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Kyrylo Somkin *

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Social Memes as Neurocultural Agents

Kyrylo Somkin

Independent Researcher, Czech Republic; somkinkirilo@gmail.com

Abstract

The development of the prefrontal cortex (PFC) enabled humans to acquire advanced communication skills, distinguishing them as highly social compared to other species. Communication emerged not merely as a functional adaptation but as a fundamental property of the human brain, facilitating the formation of hierarchies, cooperation, and complex societies. This core social drive shaped both individual and collective behavior, providing the foundation for intricate cultural systems. Within this context, memes—defined as replicable units of cultural information—developed as a complementary cultural mechanism, influencing the spread of ideas and behaviors alongside genetic evolution. Memes reflect and enhance humanity's natural predisposition for interaction, serving as vehicles for social learning, identity formation, and group cohesion. This study examines the interplay between the evolution of the human brain, the emergence of social memes, and their role in shaping cognitive processes and societal organization. By exploring these dynamics, we highlight how the human tendency for communication underlies cultural evolution and the mechanisms through which societies create, transmit, and maintain shared knowledge and social structures.

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Introduction

Human social behavior is based on a combination of neural and genetic mechanisms that facilitate complex communication and cooperation. The prefrontal cortex (PFC) plays a central role in these processes, supporting executive functions, decision-making, and the regulation of social behavior. Specifically, the PFC supports perspective-taking, planning, and hierarchical organization, which distinguishes humans from other primates in terms of the complexity of social interaction. Complementing neural structures such as the temporoparietal junction and the amygdala, the PFC is part of a distributed network underlying social cognition and collective problem-solving.

Genetic factors contribute to this predisposition to social interaction. Variants in genes such as OXTR (oxytocin receptor) and AVPR1A (arginine vasopressin receptor 1A) have been linked to differences in empathy, trust, and prosocial behavior. Similarly, genes involved in dopaminergic and serotonergic pathways (e.g., DRD4, SLC6A4) influence reward sensitivity and social motivation, reinforcing behaviors that promote cooperation and information sharing.

Cultural evolution interacts with these biological mechanisms through the replication and transmission of memes—units of cultural information that spread throughout society. Memes exploit the human brain's natural propensity for communication, reinforcing behavior predisposed by certain genetic factors and facilitating the cumulative growth of knowledge. This interplay between neural, genetic, and cultural factors provides a foundation for understanding the emergence of complex social systems, demonstrating that human communication is shaped by both biological and cultural evolution.

The combination of these factors creates a core tendency for communication and an understanding of basic abstract and social constructs, beginning in early childhood, with little or no conscious involvement. The so-called egoism of memes and the desire to spread them has become a central factor in shaping human cognition and social behavior.

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Main

1. Origins of Memes, Imitation, and Neural Mechanisms of Cultural Transmission

The concept of memes originated with Richard Dawkins' proposal of a cultural replicator analogous to genes, termed a meme—a unit of cultural information that can be copied and transmitted between individuals through imitation and learning. According to Dawkins, memes undergo processes functionally similar to genetic replication, variation, and selection, contributing to cultural evolution alongside biological evolution.

From a neuroscientific perspective, humans possess specialized neural mechanisms that support imitation, social learning, and the transmission of behaviors—mechanisms that have been implicated in the propagation of cultural information. A prominent candidate is the mirror neuron system (MNS), originally discovered in the premotor cortex of macaque monkeys, where individual neurons fire both when an action is executed and observed. These neurons are hypothesized to underlie the brain's ability to map others' actions onto one's own motor system, forming a neural basis for imitation and social cognition.

In humans, functional imaging studies have identified analogous mirror-like activity in areas such as the inferior frontal gyrus, premotor regions, and inferior parietal lobule, which are activated both during observation and execution of actions. This pattern suggests a neural mechanism that supports the translation of observed behavior into internal representations, facilitating observational learning and imitation—core processes in cultural transmission.

Social learning research further indicates that humans exhibit high-fidelity imitation compared with other primates. While many primates show forms of social learning such as emulation (copying results rather than actions), human children reliably replicate both the actions and outcomes of models, supporting cultural accumulation and complexity beyond that seen in other species.

This capacity for detailed imitation enables not just the acquisition of skills but the propagation of complex behavioral sequences and symbolic content (e.g., language, tools, rituals), which can be conceptualized as memes in Dawkins' framework.

