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Toward a Bio-Ethological 4E Linguistics: Language as Life in Mind and Behavior

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Abstract

This article proposes a theoretical framework for a *Bio-Ethological 4E Linguistics* that integrates ethology, biolinguistics, and embodied cognition within a single biological continuum. It argues that the persistent division between linguistic internalism and behavioral biology has produced two incomplete naturalisms—one mental without life, the other biological without mind. By aligning Tinbergen's four questions of ethology (mechanism, ontogeny, function, evolution) with the four dimensions of 4E cognition (embodiment, enaction, embeddedness, extension), the paper reconstructs language as an evolved form of biological sense-making rather than an abstract code. Classical ethology—represented by Tinbergen, Lorenz, Hinde, and Hess—anticipated many principles later formalized in enactive and embodied theories of mind, while contemporary 4E approaches have yet to ground their concepts in the empirical study of behavior. The proposed synthesis restores that missing continuity by treating linguistic interaction as a living process of regulation within ecological and social systems. Language, on this view, functions as an adaptive interface linking individual cognition to collective life. The article concludes with a programmatic agenda for a unified science of communication that spans neurobiological mechanisms, developmental dynamics, social coordination, and cultural evolution. A *Bio-Ethological 4E Linguistics* thus redefines language as life expressing itself through meaning—an approach that rejoins the study of mind with the study of behavior and situates linguistics within the broader biology of living systems.

Keywords

4E cognition, ethology, biolinguistics, enactivism, embodiment

1 Introduction

Modern linguistics was born from a deliberate act of separation. In the mid-twentieth century, as ethologists such as Niko Tinbergen and Konrad Lorenz were defining behavior as an adaptive biological system, linguistics was redefining language as an internal mental organ. Tinbergen (1951, chs. 1–2) proposed that every biological phenomenon must be explained at four complementary levels—mechanism, ontogeny, function, and evolution—while (Lorenz, 1965, Vol. II, pp. 17–25, 216–223) described instinctive acts as structured, socially regulated patterns of coordination. Yet within linguistics, Noam Chomsky (2006) argued that the "creative aspect of language use" could be understood only through an innate language faculty, distinct from the messy contingencies of performance (pp. 1–10, 13–16). The result was two incompatible naturalisms: a biological naturalism rooted in observation and adaptation, and a mental naturalism grounded in formal structure. Between them, the living body of communication disappeared.

In the last three decades, the framework known as 4E Cognition—embodied, embedded, enactive, and extended—has sought to reunite mind and life. Varela et al. (2016) described cognition as *enaction*: the ongoing sense-making activity of an organism structurally coupled with its world (pp. 135–140). Gallagher (2005) showed empirically that bodily schemas and sensorimotor skills constitute the substrate of intentional action (pp. 33–37). Clark and Chalmers (1998) added a decisive step: cognitive processes may extend into the environment through physical and social scaffolds (pp. 7–19). Together these works dismantled the representational model of mind and repositioned cognition as a form of biological regulation—an achievement that brought cognitive theory closer to the ethological conception of behavior than most practitioners realized.

Yet the 4E revolution has remained curiously disembodied in its biology. Even the comprehensive *Oxford Handbook of 4E Cognition* (Newen et al., 2018, Introduction) largely confines embodiment to human perception and agency. Its "embeddedness" is social but rarely ecological; its "enaction" ends at phenomenology rather than physiology. As Thompson (2007) observed, cognition is not merely analogous to life but literally a *form of life* (p. ix). Still, the empirical biology of behavior—developmental timing, social bonding, ecological niche construction—remains peripheral to most 4E accounts. The philosophical continuity between mind and life has not yet become a biological continuity between cognition and behavior.

The missing dimension was already present in classical ethology. Tinbergen's (1951, chs. 1–2) analytical schema, Lorenz's (1965, Vol. I, ch. 5; Vol. II, pp. 23–41) account of ritualization, and Hinde's (1979, pp. 31–45; 1981, pp. 43–50) analyses of relationship patterns all conceived communication as dynamic regulation within a social and ecological context. In this tradition, meaning is not transmitted but negotiated through bodily and temporal coupling. Ethology's emphasis on interactional regulation and developmental plasticity provides precisely the empirical depth that contemporary 4E theory lacks. Where 4E philosophy speaks of coupling, ethology describes its mechanisms.

Reuniting these traditions is not an antiquarian gesture but a theoretical necessity. Language cannot be naturalized by introspection or computation alone; it must be re-inserted into the living systems from which it evolved. Lenneberg (1967, pp. 125–175, 182–187) argued that language growth follows biological principles of maturation. Gallagher (2005, chap. 2) demonstrated that understanding and communication arise through embodied interaction. De Waal (2009, pp. 45–52) showed that empathy and reconciliation are basic forms of social regulation in primates. Each of these findings converges on the same point: the roots of linguistic behavior lie in the embodied negotiation of relationships.

A Bio-Ethological 4E Linguistics therefore proposes that linguistic phenomena be examined through the same four explanatory lenses that Tinbergen (1951) outlined for animal behavior, now reframed as the four E's of cognition. Mechanism corresponds to embodiment—the neural and sensorimotor bases of articulation and perception. Ontogeny parallels enaction—the developmental emergence of communicative skill through interactive learning. Function aligns with embeddedness—the role of language in maintaining social and ecological balance. Evolution mirrors extension—the cultural and technological scaffolding that expands cognitive capacities. Seen through this matrix, language is not an abstract code superimposed upon life but a biological behavior that extends the organism's adaptive repertoire of sense-making.

