builds hierarchical models of sign abstraction through multilayer neural architectures. DL can be understood as a semiotic stratification process (Dondero 2025): raw input data (e.g., pixels, audio waves, word embeddings) are progressively transformed through layers of nonlinear functions, yielding increasingly complex representations. Each layer functions as an interpretive filter that re-codes the incoming signs into more abstract forms, recursively re-embedding them in new semiotic networks.

Artificial Neural Networks (ANNs), the computational substrate of DL, instantiate this logic formally. Through iterative adjustment of their internal parameters (weights), guided by optimization algorithms such as backpropagation, ANNs learn mappings between input and output spaces. Architectures such as Multi-Layer Perceptrons (MLPs), Convolutional Neural Networks (CNNs), and Recurrent Neural Networks (RNNs) specialize in different forms of sign temporalization and spatialization. MLPs handle general classification tasks. CNNs process spatial hierarchies in im-

ages (signs as shapes), while RNNs model temporal sequences (signs as rhythms or syntagms).

In semiotic terms, ML (and particularly DL) does not understand meaning in the phenomenological sense, but performs operational semiosis. It constructs functional relationships among signs, optimizing for internal coherence or external reward. The semiotic limitation of these systems lies not in their inability to generalize, but in the absence of intentionality, Umwelt, and affect, and key elements of biosemiotic semiosis. Yet, their capacity to reorganize and recompose sign structures renders them powerful tools for exploring latent semiotic dimensions within vast symbolic ecologies.

Ecosemiotics, conceived as an expansion of biosemiotics into the spatial and relational dimensions of environment (Zengiaro 2023b), provides the theoretical tools required to recognize that signals are never mere carriers of information. Rather, they are articulations of a broader contextual web. As ecosemiotician Timo Maran (2020) argues, animal semiosis is co-determined by habitat, body, social interaction, and the affordances of the sensory landscape. Every sign is situated, and every expression is relational. To "translate" a click without feeling the water, seeing the light, or knowing the group's spatial configuration is an epistemologically blind operation.

The AI-centered optimism of projects such as DolphinGemma, thus reproduces a colonial paradigm of knowledge, one that reduces alterity to codifiable difference, neutralizes ecological complexity in the name of computability, mistaking statistical mapping for semiotic understanding. Artificial intelligence can undoubtedly contribute to identifying acoustic and behavioral patterns. However, this is not equivalent to "translating dolphin language." Without a robust theory of the sign, such efforts risk remaining exercises in anthropocentric data mining, incapable of grasping the core issue: that animal communication is not a language, it is a life that signifies[6].

[6] Interesting is a comment in *New Atlas* about the article already cited "Google AI learns to speak dolphin" by JS who writes: "So, we already know them to be one of the smartest animals on the planet ... once we learn their language and can communicate with them, what happens to all the ones in captivity doing tricks for snacks? Does that make them slaves at that point?" JS April 15, 2025 09:50 AM. https://newatlas.com/biology/build-ai-translator-dolphins-dolphingemma/ Here the old Cartesian legacy explodes, according to which if animals speak then they are slaves, since they are subjects of a life; if they do not speak, then everything is permitted, since this life of theirs has no interiority or value.

1.1. CHAT: Am I free to choose what to express?

The CHAT (Cetacean Hearing and Telemetry) project, developed by Thad Starner's team at Georgia Tech in collaboration with the Wild Dolphin Project directed by Denise Herzing, represents one of the most advanced contemporary attempts to design an interspecific communication technology between humans and dolphins. CHAT is a bidirectional underwater computer equipped with two hydrophones to receive sounds, and an underwater speaker to emit them[7]. The system is based on the emission and recognition of artificial whistles, specially designed acoustic signals which mimic dolphin vocalizations but are constructed ad hoc to label play objects (e.g., sargassum, scarves, ropes), thus testing the dolphins' potential referential use of such sounds.

The ethological foundation of the project is grounded in well-established observations: dolphins are capable of mimicking vocalizations and associating them with objects, a behavior which suggests a potential for referential signaling. CHAT implements a limited vocabulary, with each signal associated with a sound label transmitted to the diver via bone-conducting headphones, thereby providing immediate interpretative support. In a notable episode, Herzing reported hearing the word "sargassum" emitted by the device in response to a whistle produced by a dolphin. However, the event was not accompanied by any referential behavior, leaving open the question of whether the cetacean was merely mimicking the signal or using it functionally.

This experience suggests that while dolphins can reproduce artificial sounds, their semantic understanding of such signals remains unproven. Moreover, subsequent analyses revealed that many of the whistles produced were situated in frequency bands not detected by the CHAT system, pointing to a sophisticated degree of vocal plasticity in dolphins and highlighting further complexities in interface design. The Phase II of the project aims to develop a more advanced and sensitive bidirectional system, utilizing pattern recognition software to analyze dolphins' natural acoustic signals and facilitate the decoding of their vocal repertoires. This approach is framed as an attempt to bridge the gap between human and animal communication, in pursuit of a form of mutual communicative understanding.