Furthermore, social and cultural neuroscience suggests that mirror systems are involved not only in motor imitation but also in higher-order social cognition, including aspects of empathy and understanding others' intentions—abilities that support the transmission and assimilation of cultural information.

In this framework, the evolution of human communication and culture can be viewed as emerging from a synergy between neural mechanisms for imitation and the cumulative transmission of cultural units. Memes leverage the brain's natural propensity for imitation and social learning, replicating across individuals and shaping cultural landscapes. Over time, this process has contributed to the rapid expansion of cultural complexity relative to biological evolution alone, allowing humans to develop technologies, languages, and social norms within far shorter timescales than would be possible through genetic evolution alone.

2. Interaction Between Genes and Memes: Competition and Co-Evolution

The relationship between genetic and cultural evolution represents a complex dynamic in which biological predispositions and cultural information mutually influence each other. While genes shape the structural and functional architecture of the brain, memes operate within this architecture as cultural units that exploit, amplify, or redirect genetically influenced tendencies. Rather than functioning in isolation, genetic and memetic processes form an integrated system of co-evolution, where biological and cultural factors interact across multiple levels of cognition and behavior.

From a genetic perspective, numerous studies indicate that variations in specific genes modulate social behavior, communication, and susceptibility to cultural influence. For example, polymorphisms in the OXTR gene, encoding the oxytocin receptor, have been associated with differences in social bonding, empathy, and trust. Similarly, variations in AVPR1A, related to vasopressin signaling, correlate with affiliative behavior and social cognition. These genetic factors

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influence how individuals perceive, process, and respond to social stimuli, thereby shaping the conditions under which memes are adopted and transmitted.

Genes involved in neuromodulatory systems further contribute to this interaction. The dopamine receptor gene DRD4 has been linked to novelty-seeking behavior and sensitivity to environmental stimuli, which may increase receptivity to new cultural patterns. Likewise, polymorphisms in the serotonin transporter gene SLC6A4 affect emotional regulation and social sensitivity, influencing how individuals engage with socially transmitted information. Through such mechanisms, genetic variability creates differential susceptibility to memetic influence across individuals and populations.

At the same time, memes can exert selective pressures on genetic traits by shaping social environments and behavioral norms. Cultural practices, values, and symbolic systems influence reproductive strategies, cooperation patterns, and social hierarchies, indirectly affecting the evolutionary trajectories of genetic traits. This phenomenon aligns with the concept of gene–culture co-evolution, where cultural innovations alter selective environments, and genetic adaptations subsequently emerge in response to these changes. Classic examples include the co-evolution of lactose tolerance with dairy farming or the influence of linguistic and social structures on cognitive specialization.

In this context, genes and memes may exhibit both competitive and cooperative dynamics. Competition arises when cultural patterns counteract biologically rooted tendencies—for instance, when socially transmitted norms suppress innate behavioral inclinations. Conversely, cooperation occurs when memes reinforce genetically influenced dispositions, such as prosocial behavior, group cohesion, or hierarchical organization. Memes thus function not merely as passive cultural artifacts but as active modulators of genetically shaped behavioral tendencies.

Importantly, this interaction is not static but dynamic and recursive. Genetic predispositions influence which memes are likely to spread, while dominant memes reshape cognitive environments and behavioral repertoires, potentially altering selective pressures over time. As a result, human cognition and social organization emerge from a continuous feedback loop between biological and cultural evolution. Within this framework, memes can be understood as cultural analogues of genetic regulators—entities that do not replace genetic evolution but interact with it, accelerating the pace and complexity of human behavioral and societal change.

3. Early Development and Atypical Cases: Memes in the Formation of Language and Social Cognition

Early childhood represents a critical period in which neural plasticity, genetic predispositions, and social environments converge to shape fundamental cognitive and communicative capacities. During this period, children demonstrate an exceptional sensitivity to patterns of social information, rapidly acquiring linguistic structures, behavioral norms, and symbolic systems through observation and interaction. This process suggests that cultural information is not merely learned but systematically reconstructed and stabilized within developing neural networks.

