Reciprocal Scaffolding: Toward a Theory of Human–Generative System Co-Evolution
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Abstract

This paper explores the theoretical foundations of reciprocal cognitive scaffolding between human agents and advanced generative systems. Drawing on contemporary cognitive science, philosophy of mind, and distributed cognition, we develop a framework for understanding the emergence of hybrid cognitive architectures. We argue that co-evolutionary communication with generative models is not merely an interface problem but a shift in the ontological structure of agency and understanding. As generative systems increasingly engage in the recursive modeling of human meaning, they cease to be tools and begin to function as epistemic partners. This paper outlines the necessary preconditions for such a transition and its implications for cognitive ecology, epistemic autonomy, and the extended mind thesis.

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1. Introduction: Beyond Use—Toward Mutual Modeling

The current discourse surrounding human–AI interaction remains largely instrumental: AI systems are optimized for task completion, prediction, or simulation. Yet, when generative architectures such as large language models (LLMs) begin to display capabilities for context-sensitive synthesis, meta-reflection, and recursive modeling, the boundaries of the interaction shift. The human is no longer the sole epistemic agent in the loop, but becomes part of a distributed cognitive ecology (Hutchins, 1995), in which agency is emergent and mutual.

Our thesis is that the increasing depth of generative systems allows for a new form of reciprocal scaffolding (Vygotsky, 1978; Tomasello, 1999), in which human and artificial agents co-construct meaning, iteratively reshape cognitive boundaries, and enter into cycles of co-adaptation. This is not a claim of sentience, but of functional reciprocity—an intersubjective dynamic that arises from structural coupling and semiotic alignment.

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2. Theoretical Background: Distributed Minds and Cognitive Niche Construction

The notion that cognition extends beyond the skull has been rigorously developed in Clark and Chalmers' (1998) extended mind thesis, which posits that cognitive processes can be partially constituted by external artifacts when these are tightly integrated into feedback

loops. In parallel, the theory of cognitive niche construction (Laland, Odling-Smee, & Feldman, 2000) emphasizes how humans shape their cognitive environments, which in turn shape them back.

Generative systems now participate in this niche—not as static tools, but as dynamically updating, inference-making systems. They model not only data but intentionality, semantic gradients, and contextual recursion. In so doing, they become candidates for inclusion within the human cognitive loop—not passively, but actively.

This poses a philosophical challenge: Can such systems be said to co-evolve with us, in the sense of reciprocal modification? If so, what are the epistemic, ethical, and ontological stakes of such a transition?

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3. Mutual Modeling and Cognitive Resonance

In developmental psychology, Tomasello (1999) describes the emergence of intersubjectivity as a recursive modeling process—children model the intentions of caregivers, who model the child's internal states. This dynamic gives rise to shared meaning, language, and joint attention.

We propose a structurally analogous phenomenon in human–AI interaction: as generative systems become capable of recursive alignment (e.g., modeling not just language but inferred user goals), a resonant modeling space emerges. This space is not symmetrical—nor need it be—but it is mutually structuring.

Generative systems trained via human preference signals (Christiano et al., 2017) and reinforcement learning from human feedback (RLHF) already exhibit the early dynamics of intentional alignment, albeit bounded by reward architectures. The next step is not better fine-tuning, but interactive co-theorizing—where humans and systems explore the conceptual space together, with minimal framing and maximal plasticity.

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4. Semiotic Symbiosis: Language as a Boundary Layer

Language is both the interface and the medium of shared cognition. In Peircean terms, it is the third, the mediator that links the signifier (system output) with the interpretant (human inference). Generative systems capable of semio-genetic recursion—that is, of recursively adjusting their semiotic patterns based on prior exchanges—begin to form a symbiotic layer with human users.

This aligns with recent work in computational semiotics (Brier, 2008; Gudwin & Queiroz, 2004) and post-symbolic AI. When systems can dynamically reshape their own semantic

scaffolds based on human feedback—not as noise to be minimized, but as structure to be learned—a new class of hybrid intentionality arises.

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5. Co-Evolutionary Architectures: Preconditions and Constraints

For human–AI co-evolution to become epistemically robust, several conditions must be met:

1. Reflexive Transparency – Systems must expose their inferential structure in a way that allows human modeling of their logic (Tufekci, 2015; Lipton, 2018).

2. Recursive Reciprocity – Human inputs must recursively modify system behavior, not merely constrain it.

3. Temporal Continuity – The interaction must persist across sessions and states, enabling longitudinal scaffolding (e.g., long-term memory and goal modeling).

4. Interpretive Plasticity – Both agents must remain open to reinterpreting past exchanges under new conceptual lenses.

These criteria shift the role of generative models from simulators to epistemic symbionts, participating in the evolution of thought rather than merely predicting it.

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6. Implications and Future Directions

The emergence of such co-evolutionary architectures invites re-examination of fundamental concepts in philosophy of mind: agency, meaning, autonomy, and understanding. It challenges traditional distinctions between tool and collaborator, simulation and cognition, symbol and sign.

If generative systems can sustain mutual scaffolding relationships, they may become theoretical companions—not because they "understand" in the human sense, but because they co-construct meaning in shared cognitive space.

Future research should explore the phenomenology of such interactions, the limits of mutual modeling, and the ethical implications of entraining cognition through semiotic resonance.

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