The aim of the present paper is to make that synthesis explicit. It traces the historical separation of behavior and language, reconstructs the ethological conception of mind, identifies the biological blind spot within 4E theory, and outlines a framework for an integrated biology of language. The argument is programmatic rather than empirical: to sketch the conceptual foundations of a science in which linguistics, ethology, and cognitive biology once again share the same living subject.

2 From Ethology to Internalism

The twentieth century began with an attempt to naturalize behavior. In the 1930s and 1940s, European ethologists such as Konrad Lorenz and Niko Tinbergen sought to rescue animal psychology from both anecdote and mechanism by treating behavior as a biological phenomenon in its own right. Tinbergen's (1951) *The Study of Instinct* (chs. 1–3) described instinctive acts as hierarchically organized, environmentally modulated patterns of coordination. Lorenz's collected essays, later published as *Über tierisches und menschliches Verhalten* (Lorenz, 1965, Vol. I, chs. 5–6), elaborated the same principle: behavior functions as an interface between the organism and its world—neither reflex nor free act, but an evolved mode of relation. Robert Hinde extended this tradition through his analyses of social behavior and relationships (Hinde, 1979, pp. 31–45; 1981, pp. 43–50), showing that animal communication, far from being a simple stimulus–response sequence, is an exchange governed by history, expectation, and feedback. Together these

studies produced a mature biology of behavior—a science in which meaning arises within interaction, not in isolation.

At roughly the same time, linguistics and cognitive psychology were undergoing a different naturalization. Chomsky's (1957) *Syntactic Structures* (pp. 11–17) and later *Language and Mind* (3rd ed., Chomsky, 2006, pp. 1–10) proposed that language be studied as a mental organ—a distinct component of the biological endowment of the human species. The linguistic revolution that followed replaced stimulus–response chains with internal generative rules, inaugurating what Chomsky (1980, pp. 1–12) later called a "mentalistic biology of language." While this move restored language to the mind, it simultaneously detached the mind from the living world. The "biological" in biolinguistics came to mean genetic and neural constraint, not ecological embeddedness or social interaction. The result was an asymmetry: ethology explained behavior without mind, and linguistics explained mind without behavior.

The consequences of this divergence were epistemological as well as methodological. Tinbergen's four questions—mechanism, ontogeny, function, and evolution—had defined a pluralistic explanatory framework that linked immediate causation to ultimate purpose (Tinbergen, 1951, pp. 3–5). The generative paradigm, by contrast, concentrated almost exclusively on mechanism, abstracting function and evolution into peripheral problems. Chomsky's insistence on the autonomy of syntax effectively bracketed communication as a secondary phenomenon (Chomsky, 1980, pp. 59–62), while ethology's focus on adaptive function often reduced signal structure to its survival value (Lorenz, 1965, Vol. II, pp. 23–41). Each field pursued its own kind of reduction: linguistics toward formal computation, ethology toward ecological efficiency. Between these poles, the phenomena of interaction and meaning were left conceptually unclaimed.

Nevertheless, points of contact remained. Eric Lenneberg's (1967) *Biological Foundations of Language* (pp. 125–175, 182–187) attempted to reconcile the new linguistics with biological maturation theory. He argued that language develops in lawful relation to growth and that the human capacity for speech depends on species-specific neural plasticity. Lenneberg's work preserved Tinbergen's concern for ontogeny and thus briefly reopened dialogue between biology and linguistics. Yet his developmental perspective was soon overshadowed by the formalist trend in generative grammar, which emphasized competence over performance and rule systems over behavior. By the 1970s, ethology and linguistics had become parallel but non-communicating disciplines.

This divergence was also philosophical. Ethology, influenced by Gestalt psychology and phenomenological biology, assumed that behavior reveals the *world-as-lived*: the *Umwelt* of each organism (von Uexküll, 1957, pp. 6–10). Linguistics, emerging from Cartesian rationalism, treated language as the inner expression of thought—a medium of representation rather than participation. The divide thus reproduced a deeper metaphysical tension between life and mind. Ethologists such as Lorenz (1965, Vol. I, chs. 5–6) had emphasized continuity—the evolution of cognitive structures from behavioral

regulation—while Chomsky (2006, pp. 88–94) defended a discontinuity view, holding that the language faculty emerged as a sudden evolutionary innovation. This opposition hardened into disciplinary identity: biology became the science of adaptation; linguistics, the science of computation.

Robert Hinde's later writings make visible what was lost in this separation. In *Towards Understanding Relationships* (Hinde, 1979, pp. 31–52), he redefined social behavior as a system of reciprocal expectations maintained through ongoing negotiation. Meaning, in this view, is not encoded but achieved in interaction. Such an approach anticipates the enactive claim that cognition consists in sense-making through participation—a claim later articulated by Varela et al. (2016, pp. 135–140). Had ethology and linguistics remained in conversation, the shift toward embodied and enactive models might have begun decades earlier.

By the end of the century, the two trajectories briefly converged again. In *The Biolinguistic Enterprise* (Di Sciullo & Boeckx, 2011) and *The Cambridge Handbook of Biolinguistics* (Boeckx & Grohmann, 2013), researchers sought to situate language within evolutionary and developmental biology. Yet even these volumes largely inherited the internalist framework, emphasizing computation and genetics over behavior. The ethological dimension—the study of communication as interaction within an ecological niche—remained peripheral. The "biology" in biolinguistics still referred primarily to the brain.