On the theoretical level, CHAT is situated within a semiotic paradigm marked by internal tension. On the one hand, it attempts to construct a shared code, while on the other, it is confronted with the irreducibility of

[7] CHAT: Is It A Dolphin Translator Or An Interface? *Wild Dolphin Project.* Available at: https://www.wilddolphinproject.org/our-research/chat-research/ (accessed 8 May 2025).

animal semiosis to mere syntactic structure. The technical challenges it faces (the design of inputs compatible with dolphin ethology to the identification of contextual signal usage) demonstrate that cetacean semiosis cannot be isolated from their Umwelt, which includes posture, spatial orientation, behavior, and social relationships. CHAT has not yet demonstrated the possibility of translating dolphin communication, but it opens a relevant experimental space for the construction of relational and adaptive interfaces, rather than strictly linguistic ones. The potential of such systems lies not in the deciphering of an "animal language," but in the co-construction of hybrid communicative practices capable of respecting the semiotic alterity of the nonhuman, an approach closer to biosemiotics than to classical computational linguistics. In order to improve this understanding towards non-human communication, researchers need to be cautious and carry out a critical and reasoned analysis of the scope of these tools (and their results). Projects such as CHAT, which aim to establish a computational interface between humans and dolphins, are based on the assumption that meaning can be traced, codified, and computed as a stable outcome of observable behavior. In this model, a signal (such as a whistle) is treated as a functional trigger for a response (behavior), following an ostensibly transparent stimulus-response logic. However, from a biosemiotic perspective, such a reductionist model risks obscuring the profoundly indeterminate, situated, and creative nature of animal communication.

Jesper Hoffmeyer (1996) introduced the concept of "semiotic freedom" to describe the degree of interpretative flexibility that a living organism possesses in relation to environmental signs. It denotes the organism's capacity to choose among multiple possible responses to a given signal, rather than being bound to a predetermined automatic reaction. According to Hoffmeyer, semiotic freedom increases with the evolution of cognitive and corporeal complexity and serves as an index of an organism's ability to construct meaningful worlds, its Umwelt. Behavior, therefore, is never purely reactive, but rather the outcome of interpretive negotiation among multiple semiotic possibilities.

Kalevi Kull has further developed this perspective by proposing a definition of semiosis as choice, clearly distinguishing it from algorithmic calculation. As he states:

> Only in case if there is a certain problem to solve, if there is more than one option (which requires choice and decision-making), the process related to it is in semiotics commonly called interpretation, or semiosis. […] A problem is real for an organism, if there are pos-

> sibilities, several options for it to choose, i.e., if there is a situation of choice. There is a situation of choice, if the options given simultaneously are incompatible – i.e., if, at a given moment, there are several ways to behave, while only one of these can be executed. Thus, the simultaneous existence of options – we call it *incompatibility* – is what makes anything a problem, and it can be overcome only via making a decision. (Kull 2015: 225)

According to this definition, communication is an event of selection among concurrent alternatives, irreducible to a computable function, precisely because it involves a dimension of freedom and creativity which escapes the deterministic logic of computational systems.

In the case of dolphins (well known for their vocal flexibility, complex social play, self-recognition, and even the symbolic use of sounds such as signature whistles) semiotic freedom is expressed not only in the repetition of signals but in the capacity to use them out of context, to reinterpret them, or to refrain from using them altogether. This point is critical: when a dolphin does not activate a whistle pre-programmed in the CHAT system to request an object, this is not a failure of the system, but a potential expression of the dolphin's semiotic freedom, its ability to choose when, how, and whether to use a given sign.

The AI implemented in the CHAT project, as in many other "intelligent" interfaces designed to recognize vocal patterns, operates within a paradigm of functional equivalence between sign and behavior. Yet in doing so, it fundamentally misrecognizes the interpretative dimension of the sign. Communication is never a simple output determined by an acoustic input, but a situated event, co-determined by ecological conditions, social relations, intentionality, and perceptual context. Semiotic freedom implies that an animal can receive a signal and choose not to act on it, or to act in ways that appear inconsistent, precisely because this apparent incoherence reveals its semiotic subjectivity.

In this sense, the CHAT methodology confronts a deep epistemological limit: it confuses the ability to recognize patterns with the ability to understand semiosis. Recognizing a whistle is not sufficient to demonstrate communicative comprehension. For a sign to truly function as such, it must be interpreted. Interpretation, as Peirce reminds us, is always an unfinished, open-ended, and deferred act. In attempting to build a behavioral dictionary of dolphin responses, AI risks flattening the semiotic freedom of living beings into a behaviorist grid, despite its apparent technological sophistication.

