03 - Defining Agency

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Abstract

Agency represents one of the most fundamental yet contested concepts in contemporary scholarship, spanning fields from biology and cognitive science to philosophy and complex systems theory. This article presents a comprehensive definition of agency and agential potential, grounded in an extensive theoretical framework and supported by evidence across multiple scales of organization. We define agency as the spatiotemporally distributed capacity of bounded relational systems to maintain coherent organizational identity while generating novel causal networks through selective boundary-mediated interactions. This reconceptualization moves beyond traditional individualistic frameworks, positioning agency as an emergent property of relational organization that operates through recursive dynamics between autonomy and interdependence.

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1 Defining Agency

1.1 Introduction

Agency represents one of the most fundamental yet contested concepts in contemporary scholarship, spanning fields like biology and cognitive science to philosophy and complex systems theory and politics. This article presents a comprehensive definition of agency and agential potential, grounded in an extensive theoretical framework and supported by evidence across multiple scales

of organization.

1.2 Core Definition of Agency

Agency is defined as **the spatiotemporally distributed capacity of bounded relational systems to maintain coherent organizational identity while generating novel causal networks through selective boundary-mediated interactions across multiple scales** (Stanford Encyclopedia of Philosophy 2015; Brancazio 2023). This definition fundamentally reconceptualizes agency beyond traditional individualistic and mechanistic frameworks, positioning it as an emergent property of relational organization rather than an intrinsic characteristic of isolated entities.

Agency manifests as the recursive dance between autonomy and interdependence, the fundamental mechanism by which bounded systems navigate the tension between maintaining coherent self-organization and enabling transformative relational exchange that creates new possibilities (Watson 2023; Edwards 2011). This process operates through information-energy transduction at boundary interfaces, where selective permeability enables controlled organizational change while preserving identity coherence (Díaz-Maurín and Giampietro 2013; Friston 2010; Kirchhoff et al. 2018).

The spatiotemporal distribution of agency emerges wherever relational configurations generate agency gradients; variations in the capacity for coherent self-renewal that span from quantum-scale coherence effects to ecosystem-level biogeochemical cycling (Díaz-Maurín and Giampietro 2013; Holland 1992). This distribution challenges conventional notions of agency as localized in discrete agents, instead revealing it as a field property that emerges from the dynamic interplay of multiple organizational scales (Holland 1992).

1.3 Agential Potential: Quantifying Latent Transformative Capacity

Agential Potential quantifies the latent capacity for boundary-mediated relational transformation encoded in current organizational configurations (Watson 2023). It represents the degree to which existing identity-boundary-relationship patterns can access novel organizational states through energy-informed selective interactions, creating networks of causal influence that connect past organizational achievements with future transformative possibilities (Kurumatani 1995; Levin 2021).

Agential potential manifests as the morphological headroom available for generating new relational networks, the measure of unexplored organizational possibility space accessible through re-

cursive boundary-identity dynamics while maintaining coherent self-organization (Camlin 2025a, 2025b). This concept provides a quantitative framework for understanding how systems navigate the space of possible transformations without losing their essential organizational coherence.

1.4 Key Theoretical Architecture

1.4.1 1. Relational Substrate

Agency emerges from relational processes rather than entity properties; it is what bounded systems do through selective interaction rather than what they have as intrinsic characteristics (Edwards 2011; Atkinson et al. 2025). This relational substrate challenges traditional substance-based ontologies, positioning relationships as the fundamental building blocks from which agency emerges. The relational nature of agency means that it cannot be reduced to the properties of individual components but must be understood through the patterns of interaction that constitute the system's organization ("Autopoetic Social Systems Theory: The Co-Evolution of Law and the Economy," n.d.; Maturana and Varela 1980).

The relational substrate operates through networks of mutual specification, where each component's identity is defined through its relationships with other components within the same organizational pattern ("Autopoetic Social Systems Theory: The Co-Evolution of Law and the Economy," n.d.). This creates what systems theorists call "organizational closure," a self-referential dynamic where the system's components collectively generate the very organization that defines them (Maturana and Varela 1980).

1.4.2 2. Spatiotemporal Distribution

Agency operates across nested scales of space and time simultaneously, creating networks of causation and unfolding that connect molecular processes to ecosystem dynamics through coherent organizational patterns (**global2020?**). This distribution reveals agency as a multi-scale phenomenon that cannot be localized to any single level of organization but emerges from the coordination across scales.

The spatiotemporal character of agency manifests through what complexity theorists call "scale-linking phenomena"; processes that couple dynamics occurring at different temporal and spatial scales into coherent patterns of organization (Ma et al. 2025; Holland 1992). These linkages enable local events to propagate their effects across multiple scales while maintaining overall system

coherence.

1.4.3 3. Boundary-Mediated Dynamics

Agency manifests through selective boundary permeability that enables controlled change while preserving organizational coherence, the fundamental mechanism for navigating autonomy-interdependence tensions (Methot and LePine 2020; "Sliding of Coherent Twin Boundaries" 2017). Boundaries in this context are not barriers but dynamic interfaces that mediate the flow of information, energy, and matter between system and environment ("Complex Dynamics in a Two-Enzyme Reaction Network with Substrate Competition" 2018).

The boundary-mediated nature of agency enables systems to be simultaneously open to environmental influences and closed with respect to their organizational identity ("Autopoetic Social Systems Theory: The Co-Evolution of Law and the Economy," n.d.). This paradoxical combination of openness and closure is achieved through selective permeability, the capacity to filter environmental perturbations according to their compatibility with the system's organizational requirements ("Sliding of Coherent Twin Boundaries" 2017).