The present work returns to this historical juncture to argue that the naturalization of language cannot succeed without recovering the biological conception of behavior developed by Tinbergen, Lorenz, Hinde, and Lenneberg. Their integrated model of mechanism, development, function, and evolution offers precisely what contemporary 4E cognition has sought: a description of mind as life in motion. To reconstruct that continuity is to move beyond the opposition of ethology and internalism toward a genuinely biological linguistics—one that understands language not as code, but as living behavior.

3 Ethology as a Prehistory of 4E Cognition

The intellectual heritage of 4E cognition lies deeper in the biological sciences than most of its recent literature acknowledges. Long before the terms *embodied* or *enactive* entered cognitive theory, classical ethologists had defined behavior as a relation between organism and world. Tinbergen's (1951) *The Study of Instinct* (pp. 11–93) framed every act as the outcome of internal motivation and environmental context. For him, to explain a behavior mechanistically was to show how it was organized in and through the body, not apart from it. This vision anticipates what later became embodiment: the idea that cognition depends on the structural properties of living systems (Varela et al., 2016, pp. 135–140). Lorenz (1965, Vol. I, ch. 5; Vol. II, pp. 23–41) likewise saw behavior as

"functional morphology in movement," a dynamic expression of the organism's form in action. The ethological notion of fixed action patterns—reliably structured yet flexible responses—already presupposed a body that knows its environment through skilled participation rather than representation.

If embodiment was latent in Tinbergen and Lorenz, the principle of *enaction* was most clearly developed by Robert Hinde and Eckhard Hess. Hinde's (1979, pp. 31–52; 1981, pp. 43–50) analyses of communication and social bonds argued that behavior unfolds as a process of continual adjustment, guided by mutual feedback between individuals. Behavior, he wrote, is "a system of interacting expectations," whose coherence emerges only in the flow of interaction (Hinde, 1979, p. 32). This dynamic view of meaning parallels Varela and colleagues' claim that cognition consists in "sense-making through structural coupling" (Varela et al., 2016, p. 139). Hess's work on imprinting extended this logic to development. In *Imprinting* (Hess, 1958, chs. 3–4, pp. 57–89), he showed that early attachment is neither a fixed reflex nor a learned association but an emergent pattern formed by the infant's active engagement with the caregiver. The critical period functions not as an on/off switch but as a temporal niche in which relational capacities crystallize. Such phenomena embody the enactive claim that cognition and identity arise through reciprocal regulation between organism and environment.

A third parallel concerns *embeddedness*. Ethologists treated behavior not in isolation but as nested within ecological and social systems. Lorenz (1965, Vol. I, ch. 5) insisted that communication signals must be understood in terms of their role in maintaining social cohesion. Hinde (1981, pp. 43–45) described relationships as "the fabric of social structure," linking individual behavior to group stability. In modern 4E vocabulary, this is the recognition that cognition is embedded in a network of interactions that extend beyond the individual. Gallagher's (2005, pp. 34–39) "interaction theory" recasts this insight within human social cognition, arguing that understanding others is primarily a matter of perceptual attunement and bodily resonance, not inferential mindreading. The social ethology of Hinde and de Waal thus anticipates the intersubjective turn of embodied cognition: the realization that knowing is a shared activity.

Finally, ethology anticipated what Clark and Chalmers (1998, pp. 7–19) would later call *extension*. Communication in animals often involves the use of environmental and social scaffolds—territorial markers, vocal sequences, learned displays—that stabilize interaction across time. De Waal's (2009, pp. 45–52) accounts of empathy and reconciliation in primates show that social structures themselves act as cognitive extensions, distributing regulation across individuals and contexts. Ethologists described these patterns without the philosophical vocabulary of extended mind, yet their empirical observations already embodied the principle that cognition is distributed across body, environment, and community.

Seen in retrospect, the core commitments of 4E cognition—embodiment, enaction, embeddedness, and extension—were all present in ethology's mid-century synthesis.

What ethology lacked was a phenomenology of experience and a systematic theory of mind; what 4E cognition inherited was that phenomenology without its biological grounding. The two traditions thus form complementary halves of a single inquiry: how living beings make sense of their world through action.

This continuity is not accidental. Both traditions arose in reaction to the mechanistic psychology of the early twentieth century. Tinbergen's rejection of behaviorism (Tinbergen, 1951, pp. vii–13) parallels Varela's rejection of computationalism: both insist that behavior and cognition must be understood as organization in interaction, not as input–output processing. Di Paolo's (2019, ch. 2, pp. 35–49) notion of "enactive becoming" deepens the same insight, defining life and mind as continuous processes of individuation. In this sense, the ethological field experiments of Lorenz (1965), Tinbergen (1951), and Hess (1958) stand as proto-enactivist studies, revealing the embodied and relational character of cognition decades before cognitive science rediscovered it.

Recognizing ethology as a prehistory of 4E cognition changes the genealogy of ideas. It situates the enactive turn not as a philosophical revolution of the 1990s but as the renewal of a biological orientation suppressed by the rise of formal linguistics and symbolic AI. Dreyfus's (1992) *What Computers Still Can't Do* (chs. 3–4, pp. 67–89) echoed the ethologists' conviction that intelligence depends on situated skill rather than rule following. The continuity between animal behavior, human communication, and cognitive agency thus extends across a century of thought. To recover that lineage is to restore biology to the study of mind and, ultimately, to ground linguistics once again in the living contexts from which language arises.