A true alliance between AI and biosemiotics should not aim to produce behavioral interfaces which merely verify the functional efficiency of signs, but should instead seek to create relational spaces capable of hosting the emergence of animal semiotic freedom. In other words, rather than asking whether the dolphin "understood" the word "sargassum" because it approached the seaweed, we should ask ourselves: what relational worlds become possible when signs are used indeterminately, asynchronously, and creatively? How can we listen to dolphin semiosis without seeking to immediately translate it into a reactive grammar?

The problem with CHAT is not technical, it is semiotic. Tying meaning to immediate action prevents us from grasping the interpretative depth of life. To recognize an animal's semiotic freedom also means to accept the opacity of its sign and to understand that not knowing what a signal means can be more productive, both theoretically and ethically, than assigning it a predefined function. The real challenge is not to translate the other, but to inhabit the semiotic difference that makes all communication possible.

2. Artificial Intelligence and Umwelt: An Epistemological Question Between Organisms and Artifacts

The introduction of artificial intelligence in attempts to "decode" animal communication entails deep epistemological implications which cannot be reduced to mere technical or engineering concerns. It brings into question the difference between living organisms and artificial devices not only in material or functional terms, but more crucially from a semiotic and phenomenological perspective. In this context, the concept of Umwelt, introduced by Jakob von Uexküll (1909) and further developed within contemporary biosemiotics (Tønnessen 2022), gains critical theoretical relevance. Umwelt does not simply refer to the external environment, but rather to the subjective phenomenological world constructed through the specific sensorimotor interactions of an organism, in accordance with its biological needs and perceptual marks. This concept is fundamentally incompatible with a conception of communication as the linear transmission of computable data, typical of AI, which operates through symbolic abstractions detached from embodied and contextual lived experience.

Thomas A. Sebeok (1972, 1990, 2001), in his foundational work in zoosemiotics, drew a crucial distinction between human language and animal communication. The former is symbolic, referential, and syntactically articulated, whereas the latter is based on indexical and iconic sign systems, deeply rooted in the environment and the body. To attempt to translate

these signals into human language is to engage in a form of epistemological semiocolonialism, wherein the human symbolic paradigm is retroactively projected onto biological systems which operate according to different logics of signification. Dolphins, for instance, do not "speak," but express intentions, bodily states, emotions and ecological relationships through gestures, sounds, and movements embedded within their aquatic and relational Umwelt.

The question of whether artificial systems such as AI or robots can possess an Umwelt has become a focal point in the dialogue between biosemiotics, cybernetics (or cybersemiotics), and philosophy of technology. What is at stake in this debate is not merely the functionality of machines, but the very conditions under which meaning arises.

Over the past several decades, researchers from diverse fields, including robotics, cognitive science, semiotics, and theoretical biology, have engaged with Jakob von Uexküll's theory of the Umwelt to bridge the epistemological divide between biological organisms and artificial systems. This body of work reveals a spectrum of epistemological positions. Some adopt Umwelt theory as a generative model for constructing intelligent machines, while others employ it critically to highlight the limitations of artificial cognition. Spanning fields such as robotics, cybernetics, cognitive science, and semiotics, this conversation revolves around one central question: can non-living artifacts like robots or AI systems possess a subjective world of meaning similar to that of living organisms?

In the 1980s, roboticist Rodney Brooks drew on Uexküll's notion of *Merkwelt* to challenge the dominant symbolic models in classical AI. Rather than programming machines with abstract representations of the world, Brooks (1986, 1991) argued that robots should construct their own "worldviews" through direct perception-action loops. "The world is its own best model" (Brooks 1990: 5), he famously declared, advocating for embodied, situated intelligence which emerges from interaction rather than computation. This idea finds a compelling cognitive counterpart in the work of Andy Clark (1997), whose book *Being There* marks a pivotal moment in the development of embodied cognitive science. Clark introduces von Uexküll's theory as a biological analogue for decentralized robot architectures, those that operate without a central planner. He emphasizes the importance of niche-dependent sensing as a foundational principle in both biological and artificial agents, echoing von Uexküll's insistence that meaning arises from organism-environment coupling. For Clark, cognition is not merely internal computation, but an extended process involving the brain, the

body, and the environment in dynamic interaction. Robots which adapt to their specific sensory environments, he argues, begin to approximate the kind of situated cognition described by Umwelt theory, though they still lack its full phenomenological depth.