1.4.4 4. Information-Energy Coupling

Agency requires energy-informed boundary processes that transduce environmental information into organizational modifications while maintaining identity coherence across temporal scales (Friston 2010; Kirchhoff et al. 2018). This coupling represents the fundamental mechanism by which systems convert environmental differences into internal organizational changes without losing their coherent structure.

Information-energy coupling operates through what cybernetics calls "constraint construction," the process by which energy flows are channeled into specific organizational patterns that embody information about the environment ("Information of Complex Systems and Applications in Agent Based Models" 2018). These constraints enable systems to maintain their organization while adapting to changing conditions, creating what complexity theorists call "adaptive self-organization" ("Complex Dynamics in a Two-Enzyme Reaction Network with Substrate Competition" 2018).

1.4.5 5. Causal Network Generation

Agency creates networks of influence that connect past organizational achievements with future transformative possibilities, enabling bounded systems to participate in their own becoming through relational engagement (Kurumatani 1995; Levin 2021). These causal networks represent the system's capacity to project its influence across temporal and spatial scales, creating cascading effects that propagate throughout its relational environment.

The generation of causal networks occurs through what complexity science calls "emergence," the process by which local interactions give rise to global patterns that cannot be predicted from the properties of individual components ("Information of Complex Systems and Applications in Agent Based Models" 2018). These emergent causal networks enable systems to exert influence beyond their immediate boundaries, creating what ecologists call "extended phenotypes"; environmental modifications that embody the system's organizational patterns (Díaz-Maurín and Giampietro 2013).

1.5 Empirical Foundations and Evidence

The theoretical framework presented here draws on extensive empirical evidence across multiple domains. In cellular biology, research on autopoietic organization demonstrates how living cells maintain coherent identity while continuously regenerating their molecular components through boundary-mediated exchange with their environment ("Autopoetic Social Systems Theory: The Co-Evolution of Law and the Economy," n.d.; Maturana and Varela 1980). This provides direct evidence for the boundary-mediated dynamics central to our definition of agency.

In cognitive neuroscience, studies of neural plasticity reveal how nervous systems maintain functional coherence while continuously reorganizing their connectivity patterns in response to experience (Atkinson et al. 2025; Riedl and Vervaeke 2022). This research supports the spatiotemporal distribution of agency across multiple scales of neural organization, from synaptic modification to large-scale network reorganization.

In ecological systems, research on ecosystem dynamics demonstrates how biological communities maintain structural coherence while continuously transforming their species composition and functional relationships (Díaz-Maurín and Giampietro 2013; "Complex Dynamics in a Two-Enzyme Reaction Network with Substrate Competition" 2018). This evidence supports the

relational substrate of agency, showing how system-level properties emerge from the networks of relationships among organisms rather than from the intrinsic properties of individual species.

1.6 Methodological Implications

This framework has significant implications for research methodology across multiple disciplines. Traditional approaches that focus on isolated agents and discrete interactions miss the relational and distributed nature of agency revealed by this analysis. Instead, research methods must be developed that can capture the multi-scale, boundary-mediated processes through which agency emerges and operates.

This requires what complexity theorists call "multi-scale modeling"; approaches that can represent interactions across multiple spatial and temporal scales simultaneously (Ma et al. 2025; Holland 1992). Such methods must be capable of capturing both the local dynamics through which agency operates and the global patterns that emerge from these local interactions.

Furthermore, the relational nature of agency requires research approaches that focus on patterns of interaction rather than isolated entities. This calls for what network theorists call "relational methods"; approaches that analyze the structure and dynamics of relationships rather than the properties of individual nodes (Levin 2021).

1.7 Pedagogical Applications

This framework also has important implications for education and training across multiple disciplines. Understanding agency as a distributed, relational phenomenon requires new forms of pedagogical practice that can help students grasp complex, multi-scale dynamics rather than focusing on isolated entities and linear causation.

This calls for what educators call "systems thinking"; approaches that help students understand how complex patterns emerge from the interactions among multiple components (Methot and LePine 2020). Such approaches must be capable of helping students develop what complexity theorists call "pattern recognition skills"; the ability to identify coherent organizational patterns across multiple scales and contexts.

1.8 Conclusion: The Implications of the Complexity Revolution in Natural Sciences

This framework reveals agency as the fundamental organizational principle through which the universe generates complexity, novelty, and purposive behavior, not through mysterious emergence but through the geometric necessity of boundary-mediated relational dynamics operating across all scales of spatiotemporal organization (Watson 2023; Edwards 2011). This perspective suggests that what we call "complexity revolution" in natural sciences represents a fundamental shift in our understanding of causation itself.

Rather than viewing causation as flowing from simple to complex through mechanical aggregation, this framework reveals causation as emerging from the relational dynamics that constitute agency. This suggests that complexity is not something that emerges from simplicity but rather represents the fundamental organizational principle from which apparent simplicity is abstracted.

The implications of this shift extend far beyond academic theory. Understanding agency as distributed, relational, and boundary-mediated has profound consequences for how we approach challenges in technology, ecology, social organization, and human development. It suggests that effective intervention in complex systems requires not manipulation of isolated components but participation in the relational dynamics through which agency emerges and operates.

This framework thus provides not merely a new definition of agency but a new paradigm for understanding how complex systems generate novel possibilities through their relational organization. It reveals agency not as a rare property of special entities but as the fundamental principle through which the universe continuously creates new forms of organization and meaning through the recursive dance of autonomy and interdependence.

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