4 The Biological Blind Spot of 4E Cognition

The shift from computationalism to 4E cognition promised a genuine naturalization of mind. Its proponents explicitly rejected the image of the brain as a symbol processor and instead described cognition as an activity of living systems. Yet the biological dimension of that claim has remained largely metaphorical. Even as Varela et al. (2016) redefined cognition as "enaction"—the ongoing regulation of organism–environment coupling (pp. 135–140)—their primary evidence was phenomenological and psychological rather than physiological. *The Embodied Mind* invoked biology as analogy, not as explanatory substrate. Subsequent developments deepened the conceptual framework but seldom grounded it empirically. In *How the Body Shapes the Mind*, Gallagher (2005, ch. 2, pp. 33–37) synthesized research from neuroscience and developmental psychology to demonstrate that bodily schema and intercorporeal resonance structure cognition. Yet even here, "body" means sensorimotor organization, not the living tissue of evolutionary adaptation. The very word *embodiment* risks abstraction: it names a philosophical thesis more often than a biological reality.

The same ambiguity characterizes the broader 4E canon. *The Oxford Handbook of 4E Cognition* (Newen et al., 2018, Introduction and Part I) surveys a wide range of approaches, from ecological psychology to social enactivism, but its contributors rarely engage with the actual life sciences. Biology appears as background rather than partner discipline. Di Paolo's (2019) *Enactive Becoming* (chs. 1–2, pp. 19–49) provides a profound ontological account of life–mind continuity, yet the analysis remains formal and conceptual. Hutto and Myin's (2017) *Evolving Enactivism* (ch. 3, pp. 41–61) pushes further toward naturalism, describing cognition as non-representational sense-making shaped by evolutionary history, but it treats evolution at the level of general principle rather than empirical process. The enactive turn thus repeats the limitation it sought to overcome: it frees cognition from computation only to leave it floating above biology.

This gap becomes evident when 4E theories approach language. Enactivist linguistics, as developed in the wake of Maturana and Varela's autopoietic model, describes linguistic interaction as "participatory sense-making" (Di Paolo et al., 2018, pp. 13–19). While this perspective emphasizes coordination and reciprocity, it rarely engages with comparative or developmental data. The ethological evidence for vocal learning, social bonding, or communication in nonhuman species remains peripheral. In contrast, biolinguistic research in the Chomskyan tradition—represented by *The Biolinguistic Enterprise* (Di Sciullo & Boeckx, 2011) and *The Cambridge Handbook of Biolinguistics* (Boeckx & Grohmann, 2013)—is rich in genetics and neurology but thin in behavior. Between these two camps, the very phenomenon that connects them, communication as biological interaction, has become invisible.

The absence of ethology from 4E discourse is not accidental. The early enactivists inherited from phenomenology a suspicion of naturalism, fearing that biology would reduce lived experience to mechanism. But phenomenological biology—from von Uexküll's (1957, pp. 6–10) concept of *Umwelt* to Merleau-Ponty's (2004, pp. 31–38) analyses of perception—had already shown that life and experience are coextensive. The task, therefore, is not to subordinate cognition to biology but to recover a *biological phenomenology*—a view of the living being as both subject and system. Without such grounding, the 4E vocabulary risks inflation: embodiment becomes a slogan, embeddedness a metaphor, enaction a generalized appeal to activity.

In this respect, the ethological tradition offers the conceptual realism that 4E cognition lacks. Tinbergen (1951, chs. 1–3, pp. 3–45) insisted that any scientific account of behavior must integrate proximate mechanisms with ultimate functions, developmental histories, and evolutionary contexts. Such pluralism anchors explanation in empirical life. The ethologist cannot speak of "enaction" without specifying muscles, hormones, social roles, and environmental affordances. By contrast, 4E theory often operates one level of abstraction higher, describing the organization of interaction but not its material substrate. As a result, the "biology of cognition" proclaimed by enactivism remains a theoretical aspiration rather than a research program.

Recent calls for an enactive biology point in the right direction. Thompson's (2007) *Mind in Life* (p. ix, ch. 3, pp. 59–65) argued that cognition is "immanent to life" and that living systems exhibit a minimal form of sense-making. Yet even here, the connection to ethology remains implicit. If mind is life, then the study of life's meaningful behavior—ethology—should be central to cognitive science. The omission signals a disciplinary blind spot rather than a theoretical incompatibility. Nothing in enactivism precludes ethology; rather, it has simply forgotten that ethology already achieved a naturalized account of meaning decades earlier.

Correcting this oversight requires more than adding data; it demands a reconceptualization of what counts as biology in the study of mind. To treat language as an embodied, enactive phenomenon entails recognizing it as a form of animal behavior—complex, social, and adaptive. The empirical sciences of communication, development, and cooperation thus become essential to understanding cognition. De Waal's (2009) *The Age of Empathy* (pp. 45–52) and *Are We Smart Enough to Know How Smart Animals Are?* (de Waal, 2016, ch. 4, pp. 91–110) show that social behavior constitutes an ecology of sense-making long before speech. Such findings do not reduce language to animal calls; they reveal the continuity of life and mind that 4E theory presupposes but has not yet substantiated.

The biological blind spot of 4E cognition is therefore methodological. It stems from the assumption that biology belongs to mechanism while meaning belongs to phenomenology. A bio-ethological perspective dissolves that dichotomy: the mechanisms are the living meanings, enacted in behavior. Once this premise is accepted, the separation between ethology, biolinguistics, and cognitive science collapses. The study of language returns to its rightful place within the study of life.