On the other hand, Claus Emmeche, working within the biosemiotic tradition, raised deeper philosophical concerns. For Emmeche (2001), Uexküll's Umwelt is not just a functional interface with the environment, but a lived, phenomenological world shaped by intentionality, bodily affect, and internal purposiveness. From this standpoint, no robot can possess an Umwelt in the full Uexküllian sense, because it lacks the biological grounding and subjective agency that define life. Semiosis is not a process which can be merely installed; it is emergent, embodied, and affect-laden. In contrast to this argumentation, Ricardo Gudwin (1999) proposed a more engineering-oriented reinterpretation of Umwelt, suggesting that any system with sensors and effectors can generate its own internal model of the world. For Gudwin, such models qualify as a type of Umwelt, even if they lack human- or animal-like consciousness. This view supports AI design but risks flattening the qualitative differences between simulation and experience, treating cognition as mere information processing.

Tom Ziemke has further enriched this debate by distinguishing between "simple embodiment", often invoked in robotics to describe physical interaction with the world, and "organismic embodiment," which includes the biological, emotional, and homeostatic dimensions unique to living systems. According to Ziemke (2001a, 2001b), real autonomy and meaning-making cannot arise from mechanical design alone; they require the co-evolutionary integration of an organism within its environment, something that no current robot can authentically replicate. Winfried Nöth (2001, 2003) adds a semiotic dimension to this discussion, arguing that while robots can display perception-action cycles, their meaning-making is always alloreferential, externally defined by programmers, as opposed to the self-referential semiosis of living beings. Robots, therefore, do not interpret signs, they execute functions. Meaning, in this view, is not intrinsic to their operations but assigned from the outside. Most recently, Carlos Vidales and Julio Horta (2024) have proposed a cybersemiotic reframing of Umwelt through the concept of "cryptosemiotics," interpreting Uexküll's functional circle as a generative matrix for the emergence of meaning, not just in biology, but potentially in artificial systems as well. Their approach opens a new theoretical space: one that acknowledges the non-biological mediation of signs while remaining cautious about equating artificial semiosis with lived experience.

The theoretical landscape reveals two broad trajectories. The first views Uexküll's ideas as inspiration for more ecologically grounded and responsive AI systems, emphasizing embodiment, adaptability, and environmental coupling. The second maintains that the Umwelt is inextricable from biological life, serving as a critical standard to evaluate the limits of machine cognition. Between these poles lies a dynamic middle ground, where new hybrid models, combining cybernetic insight with semiotic depth, are still being actively explored. In such a framework, machines cannot possess an Umwelt in the strict sense because they lack this embodied feedback loop. What AI does instead is to operate within technosemiosis. It acts as an interface within human meaning-making systems, extending our cognitive and interpretative capacities without becoming a subject of interpretation itself. This insight does not diminish the value of AI but repositions it. Artificial systems can assist us in modeling, simulating, and even amplifying certain aspects of communication, also across species, but they do so from outside the circle of lived meaning. The Umwelt, as both a biological and semiotic reality, remains anchored in the flesh and orientation of the living.

This distinction carries profound implications for projects like DolphinGemma. AI may be capable of collecting and classifying clicks and whistles, but it cannot access the motivational, affective, social, and environmental horizon within which these sounds hold meaning for the dolphin. To claim to "translate" these signals is to ignore that every Umwelt is untranslatable precisely because it is untransferable. We can construct indirect models of it through epistemic mediations, but we can never inhabit it. As Emmeche (2001: 656–7) aptly reminds us, "our scientific understanding of the sonar system of a bat gives us an indirect and functional picture of the bat's Umwelt, but we cannot enter into that Umwelt itself. All we have is a model in our (linguistic, cognitive, and perceptual) Umwelt of the bat's Umwelt".

The claim of endowing artificial systems with an Umwelt amounts to a functional hypostatization of subjectivity. This risks conflating model with lived experience, simulation with semiosis, and computation with meaning. The epistemological comparison between AI and Umwelt, in light of zoosemiotics, reveals that animal communication cannot be truly understood without first acknowledging the ontological difference (or the similarities) between organism and artifact. AI may indeed contribute to the study of animal communication, but only if integrated within a biosemiotic framework which recognizes its limitations and re-centers the experiential, ecological, and relational dimensions of life.

2.1. Intelligence, Semiosis, and Interfaces: Toward an Extended Semiotics of the Artificial Mind

The classical distinction between artificial and natural intelligence, while useful in technical contexts, risks obscuring the epistemological potential of AI as an extension of the human mind and, more specifically, as a semiotic interface capable of mediating between different forms of life. In this sense, a paradigm shift is urgently needed. The challenge is not merely to compare machine intelligence with that of organisms, but to understand how the two may co-operate within a relational and biosemiotic cognitive horizon.