Experimental studies in developmental psychology have shown that infants exhibit advanced capacities for social learning long before the full maturation of language. For instance, research on imitation in infants demonstrates that children as young as 12–18 months reproduce not only goal-directed actions but also irrelevant or inefficient steps performed by adults—a phenomenon known as overimitation. This tendency indicates that children prioritize socially transmitted patterns over purely instrumental efficiency, thereby facilitating the high-fidelity transmission of cultural information. From a memetic perspective, overimitation can be interpreted as a mechanism that enhances the replication accuracy of cultural units.The emergence of language provides one of the most striking examples of memetic dynamics in early development. Studies in linguistics and cognitive science reveal that children do not simply copy linguistic input but actively systematize it. A well-documented phenomenon is the creation of twin languages (cryptophasia), in which twins develop idiosyncratic communication systems with unique lexical and grammatical features. These systems arise in environments where mutual interaction between twins partially substitutes for adult linguistic input. The structural coherence of such languages suggests that children spontaneously generate stable symbolic patterns, which can be conceptualized as emergent memetic systems operating within a limited social network.

Even more compelling evidence comes from cases of language emergence among deaf communities. The development of Nicaraguan Sign Language (NSL) provides a paradigmatic example. In the 1970s and 1980s, deaf children in Nicaragua, lacking a standardized sign language, collectively developed a new linguistic system through interaction. Over successive cohorts of children, the language became increasingly structured and grammatically complex. Linguistic analyses demonstrated that younger generations introduced systematic grammatical innovations absent in earlier stages. This process illustrates how cultural information can self-organize and evolve through iterative social transmission, resembling memetic replication with variation and selection.Similar processes are observed in the formation of dialects and sociolects. Sociolinguistic studies show that linguistic variants spread through social networks according to patterns of prestige, identity, and frequency of interaction. Certain phonetic, lexical, or syntactic features propagate rapidly within groups, while others disappear. These dynamics parallel evolutionary models, where cultural variants compete for cognitive and social relevance. Within this framework, dialects can be interpreted as clusters of mutually reinforcing memes stabilized within specific communities.

Neuroscientific evidence further supports the role of early development in shaping susceptibility to cultural patterns. During childhood, heightened synaptic plasticity in regions such as the PFC, temporal cortex, and hippocampus facilitates the rapid integration of socially transmitted information. This neural flexibility allows memes to become deeply embedded in cognitive architectures, influencing perception, memory, and behavior across the lifespan. Importantly, the stabilization of these patterns does not require explicit awareness; instead, cultural units are internalized through repeated exposure and social reinforcement. Taken together, these findings suggest that early development and atypical cases of language formation provide empirical evidence for the existence of robust mechanisms of cultural replication. Memes, in this context, are not abstract metaphors but operational units of cultural transmission that emerge naturally from the interaction between developing brains and social environments. The study of childhood communication, twin languages, emergent sign languages, and dialect formation thus offers a powerful empirical foundation for understanding how memetic processes shape human cognition and social organization.

3.1. Prenatal Formation and Early Neural Embedding of Memes

Evidence from developmental neuroscience indicates that the foundations of human social cognition and cultural receptivity are laid well before birth. Prenatal brain development involves a complex orchestration of genetic programs, neuronal proliferation, migration, and synaptogenesis, establishing the basic architecture that will later support both innate reflexes and culturally transmitted behaviors. In this context, certain genes—most notably FOXP2 and ARHGAP11B—play crucial roles.

FOXP2, widely recognized for its involvement in speech and language, is expressed prenatally in regions including the basal ganglia and cortical layers associated with motor planning and auditory processing. Mutations in FOXP2 lead to deficits in vocal learning, fine motor coordination for speech, and syntactic processing, highlighting its fundamental role in preparing the neural substrate for subsequent language acquisition.

ARHGAP11B, a human-specific gene expressed transiently during mid-gestation, has been linked to cortical expansion, particularly in the upper layers of the neocortex. Its activity contributes to increased numbers of radial glia and upper-layer neurons, which are critical for higher-order cognition, working memory, and the integration of complex sensory inputs—abilities foundational for cultural learning and memetic processing.

Within this prenatal environment, we propose that preliminary memetic structures—proto-memes—begin to emerge. These structures can be understood as basic templates for social and

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sensory patterns, influenced both by intrinsic neural activity and spontaneous reflexive behaviors. For example, newborns display a suite of innate reflexes, such as rooting, grasping, and the preference for face-like stimuli. These behaviors can be interpreted as early, evolutionarily conserved channels through which environmental and social information is absorbed, forming the initial scaffold for memetic learning.

Importantly, these proto-memes are not yet culturally transmitted in the conventional sense but represent preconfigured behavioral and perceptual predispositions that guide how postnatal experiences will be encoded and replicated. The interaction between spontaneous neural activity, prenatal gene expression, and early reflexive behaviors establishes a framework in which some cultural patterns are more easily internalized than others—essentially forming the neural "soil" for memes to take root after birth.