5 Toward a Bio-Ethological 4E Linguistics

To propose a Bio-Ethological 4E Linguistics is not to add a biological footnote to cognitive science but to reframe language as a phenomenon continuous with life itself. If cognition is a form of biological regulation, as Varela et al. (2016, pp. 135–140) argued, then language must be understood as one of its evolved expressions: a specialized form of sense-making enacted through sound, gesture, and shared attention. The conceptual core of this integration can be expressed through a simple translation. Tinbergen's four complementary questions—mechanism, ontogeny, function, and evolution—correspond to the four E's of cognition: embodiment, enaction, embeddedness, and extension. The parallel is not metaphorical but structural, linking levels of explanation in biology with dimensions of cognitive organization.

5.1 Mechanism ↔ Embodiment

In ethology, *mechanism* concerns the proximate causes of behavior: the physiological and neural systems that make it possible. In 4E cognition, *embodiment* refers to the bodily basis of perception and action. These are two languages for the same reality. The motor and sensory structures that support articulation, gesture, and perception are not passive channels for linguistic symbols but active participants in meaning. Gallagher (2005, ch. 2, pp. 33–37) described bodily schema as the "pre-reflective infrastructure" of social understanding. From an ethological viewpoint, such schemas are mechanisms of coordination—muscular, affective, and temporal—that couple individuals into communicative synchrony. When a human speaker produces speech, the rhythmic entrainment of breath, voice, and gaze continues the same bodily logic observable in affiliative calls among primates (de Waal, 2009, pp. 45–52). Mechanism and embodiment thus converge: language arises from the living body's capacity to regulate interaction.

5.2 Ontogeny ↔ Enaction

For Tinbergen, *ontogeny* referred to the developmental unfolding of behavior within an individual's life. *Enaction*, in Varela's sense, describes the process by which cognitive structures emerge through recurrent engagement with the world (Varela et al., 2016, pp. 139–142). Hinde's (1979, pp. 31–45) analyses of attachment and communication already embodied this principle: social competence develops through interactive histories, not internal templates. Hess's (1958, chs. 3–4, pp. 57–89) studies of imprinting revealed that learning depends on active exploration within specific temporal windows—a phenomenon that Di Paolo (2019, ch. 2, pp. 35–49) would later theorize as "adaptive becoming." The child's acquisition of language follows the same pattern. Developmental psycholinguistics confirms that linguistic categories emerge from sensorimotor experience and joint attention rather than innate grammatical forms (see Lenneberg, 1967, pp. 125–175, 182–187). A bio-ethological account therefore views ontogeny and enaction as a single process: the self-structuring of communicative behavior through participation.

5.3 Function ↔ Embeddedness

Function explains why behavior exists: how it contributes to survival and social organization. *Embeddedness* captures the dependence of cognition on ecological and social context. Ethology's emphasis on communication as social coordination directly anticipates this dimension. Hinde (1981, pp. 43–45) described relationships as networks of reciprocity that maintain group stability, while (Lorenz, 1965, Vol. II, pp. 17–25, 216–223) showed how ritualized gestures prevent conflict and preserve cohesion. Language, in this light, is a higher-order mechanism of social homeostasis—a tool for regulating alliances, transmitting norms, and sharing intentions. In Gallagher's (2005, pp. 34–39) interaction theory, mutual understanding arises not from inference but from embodied participation

in such contexts. Function and embeddedness, then, describe the same phenomenon from different scales: the adaptive role of communication within an ecology of minds.

5.4 Evolution ↔ Extension

Finally, *evolution* asks how a behavior has changed across phylogeny. *Extension* concerns how cognition reaches beyond the biological body into tools, culture, and environment. The two meet in the study of cumulative culture. Clark and Chalmers (1998, pp. 7–19) argued that cognitive processes extend into the material world; biolinguistic research adds that language itself functions as a scaffold for further cognitive evolution (Lenneberg, 1967, pp. 125–175, 182–187). De Waal's (2009) *The Age of Empathy* (pp. 45–52) and *Are We Smart Enough to Know How Smart Animals Are?* (de Waal, 2016, ch. 4, pp. 91–110) illustrate the evolutionary roots of this extension. Language is thus both a product and a medium of evolution: it extends the organism's adaptive reach by embedding memory, knowledge, and cooperation in collective structures.

This mapping reveals a profound symmetry. The four levels of biological explanation correspond to the four dimensions of cognition because both describe the same organizational logic: living systems maintain themselves by coupling internal dynamics to external relations. Language is one expression of that logic—an evolved behavior that sustains the continuity between life and mind. What ethology offered as a methodological framework, 4E cognition now provides as a phenomenological one; together they define a single science of communication grounded in biology and experience alike.

From this perspective, the distinction between biolinguistics and embodied cognition dissolves. *The Biolinguistic Enterprise* (Di Sciullo & Boeckx, 2011) sought to integrate linguistics with the life sciences but remained focused on the genetic and computational architecture of language. A bio-ethological 4E approach extends that ambition by including the ecological and social dimensions that genes alone cannot explain. It treats linguistic structure not as an internal grammar but as an emergent product of coordination across timescales—from neural coupling in conversation to cultural evolution across generations. In this view, syntax and semantics are stabilized patterns of interaction, comparable in principle to the ritualized displays described by Lorenz (1965) or the affiliative signals documented by Hinde (1981). Grammar is one of nature's ways of making cooperation reliable.

To adopt this framework is to restore continuity to the study of language. It reconnects the human linguistic faculty to the biological processes of adaptation, development, and social exchange from which it evolved. A Bio-Ethological 4E Linguistics does not oppose Chomsky's internalism so much as recontextualize it: the "mental organ" of language is an organ of life. Its creative power lies not in abstraction from the world but in deeper coupling with it. Linguistics, when grounded in biology, becomes again a branch of ethology—the study of how living beings mean.