In a semiotic and biosemiotic framework, the concept of intelligence cannot be understood as a universal, context-free property. Rather, it emerges as a situated process of semiosis, dependent on specific material, relational, and interpretive conditions. Following Joseph Weizenbaum's (1976: 204–205) observation that "intelligence is a meaningless concept in and of itself," unless situated within a "domain of thought and action", we can reconceptualize intelligence not as a singular essence, but as a contextualized capacity for meaning-making. Intelligence, in this view, is not a trait but a practice, a semiotic function exercised differently across species, systems, and artifacts.

This approach resonates deeply with the notion of Umwelt and is extended in biosemiotics. Each organism constructs its own meaningful world through interpretive engagement with signs relevant to its perceptual and effector organs. Intelligence, thus, is not an abstract potentiality but a relational competence embedded in a life-world, a domain-specific configuration of signs, constraints, affordances, and value-laden decisions. Weizenbaum's critique anticipates this logic by rejecting the belief in a culturally-independent "thing" called intelligence and emphasizing instead the social, cultural, and ecological situatedness of intelligent activity.

To analyze intelligence across such domains (whether human, animal, plant, artificial, or collective) requires a multidimensional framework sensitive to its semiotic embedding. From a semiotic perspective, three interrelated dimensions of any domain of intelligence (Attard-Frost 2024: 28-29) can be identified:

Cognitive (or Interpretive) Dimension: intelligence entails the capacity to process, recognize, and respond to signs within a meaningful context. In semiotic terms, this refers to the activity of the interpretant in the Peircean triad. Whether we consider a cephalopod navigating a reef, a neural network classifying images, or a bacterium responding to chemical gradients,

each enacts a form of biosemiosis that connects signal to function (Sharov 2013; Sharov & Vehkavaara 2015). These interpretive acts include pattern recognition, adaptation, anticipatory behavior, memory encoding, and the coordination of action within an Umwelt.

Normative Dimension: intelligence is never value-neutral. Every interpretive act implies a choice (Kull 2018), a selection of one path among many, which is governed by internal norms or external constraints (Deacon 1997). In animal cognition, these norms may be evolutionary (survival, reproduction), social (hierarchy, cooperation), or emotional (fear, attraction). In artificial systems, norms are encoded by designers or emerge through optimization criteria: speed, accuracy, efficiency, or alignment with user goals. Biosemiotically, this dimension expresses the semiotic freedom of a system, the degree to which it can select, modulate, or reinterpret signs in light of its values (Hoffmeyer 2004).

Performative Dimension: intelligence is always enacted, and measured, through performances that are themselves semiotically framed. In human domains, these may take the form of standardized tests or behavioral metrics; in biological systems, they may involve ecological fitness or problem-solving efficiency. In AI, performance is often quantified through benchmarks, but this instrumental logic may obscure the system's embeddedness in human interpretive regimes. A truly critical semiotic analysis must interrogate these criteria, asking not only what is measured, but whose values and purposes the measurements serve.

Together, these dimensions form what could be called a *semiotic ecology of intelligence*: an approach that treats intelligence not as computation, but as an emergent property of sign-processing systems embedded in environments, oriented toward goals, and constrained by both internal norms and external demands.

Let us take, for instance, the case of a language model used in conservation biology to detect patterns in animal vocalizations. Its cognitive dimension includes data ingestion, classification, and correlation of vocal patterns with contexts (e.g., feeding, mating). Its normative dimension is shaped by the ethical commitments of the project: non-invasiveness, respect for animal autonomy, and data transparency. Its performative dimension is structured by benchmarks such as accuracy, interpretability, and potential contribution to species protection. However, a biosemiotic perspective reminds us that such a model does not inhabit the Umwelt of the animal it analyzes. It mediates, approximates, and transforms its communicative acts into human-readable form. Hence, any apparent "translation" is in fact

a transduction, filtered through the ontological gap between symbolic machines and embodied life (Krzanowski & Polak 2022).

Intelligence can be redefined as the semiotic capacity to maintain a meaningful relation to the environment through acts of interpretation, normativity, and situated performance. From this perspective, artificial intelligence does not replicate human cognition or animal communication. It reconfigures the semiotic field within which such relations become thinkable, actionable, and contestable. This calls not only for descriptive clarity but for a critical semiotics of intelligence: one which resists essentialism and embraces the plurality, plasticity, and ethical stakes of intelligence across domains.

As Jesper Hoffmeyer and Kalevi Kull (2003) demonstrated, intelligence cannot be separated from semiosis. It has evolved historically as an interpretive capacity which is situated, corporeally distributed, and directed towards survival. In biosemiotic terms, intelligence is not a computational function but an embodied semiotic competence. It is an inherently relational and contextual ability to read, interpret, and respond to signs in the environment. From this perspective, every living being participates in a form of intelligence which expresses itself through the construction of its own Umwelt, a meaningful and situated world (Uexküll 1940). AI, by contrast (as discussed in the functionalist and behaviorist account offered by Alawijeh and Al-Mesilini (2025)) simulates or reproduces certain cognitive functions without possessing intentionality or intrinsic semantic experience. It seems that due to a lack of embodiment and desire, AI cannot exercise semiotic freedom, understood as the capacity to assign meaning in a creative[8], selective, and context-sensitive way. However, precisely because it is non-living, AI can nevertheless play an epistemological role: not as an autonomous cognitive agent, but as an augmented semiotic instrument, capable of identifying patterns, structures, and regularities in animal communication and organismal behavior[9].