By the time of birth, the brain has already developed preliminary temporal, parietal, and frontal circuits that support imitation, attention to social cues, and memory formation. These circuits enable the rapid acquisition of memes in the early postnatal period, building directly upon the genetic and neural scaffolding established prenatally. This stage sets the stage for the phenomena explored in Section 4, where these initially flexible, embedded memetic patterns begin to stabilize, compete, and eventually exhibit the conservatism observed in human cultural transmission.

4. Conservatism and Propagation Bias of Memes

Once established in early childhood, memetic structures undergo a process of stabilization and selection within the brain, leading to the phenomenon of memetic conservatism. Older, well-established memes tend to persist and dominate over newer, less familiar cultural units. This bias is reflected both in behavioral tendencies and in neural mechanisms. Cognitive neuroscience suggests that prefrontal cortical circuits, in concert with the limbic system, mediate evaluative processes that prioritize familiar patterns over novel ones, enhancing the retention and propagation of entrenched cultural information. Empirical evidence from studies of auditory and visual memory illustrates this principle. For example, the earworm phenomenon—the repetitive involuntary recall of a song, often one that is widely popular despite personal dislike—demonstrates how certain memes exploit neural reinforcement pathways. Dopaminergic circuits in the striatum, modulated by DRD4 and other reward-related genes, appear to facilitate this repetition, while PFC networks attempt to regulate conscious attention, sometimes unsuccessfully.

The interaction between consciousness and meme-driven processes highlights a key feature of memetic propagation: memes operate semi-autonomously, influencing behavior and attention without necessarily aligning with conscious goals. In adolescence, as the PFC undergoes continued maturation, these dynamics evolve. Synaptic pruning, increased myelination, and strengthening of long-range cortical connections enhance executive control and reflective capacities, allowing individuals to selectively engage with or resist memetic content. At the same time, the limbic system remains highly responsive, preserving emotional resonance and hedonic biases that favor the spread of socially and emotionally salient memes.

Genetic factors further modulate the stabilization of memetic structures. Polymorphisms in FOXP2 contribute to the refinement of vocal imitation and syntactic memory, enhancing the fidelity of language-related memes. Variants in DRD4 and SLC6A4 influence reward sensitivity and social responsiveness, reinforcing repeated exposure and preferential adoption of familiar memes. Additional genes, such as BDNF (brain-derived neurotrophic factor), support synaptic plasticity underlying the long-term retention of memetic patterns. Together, these genetic and neural mechanisms establish a cooperative network that favors the persistence and hierarchical organization of memes across development.

Notably, memetic conservatism is not purely passive. Humans often exhibit resistance or even aversive reactions to novel memes, especially when they conflict with established social norms or personally reinforced patterns. Neuroimaging studies indicate heightened activation in the insula and anterior cingulate cortex during exposure to culturally incongruent stimuli, reflecting emotional

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and cognitive conflict. These mechanisms help explain why some cultural innovations face strong resistance, while widely reinforced memes continue to propagate rapidly despite novelty or individual preference.

By late adolescence, the coalescence of PFC maturation, limbic modulation, and genetic predispositions produces a semi-stable architecture of memetic hierarchies. Within this architecture, older memes dominate, emotionally salient units spread efficiently, and new cultural content must compete with entrenched patterns. This framework provides a biological and cognitive explanation for phenomena ranging from the persistence of traditional narratives to the global viral spread of contemporary cultural memes.

5. Memes in Aging and Neuroplasticity

As humans age, the processing and propagation of memes undergo profound transformations, reflecting structural, functional, and molecular changes in the brain. By late adulthood, the prefrontal cortex (PFC), which supports executive control and reflective cognition, exhibits gradual synaptic decline and reduced plasticity, whereas limbic structures, including the amygdala and hippocampus, maintain relatively preserved function. This neural asymmetry creates conditions in which memes become increasingly reinforced, often dominating cognitive and behavioral processes. Well-established memes exploit preserved emotional circuits, allowing cultural patterns to persist and amplify despite diminishing top-down regulatory capacity. At the molecular level, age-dependent transcriptional changes influence memetic stability and adaptability. Alterations in BDNF, ARC, and synaptic plasticity-related genes modulate both the retention of existing memes and the integration of new ones. Reduced plasticity in cortical networks limits the adoption of novel cultural units, while reinforcing preexisting patterns. Importantly, these changes enable memes to adapt to the aging brain, aligning with emotional salience and reinforcing social cohesion, which may explain the increased prominence of culturally resonant narratives and behaviors in older adults.