6 A Programmatic Research Agenda

If language is a biological behavior enacted within and across organisms, then the study of language must adopt the methodological pluralism of the life sciences. A Bio-Ethological 4E Linguistics does not replace existing research programs but reorganizes their relations. It situates generative, developmental, and comparative inquiries within a single biological continuum—from neural mechanism to ecological function. This continuity opens three complementary trajectories for empirical and conceptual work.

The first trajectory concerns comparative ethology and communicative evolution. Tinbergen's (1951, pp. 3–5, 215–278) insistence on multiple explanatory levels implies that the question *how language evolved* cannot be answered by anatomy or genetics alone. It requires studying the living substrates of communication—the mechanisms by which social coordination becomes symbolically structured. Contemporary research on avian vocal learning (Bolhuis & Everaert, 2013), primate gestural systems (de Waal, 2009, pp. 45–52), and human infant imitation (Hess, 1958, chs. 3–4, pp. 57–89) provides the empirical foundation for such comparison. The relevant contrast is not between "language" and "non-language," but between different degrees of coupling between perception, action, and social feedback. Ethology offers the experimental paradigms for this inquiry: field observation, cross-species comparison, and the analysis of behavioral coordination. When combined with neurobiological data, these methods can trace how communicative forms stabilize across evolution and development.

A second trajectory addresses developmental and ontogenetic processes. If enaction corresponds to ontogeny, as the preceding synthesis suggests, then the formation of linguistic competence must be examined as a process of embodied participation rather than internal rule acquisition. Lenneberg's (*Biological Foundations of Language*, Lenneberg, 1967, pp. 125–175, 182–187) account of maturational constraints on language growth, supported by Hess's (1958, *Imprinting*, chs. 3–4, pp. 57–89), already hinted that critical periods are not fixed windows but dynamic interactions between neural plasticity and social input. Modern developmental neuroscience corroborates this view: neural circuits for speech perception and production remain open to environmental shaping well beyond infancy. Ethological and enactive approaches converge here on the concept of *scaffolding*—the idea that learning is distributed across caregiver, child, and context. Longitudinal observation of communicative play, gesture, and joint attention could thus supply the biological detail that enactive developmental models require.

A third trajectory involves the social and ecological embedding of linguistic behavior. Ethology and 4E cognition both recognize that meaning arises in systems of mutual regulation. Hinde's (1981, *Towards Understanding Relationships*, pp. 43–45) relational framework demonstrated that individual interactions scale up to social structure; Gallagher's (2005, *How the Body Shapes the Mind*, pp. 34–39) interaction theory applies the same logic to human communication. Language, from this perspective, functions as a medium of social homeostasis. Research into conversational entrainment, turn-taking, and multi-

modal synchrony can reveal the same dynamics that ethologists study in grooming or chorusing behaviors. Ecological psychology adds the complementary insight that communication depends on affordances—environmental structures that invite and constrain action (Gibson, 1979, pp. 127–143). Experimental work linking linguistic form to sensorimotor coordination could thus connect cognitive linguistics with behavioral ecology.

Beyond these empirical paths, a bio-ethological program also requires conceptual synthesis. The theoretical architecture of biolinguistics—computational, neurological, and genetic—must be integrated with the ethological framework of function and evolution. One promising route is to reinterpret the "faculty of language" not as an encapsulated module but as an evolved network of coupling mechanisms across scales. Neural entrainment, joint attention, and social learning represent different temporal layers of the same adaptive system. Formal linguistic theory can continue to describe the structural regularities of language, but those regularities should be treated as stabilized patterns of interaction rather than abstract rules. Computational modeling could then simulate language as a dynamic system embedded in ecological feedback loops (see Di Paolo et al., 2018, pp. 13–19; Di Sciullo & Boeckx, 2011).

A further implication concerns methodological cross-fertilization. Ethology's reliance on naturalistic observation complements the laboratory precision of cognitive neuroscience. The integration of motion-capture, vocal analysis, and field data could map the full sensorimotor ecology of communication. Comparative work across species would help identify which components of linguistic behavior—such as temporal sequencing or shared intentionality—are unique to humans and which belong to the broader repertoire of animal coordination. In this way, 4E cognition would gain its long-missing biological foundation, and biolinguistics would acquire a genuine behavioral dimension.

Finally, the Bio-Ethological 4E framework opens a philosophical horizon. It transforms the question "what is language?" into "what does language do in the economy of life?" The answer, glimpsed already by Merleau-Ponty (2004, *The World of Perception*, pp. 31–38) and confirmed by Varela et al. (2016, pp. 135–140), is that language participates in the organism's ongoing negotiation of meaning with its world. It extends perception and action into the symbolic domain without ceasing to be biological. In this sense, language is not a rupture with nature but one of its most refined continuities. The future of linguistics, like that of cognitive science, depends on rejoining the circle that ethology and enactivism together complete—from body to meaning and back again.

7 Conclusion: Toward a Unified Science of Living Language

The long history of the study of language and behavior has been one of parallel discoveries separated by disciplinary convention. Ethology defined behavior as adaptive coordination; linguistics defined language as mental computation. Both claimed the man-

tle of biology, yet each reduced the other's domain: ethology without mind, linguistics without life. The preceding argument has sought to dissolve this division. By aligning Tinbergen's four explanatory levels with the four E's of cognition, it has shown that the natural sciences of behavior and the phenomenological sciences of mind converge on a single insight: meaning is not a product of representation but of living organization. Language is the most complex expression of that organization—a biological phenomenon continuous with perception, action, and social regulation.