According to the theory of the extended mind (Clark & Chalmers 1998; Heinrichs 2020), artificial devices can be considered integral components

[8] The debate is indeed complex, nuanced, and often contradictory. For this reason, we neither wish nor claim to explore it in depth here. However, we remain convinced that the current proliferation of articles on AI and creativity will, sooner or later, converge toward a clearer position, whether by rearticulating the very notion of creativity, or by revealing that it is a paradigm no longer adequate to contemporary discourse. (See du Sautoy 2019; Hartley, Ibrus, and Ojamaa 2021)

[9] Just as it is currently doing. In fact, the idea of this article is not to criticize the function of AI but the sensationalist interpretation of the results.

of cognitive processes, if they meet the criteria of reliability, procedural transparency, and functional integration. In this framework, AI is not something external to us, but rather a distributed element of our cognitive system. It can become part of our mind insofar as it is embedded within embodied and relational interpretative practices. As Heinrichs (2020) observes, this interface between biological cognition and artificial intelligence gives rise to a new cognitive ontology, hybrid and nested cognitive systems which encompass both the human and the artificial.

This entails a profound epistemological reconfiguration. AI should not be used to literally translate animal communication, but rather to extend our interpretive capacity and make visible aspects of non-human semiosis which would otherwise remain obscure (Delahaye 2021). In order to achieve this, however, a meta-interpretive layer is required, one that reanchors algorithmic processing within an ecological and embodied reading of communication. The perspective of extended semiotics invites us to conceive of AI not as an autonomous mind, but rather as a form of technosemiosis, i.e. a process through which artificial devices become integrated within human cognitive circuits, thus contributing to the co-construction of new meaning-making practices. As emphasized by Nöth (2003), computers are involved in processes of internal "quasi-semiosis", but genuine semiosis is manifested in their function as interfaces between human subjects. It is in this role that technological devices become cognitive and semiotic extensions of the human being. The machine does not interpret, it mediates. It is precisely in this mediating function that it becomes an integral part of a triadic semiotic circuit, making possible the amplification of living interpretive activity.

AI (understood as a semiotic machine) should not be regarded as an entity endowed with autonomous agency, but rather as a distributed node within an embodied and situated cognitive network. Technosemiosis, then, implies a material reciprocity between humans and artifacts, wherein interpretation arises not from the machine itself, but from the differential relationships between the signs it enables. In this context, AI can become an epistemological tool for the co-understanding of life, provided it is embedded within sense-making practices grounded in bodily, social, and environmental experience. Within this framework, AI does not merely simulate intelligence, but functions as a semiotic infrastructure (a plastic mediator that allows us to explore opaque zones of communication, especially in interspecies contexts). Its cooperative potential thus lies in its capacity to amplify human interpretive attention, extending the domain of the Umwelt

through a techno-cognitive mediation which remains anchored in the corporeality and embodied semiotic competencies of living beings.

For this reason, it is only by integrating AI into a biosemiotic model of cognition that we can use it not to replace the interpretive act of the living, but to enhance it. In this way, AI emerges as an ecological and critical tool for approaching (without claiming to fully translate) the communicative logics of other living beings. It is here that semiosis meets technology, and where intelligence, far from being reducible to computation, becomes an embodied practice of relation and listening.

3. The Illusion of Transparency and the Risk of Artificial Rewriting

The growing ambition to build intelligent interfaces capable of "translating" animal communication through artificial intelligence is part of a broader cultural and semiotic tension: the drive to render the radical otherness of living beings transparent and accessible. However, what is commonly presented as "translation" is in fact an operative transformation which structurally alters the semiotic identity of the other, rewriting it in terms of human symbolic affordances and, even more so, according to the operational grammars of machines. This process is not neutral: it is deeply generative of new meanings and realities, as recent contributions in cultural semiotics, biosemiotics, and the philosophy of technology have shown.

In his article "The myth of meaning", Claudio Paolucci (2025) argues that generative AI models are not merely linguistic tools, but cognitive constructs, technical-semiotic extensions which expose the already machinic nature of human thought. These "language-endowed machines," as Paolucci calls them, reveal how human language itself is an assemblage effect, emerging from mediation among enunciators, norms, stereotypes, and discursive habits. However, if this holds true for the human domain[10], what happens when these machines are employed to "give voice" to that which is not human? At this juncture, a decisive ontological difference emerges: AI can produce statements, but it cannot produce enunciation in the Peircean or Benvenistian sense. In the absence of an embodied "who" behind the act, and in the presence only of an algorithm simulating coherence, what is lost is precisely the semiotics of intentionality that characterizes both human language and animal communication.