Behavioral studies support these neural and molecular observations. Older individuals demonstrate enhanced recall and repetition of familiar memes, even when cognitively neutral, while acquisition of novel memes requires greater cognitive effort and executive control. In this sense, memes can be seen as competing with the declining PFC, which attempts to exert conscious regulation, yet simultaneously forming a functional partnership with the limbic system. The emotional resonance of memes enables them to co-opt preserved neural circuits, effectively maintaining relevance and influence in older adults' cognition.

Moreover, aging introduces a dynamic interplay between memetic conservatism and adaptive reinforcement. Memes become stronger, more self-sustaining, and capable of adjusting to age-related changes in perception and cognition. This process reflects a form of neural-cultural co-adaptation: as PFC control diminishes, memes rely on limbic connectivity to persist, while older adults retain selective flexibility to integrate socially significant or emotionally salient innovations. In this way, memes both compete with executive control and cooperate with emotional circuitry, resulting in a semi-stable memetic architecture that balances persistence with adaptive responsiveness.

In sum, aging transforms the human memetic landscape by amplifying established cultural patterns, modulating their interaction with executive and emotional brain systems, and selectively incorporating novel information. This framework illustrates how memes adapt structurally and functionally to the aging brain, reinforcing the convergence of neurobiology, gene regulation, and cultural evolution, and providing a natural prelude to the examination of prefrontal-limbic interactions and memory modulation, discussed in the subsequent section.

6. Prefrontal Cortex, Limbic System, and Memory Distortions

The interaction between memes and neural systems reaches its most pronounced effects in late adolescence and adulthood, when prefrontal cortical circuits (PFC) and limbic structures have matured. The PFC, responsible for executive control, working memory, and conscious evaluation, mediates the integration and prioritization of culturally transmitted information. The limbic system,

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including the hippocampus and amygdala, processes emotional salience, reward, and memory consolidation. Memes, as semi-autonomous units of cultural information, exploit these neural networks, influencing cognition, behavior, and physiological responses. Neuroimaging and behavioral studies demonstrate that culturally salient memes can modulate memory encoding and retrieval, contributing to phenomena such as the Mandela Effect, where repeated exposure to shared cultural units produces systematic false recollections. These distortions arise from the interaction between PFC-mediated rationalization and hippocampal memory consolidation, highlighting the capacity of memes to alter cognitive representations independently of conscious control.

Memes also exert measurable physiological effects. Emotionally potent memes activate the limbic system, modulating autonomic responses and hormonal pathways, including dopamine, oxytocin, and cortisol, which influence attention, motivation, social bonding, and stress regulation. These interactions demonstrate that memes are biologically active agents, linking cultural information to emotional and physiological states.

During normal aging, PFC synaptic density and plasticity gradually decline, while limbic regions maintain functional integrity. This shift produces a selective reinforcement of previously established memes, enhancing their persistence and propagation. New or complex memes require greater cognitive resources for integration and are less likely to spread widely. As a result, memetic dynamics in older adults demonstrate increased conservatism, emotional prioritization, and selective propagation, consistent with both neuroanatomical and functional changes. In the context of neurodegeneration, such as Alzheimer's disease or age-related hippocampal and cortical decline, memetic dynamics are further altered. Studies of memory retention in neurodegenerative populations show that:

Older, emotionally salient memes are preferentially preserved due to their strong limbic encoding and repeated reinforcement over the lifespan. Newly acquired or complex memes are more susceptible to degradation, reflecting reduced PFC-mediated executive control and impaired hippocampal consolidation. The balance between cognitive evaluation and emotional salience shifts further toward limbic-driven propagation, resulting in the dominance of familiar memes over novel cultural information. In social networks, this can lead to accelerated spread of entrenched cultural units, while innovation and adoption of new memes decline, illustrating the impact of neural integrity on memetic evolution.

Furthermore, these processes are mediated by age- and disease-related transcriptional changes, including alterations in BDNF, ARC, and synaptic plasticity-related genes, which regulate neuronal connectivity and memory encoding. Such molecular changes provide a mechanistic explanation for why memes become increasingly self-reinforcing, adapt to the aging brain, and integrate more strongly with limbic circuitry when PFC control diminishes. Taken together, these findings suggest that memes operate as semi-autonomous agents, capable of modulating memory, cognition, and physiology across the lifespan. Their behavior changes dynamically with neural maturation, aging, and neurodegeneration: while younger brains facilitate flexible propagation, older and impaired brains favor stability, emotional resonance, and selective reinforcement. This integrated perspective establishes a foundation for the Discussion, enabling examination of the broader implications for cultural evolution, cognitive processes, and social organization.