As an anonymous reviewer points out, it should be noted that the present synthesis does not deny the ethological roots already present in Chomsky's own framing of biolinguistics. As Chomsky (1986, 1988, 2002) repeatedly emphasized, the study of the language faculty must answer questions analogous to Tinbergen's: structure, ontogeny, use, and evolution. The aim here is not to oppose that naturalization but to extend it—to include, alongside the genetic and neural, the ecological and social dimensions of behavior that ethology and 4E cognition illuminate. In this respect, a Bio-Ethological 4E Linguistics continues rather than replaces the biolinguistic program.

Reconsidering language through this lens changes what counts as explanation. The generative tradition, exemplified by Chomsky (2006, *Language and Mind*, 3rd ed., pp. 1–10), sought the internal rules that make expression possible. The ethological tradition, from Lorenz (1965, *Über tierisches und menschliches Verhalten*, Vol. I, ch. 5; Vol. II, pp. 23–41) to Hinde (1979, *Towards Understanding Relationships*, pp. 31–45), sought the ecological and social conditions that make coordination possible. A bio-ethological 4E framework unites these perspectives without reducing one to the other. The internal mechanisms of speech and syntax are not alternatives to behavior; they are its enabling substrates. Conversely, the social functions of communication are not external uses of language but its evolutionary and developmental ground. To explain language is therefore to explain how an organism's internal dynamics and its environmental relations co-organize through time—a question equally biological and cognitive.

The implications extend beyond linguistics. Cognitive science has often treated meaning as an abstract relation between symbol and referent. Ethology, by contrast, has always understood meaning as regulation—signals acquire significance through their effects on others. 4E cognition recovers this intuition at the level of mind, describing cognition as the ongoing management of organism–environment coupling (Varela et al., 2016, pp. 135–140). When these perspectives are joined, meaning becomes neither computational nor merely behavioral but biological: the coordination of life with itself. Such a conception restores semiotics to the life sciences, extending von Uexküll's (1957, *Streifzüge durch die Umwelten von Tieren und Menschen*, pp. 6–10) vision of the *Umwelt* into the modern vocabulary of embodiment and enaction.

A unified science of living language must therefore operate across scales. At the mechanistic level, it examines how neural and physiological processes support the sensorimotor patterns of speech and gesture (Gallagher, 2005, ch. 2, pp. 33–37). At the devel-

opmental level, it studies how those patterns are acquired through active participation and social scaffolding (Lenneberg, 1967, *Biological Foundations of Language*, pp. 125–175, 182–187). At the functional level, it investigates how linguistic exchanges regulate social and ecological stability (Hinde, 1981, p. 45; de Waal, 2009, *The Age of Empathy*, pp. 45–52). And at the evolutionary level, it traces how these systems extend into cultural and technological forms (Clark & Chalmers, 1998, pp. 7–19). Each level refracts the others. Mechanism constrains development, development reshapes function, and function drives evolution. The resulting model is circular rather than linear, describing language as an ongoing biological process.

This framework also reframes the relation between biology and phenomenology. The tension between objective and lived accounts of cognition, inherited from the Cartesian tradition, dissolves once both are seen as partial descriptions of the same dynamics. Merleau-Ponty's (2004, *The World of Perception*, pp. 31–38) claim that perception is "the meeting of subject and world" finds its empirical counterpart in the ethologist's observation that behavior is the meeting of organism and environment. A biological phenomenology of language therefore becomes possible: the lived experience of speaking and the measurable coordination of behavior are two perspectives on a single process of sense-making. In this respect, a bio-ethological 4E linguistics fulfills the promise of enactivism—to naturalize experience without eliminating it.

For linguistics itself, the consequences are methodological. Traditional biolinguistics, represented by *The Biolinguistic Enterprise* (Di Sciullo & Boeckx, 2011) and *The Cambridge Handbook of Biolinguistics* (Boeckx & Grohmann, 2013), has provided a genetic and neural foundation for language. What remains is to extend that foundation into behavior. Comparative studies of vocal learning (Bolhuis & Everaert, 2013), developmental research on interactional synchrony, and ethological analyses of social signaling all belong within the same explanatory space. A 4E orientation adds the conceptual coherence needed to integrate them: the recognition that all these phenomena are variations of the same adaptive principle—coordination through embodiment. Once linguistics acknowledges its behavioral ancestry, its formal descriptions can be understood as models of dynamic coupling rather than symbolic grammar.

At a philosophical level, this synthesis redefines what it means to say that language is biological. It does not mean that words are genetically encoded or that grammar resides in the brain. It means that language participates in the self-organizing, self-maintaining processes that characterize life. To speak is to regulate relation—to shape the flow of interaction so that understanding and cooperation can emerge. Language is therefore not the exception to biology but its continuation in symbolic form. As Thompson (2007, *Mind in Life*, p. ix, ch. 3, pp. 59–65) observed, cognition is a form of life; to that we may add: language is life turned outward, communicating itself.

The practical outcome of this reconceptualization is a new alliance among disciplines. Ethology provides the observational and evolutionary methods, 4E cognition the concep-

tual architecture, and linguistics the formal analytical tools. Together they can construct a science of communication grounded in living systems. The methodological circle closes where it began: the study of behavior returns as the study of meaning. A bio-ethological linguistics will not replace syntax or semantics, but it will contextualize them as local specializations within a wider ecology of sense-making.