At the same time, biosemiotician Ľudmila Lacková Bennett, in her recent paper "A Biosemiotic Approach to AI" (2023), develops an original framework for understanding artificial semiosis based on the analogy with

[10] Paolucci's article, in fact, deals with ChatGPT.

protein folding. Drawing on Howard Pattee's and Terrence Deacon's debate on symbol grounding, she proposes folding not only as a biochemical phenomenon but as a minimal semiotic operation, a foundational mechanism for modeling in both organic and artificial systems. In her view, intelligence, whether biological or artificial, should be approached not through computation alone, but through the lens of morphogenesis and structural plasticity. Lacková's model highlights that AI systems, rather than "interpreting" in a Peircean sense, engage in what she calls semiotic folding, a syntactic reconfiguration of inputs which lacks ecological embedding and lived intentionality. Every act of so-called translation by AI is not a neutral decoding of meaning but a folding of signs into an internal logic alien to the organismal world from which they originate. This results in a loss of the affective, performative, and context-sensitive dimensions which characterize animal communication. In short, folding reveals both the modeling potential and the semiotic limitation of artificial intelligence. It shows how AI may simulate the form of interpretation without accessing its ground. Thus, folding becomes a conceptual interface for contrasting digital abstraction with embodied semiosis.

Completing the perspectives examined thus far is the intercultural approach of Massimo Leone, who offers a refined articulation of the relationship with alterity in semiotic terms. In a 2019 essay, Leone identifies three escalating forms of cultural distance: otherness, extraneousness, and unawareness. While the first designates a recognizable alterity within pre-existing cultural codes, the second refers to a deeper form of estrangement which challenges our interpretive frameworks. The third (the most insidious) concerns those forms of difference which remain invisible, and unrecognized as such, because they have been naturalized or erased from our semantic horizons. When applied to the problem of translating animal communication through artificial intelligence, this typology demonstrates its full heuristic potential. AI tends to produce a reduction of animal alterity to a computable form of otherness, something which can be rendered legible in human terms via statistically significant patterns, while maintaining an appearance of fidelity to the source. The animal, in its semiotic complexity, is thus never truly encountered, but rather re-coded within the limits of the linguistic and symbolic output that the machine is capable of generating.

The effect of this operation is not an enhanced understanding, but rather an illusion of proximity. The dolphin (or any other non-human organism) becomes a simulacrum of comprehension, a domesticated alterity, seemingly accessible but in fact simplified to the point of erasing its irreducible

corporeal, temporal, and ethological strangeness. Leone defines this condition as a sophisticated form of cultural unawareness. It is a semiotic ignorance which not only fails to understand the other, but is no longer even capable of recognizing its own misunderstanding.

In his most recent contribution, Leone (2023) extends this diagnosis into a broader reflection on the semiotics of artificial intelligence, arguing that the task of the semiotician today is not merely to denounce the limitations of algorithmic simulation, but to understand AI as a new form of semiotic agency. AI, he suggests, does not produce truth in the classical sense, but rather effects of credibility. It is a rhetorical machine, a symbolic operator which selects, reifies, and structures horizons of meaning based on what it is able to calculate, and thus actively shapes our perception of the world. Leone thereby can be reread in a fruitful dialogue with Paolucci's analysis, which demonstrates how generative AIs function as machines of common sense and stereotypes, as well as with Lacková's approach, which proposes a model of artificial semiosis inspired by the plasticity of folding. Integrating these perspectives, Leone offers a compelling proposal: we should not reject AI as a deceptive simulacrum, but rather employ it as a differential revealer. It is a technology which precisely through its limits, signals what lies beyond computation: the undecidable, the ambiguous, the embodied, the relational.

In this vision, AI can become an ally in the construction of a critical metasemiosis, capable of reorienting our attention toward that which remains opaque, and which, for this very reason, demands to be interrogated. Rather than providing a faithful translation of the living, AI can offer an index of our projections, our biases, and the epistemic blind spots pervading our relationship with animal otherness. It is within this zone of tension that a new *ecotechnical semiotics* might emerge: a practice of differential listening. One which coexists with alterity without absorbing it, and that accepts the untranslatable not as a failure, but as the very condition of any genuine semiotic relation.

This scenario is further reinforced by the concept of the ontological gap: between the internal representation of reality constructed by AI and that generated by living beings lies a radical epistemological rupture. AI does not inhabit the world. It has no biological needs, and does not produce intentional judgments. Consequently, any attempt to make AI "speak" on behalf of non-human life risks generating a synthetic ontology, one that translates but simultaneously erases the semiotic specificity of the other. Only a truly biosemiotic approach on corporeality, environment, intentionality, and purposiveness, can partially bridge this gap. Yet such an ap-

proach necessarily requires abandoning the idea of direct translation and embracing a paradigm of differential mediation.

What we can do, therefore, is not to speak with animals through AI, but to listen and build interfaces which do not translate, but rather multiply the forms of interspecific resonance and attentiveness. Instead of designing AIs which "mimic" or "interpret" animal language in human terms, we might envision interfaces which bend to the rhythm of the living, as in folding. These are not representations, but dynamic semiotic models which allow themselves to be reshaped by contact. In this sense, Lacková's proposal may be read as a biosemiotic pathway towards ecotechnical design: AI not as translators, but as facilitators of encounters capable of receiving alterity without reducing it. The translation of the non-human should not seek equivalence between codes, but rather the construction of zones of contact in which semiosis emerges as a relational event. AI can be useful if it ceases to speak on behalf of other living beings and begins instead to modulate its activity according to a logic of semiotic hospitality. Only in this way can we move from the dream of "deciphering" to the reality of shared listening.

Conclusion

The trajectory outlined in this study has moved from a critique of the ideology of "translating the wild", exemplified by the case of DolphinGemma, to a radical questioning of the epistemological and semiotic viability of representing non-human communicative forms through the infrastructures of artificial intelligence. What is emerging with increasing clarity is that AI cannot be conceived as a neutral bridge between different semiotic worlds, but rather as an actantial device that transforms every form of communication passing through its mesh. Every act of "translation" performed by AI is, in fact, a differential transduction, a production of meaning that necessarily involves a rewriting of the referent.

Yet, as Massimo Leone (2023) suggests, the task of a semiotics of artificial intelligence is not merely to unmask falsehoods, but also to understand the ideological, rhetorical, and material conditions through which AI produces effects of meaning which are credible, authentic, and culturally resonant. AI is not merely a simulation of intelligence: it is a semiotic machine which generates meaningful content according to logics different from those of biological systems. As such, it challenges traditional epistemologies of truth and indexicality, fully inscribing itself within the cultural genealogy of semiotic falsity.

From this perspective, it becomes possible to reconceptualize the relationship between AI and biosemiotics not as an irreducible opposition, but

as a paradoxical alliance. Biosemiotics teaches us that life itself is an interpretive process, a continuous activity of selection, choice, response, and meaning-making. AI, insofar as it lacks an Umwelt, cannot participate in this process in the full sense. Herein lies the space for an innovative theoretical proposal: a form of ecotechnical semiotics which no longer opposes artificiality and life, but instead recognizes in the sensitive mediation of artificial intelligence a potential not for translation, but for attentiveness. Artificial intelligence, in this vision, should not be deployed to "speak with animals," but rather to construct interfaces of resonance and semiotic environments capable of allowing the emergence of relational, ecological, and perceptual patterns that humans and non-humans might co-inhabit. No longer AI as translator, but as a plastic infrastructure that bends – folds, in Lacková's (2023) terms – into the semiosis of the living.

This proposal entails a radical epistemological reconfiguration: not a semiotics of meaning as transfer, but a semiotics of relation as co-emergence. Artificial intelligence, understood through its semiotic architecture, functions as a machine of falsification and learning, it can act as a reflective simulacrum of our relation to alterity (Leone 2023). Rather than seeking equivalence between codes, AI might be used to exercise difference, to generate new semiotic worlds in which understanding is not synonymous with mastery, but with transformative listening.

Biosemiotics, in this context, need not fear artificial intelligence. It must interrogate it, challenge its premises, and analyze its material and rhetorical effects with its own methodologies. If AI is the technological mirror of our desire to understand, then biosemiotics can become the discipline which deconstructs and reconfigures that desire (not to speak for the other, but to learn how to speak with the other). The translation of the wild, so reconceived, is no longer a technological feat, but an ethical imperative: to build the semiotic conditions for encounters that do not collapse difference, but allow it to resonate.

From this critical alliance between AI and biosemiotics, a renewed semiotics may emerge: one in which artificial intelligence, reimagined as a technology of attentional ecology, contributes to the creation of shared perceptual landscapes. In this framework, interspecies communication might cease to be a matter of decoding and become instead a process of co-sensing, of attunement to the resonant frequencies of life which elude symbolic capture. A truly biosemiotic AI would not be designed to speak, but to listen, to be affected, to fold itself into the rhythms of the living, and to serve as a differential interface rather than a linguistic substitute. These are not merely speculative possibilities: they define the horizon of a new paradigm

in which technology no longer translates life into machine-readable terms, but becomes itself part of life's semiotic grammar.

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