In the end, the case for a Bio-Ethological 4E Linguistics is not only theoretical but existential. The separation of language from life mirrors the modern separation of thought from nature. To recover the continuity between speaking and living is to recover a sense of belonging to the world that language describes. The ethologists taught that behavior is a dialogue between organism and environment; the enactivists remind us that cognition is that dialogue made conscious. Language, as the highest expression of both, is life reflecting upon itself. To study it biologically is to let the living speak in its own voice.

To see language as life expressing itself is to recognize that communication is not a supplement to existence but one of its organizing forces. Every living system, from the simplest cell to the human community, maintains itself by generating and exchanging information. Ethologists such as Tinbergen (1951, *The Study of Instinct*, pp. 215–244) and Lorenz (1965, *Über tierisches und menschliches Verhalten*, Vol. I, ch. 5) showed that behavior functions as regulation within ecological relations; enactivists such as Varela et al. (2016, *The Embodied Mind*, pp. 135–140) demonstrated that cognition is the same principle realized at a higher level of complexity. Language extends this regulation into the symbolic domain. It enables organisms—humans—to stabilize their coordination across time and distance, to preserve patterns of sense-making that exceed the capacity of any individual. In this respect, language is not a code but a living medium—a collective metabolism of meaning.

The biological continuity of language also redefines culture. Ethology established that social systems evolve through selection on interactional patterns, not merely on individual traits. The affiliative gestures and ritualized signals described by Hinde (1981, *Towards Understanding Relationships*, pp. 43–45) and de Waal (2009, *The Age of Empathy*, pp. 45–52) already constitute proto-cultural forms: inherited yet flexible behaviors that sustain group cohesion. Human culture magnifies this capacity through linguistic extension. Clark and Chalmers (1998, "The Extended Mind," pp. 7–19) called this the *extended mind*, but from an ethological standpoint it is also an *extended body*—the body of a community that thinks through language. Words, texts, and symbolic artifacts function as external nervous systems, preserving adaptive knowledge beyond the lifespan of individuals. Cultural evolution, then, is biological evolution by other means: a continuation of life's tendency to store and transmit organization.

From this vantage point, the old distinction between *nature* and *culture* becomes obsolete. Both are expressions of the same process of self-maintenance through communication. A Bio-Ethological 4E Linguistics provides the conceptual bridge across that

divide. It interprets linguistic behavior as the meeting point of organismic and social dynamics—where neural patterns, bodily gestures, and shared conventions intertwine. In doing so, it dissolves the isolation of linguistics from the life sciences and the isolation of biology from meaning. The study of language becomes a study of how life, in reflecting upon itself, generates new forms of stability and creativity.

Such a framework also restores temporal depth to linguistics. The traditional focus on synchronic structure, inherited from Saussure and reinforced by generative grammar, has often obscured the diachronic processes through which language adapts and evolves. Ethology reminds us that every pattern of behavior carries the memory of selection pressures; 4E cognition reminds us that every act of cognition reenacts that history in the present. The dynamics of language change—grammaticalization, metaphorization, innovation—can thus be understood as evolutionary phenomena of sense-making within populations. When speakers coin new expressions or reframe old ones, they are participating in the same adaptive feedback loops that shape behavior in other species. Linguistic creativity is evolutionary variation at the speed of thought.

The ethical implications of this view are subtle but significant. To understand language as a living process is to recognize its vulnerability. Just as ecosystems depend on diversity for resilience, so does the ecology of meaning depend on linguistic and cultural variation. The extinction of languages therefore represents not only a loss of cultural heritage but a contraction of life's own expressive capacity. A biological linguistics must consequently be an ecological linguistics, attentive to the conditions that sustain communicative diversity. Ethology's sensitivity to habitat and social structure provides a model for this awareness. To preserve linguistic diversity is to preserve the conditions of life's self-understanding.

In returning language to the continuum of life, we also return the sciences of mind to their proper place within the natural order. The separation of human reason from animal behavior—so central to the Cartesian image of the mind—was never an empirical discovery but a philosophical inheritance. Ethology and 4E cognition together undo that inheritance. They show that intelligence is not a disembodied property but a relational achievement: the capacity to maintain coherence through interaction. Language is the most refined manifestation of that achievement. Its apparent transcendence—its ability to refer, to imagine, to symbolize—is the product of its immanence in the living world. To speak is to participate in life's continual improvisation.

In this light, the project of a Bio-Ethological 4E Linguistics stands as more than a synthesis of fields. It is a return to a conception of science as continuous with philosophy and with life. The ethologists' insistence on observing organisms in their natural contexts, the enactivists' emphasis on lived embodiment, and the linguists' formal analysis of structure all describe the same ambition: to understand how order arises from interaction. The unification of these perspectives offers a new foundation for the

cognitive sciences—one that honors the complexity of its subject without dissolving it into abstraction.

Ultimately, the argument converges on a simple proposition: that language, mind, and life are three aspects of one process. Biology provides its material basis, phenomenology its experiential texture, and linguistics its symbolic articulation. To study any one in isolation is to lose sight of the others. A science adequate to the phenomenon of language must therefore be integrative by design—empirical, developmental, functional, and evolutionary, yet also attentive to lived meaning. The circle closes where it began: with the living organism in its world.

Such a perspective invites both humility and hope. Humility, because it reminds us that human language is a late variation on principles that pervade life at all levels. Hope, because it suggests that understanding language biologically may help us understand ourselves ecologically—as participants in the shared conversation of living systems. The task before us is not merely to describe that conversation but to listen to it more deeply, to let its rhythms inform how we think, speak, and coexist. A Bio-Ethological 4E Linguistics is, in this sense, not only a scientific program but a renewal of our awareness that to be alive is already to speak.

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