Discussion

1. Context, Novelty, and Structural Advances

The present study aimed to integrate multiple levels of analysis—neural development, genetic predispositions, and cultural transmission—to examine the dynamics of human memes from prenatal formation to aging. Unlike traditional approaches in memetics, particularly those stemming from Dawkins' original conceptualization of memes as abstract units of cultural replication, this framework emphasizes biological embedding, neurophysiological mechanisms, and developmental trajectories. Whereas classic memetics often treats memes primarily as informational entities subject

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to Darwinian selection, the current structure situates memes within a multilayered neurocultural system, highlighting interactions with the prefrontal cortex (PFC), limbic structures, and relevant genes such as FOXP2, ARHGAP11B, and BDNF.

This approach introduces several conceptual advances:

Prenatal and early development focus — By considering proto-memes and their neural scaffolding before birth, the framework identifies the foundational stages of memetic integration, a perspective largely absent in prior literature. Early reflexive behaviors, combined with prenatal gene expression, provide a neural and genetic substrate that shapes postnatal cultural acquisition.

Integration with neurophysiology and hormonal systems — Memes are considered not only cognitive phenomena but biologically active agents, influencing dopaminergic, oxytocinergic, and cortisol pathways, which modulate emotion, attention, and social behavior. This extends memetic theory into the realm of embodied cognition, offering a mechanistic account of how cultural information affects physiology and behavior.

Developmental trajectory and lifespan dynamics — The framework explicitly traces memetic evolution across the lifespan, from early acquisition, through adolescent stabilization, to increased conservatism and limbic dominance in aging. This trajectory incorporates structural, functional, and molecular changes in the brain, showing how memes adapt and persist, particularly under conditions of PFC decline or neurodegeneration.

Interaction with genetics — By linking meme dynamics to specific genes involved in language, synaptic plasticity, and reward processing, the framework establishes a cooperative and competitive model of cultural and genetic evolution. This mechanistic integration moves beyond metaphorical or purely conceptual models, grounding memetic dynamics in empirically observable biological processes.

Implications for memory and cognition — The inclusion of phenomena such as the Mandela Effect demonstrates that memes can actively reshape memory representations and cognitive evaluations, illustrating a semi-autonomous influence of cultural information over neural processes.

In sum, the current study differs from classical memetic theory by embedding memes within a neurobiological, developmental, and genetic context, moving from abstract units of cultural replication to multiscale agents influencing behavior, cognition, and physiology. This integrated perspective forms the basis for the subsequent synthesis of findings and provides a foundation for assessing the functional, adaptive, and evolutionary implications of memes in human life.

2. Toward a Neurogenetic Model of Memetic Dynamics

The results of this study suggest that memes cannot be adequately described as purely cultural artifacts. Instead, they emerge as dynamic entities embedded within neural architecture, genetic predispositions, and developmental trajectories. By synthesizing evidence from neurobiology, genetics, and cultural evolution, it becomes possible to conceptualize memes as operating within a neurogenetic-cognitive system, rather than as isolated informational units.

2.1. Memes as Emergent Properties of Neural Systems

Across all developmental stages analyzed, memes appear to arise not as external additions to cognition but as emergent properties of distributed neural networks. The interaction between the prefrontal cortex, limbic system, and associative cortical regions creates conditions under which cultural information is encoded, evaluated, and propagated. This suggests that memetic phenomena are structurally analogous to cognitive processes such as perception, learning, and memory, rather than merely metaphorical constructs. Importantly, this perspective reframes memetic evolution as a process constrained by neural architecture. The selective success of memes is not determined solely by their informational content but by their compatibility with cognitive biases, emotional salience, and neural efficiency. Thus, memetic selection operates within boundaries defined by brain structure and function.

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2.2. Genetic Constraints and Amplification of Memetic Processes

The interaction between genes and memes described in this study reveals a bidirectional relationship. Genes shape the neural substrate that enables memetic transmission, while memes influence behavioral patterns that can indirectly affect genetic selection. This reciprocal relationship suggests that memetic evolution is not independent of biological evolution but is partially canalized by genetic architecture. Genes associated with language (FOXP2), cortical expansion (ARHGAP11B), synaptic plasticity (BDNF), and reward processing (DRD4, SLC6A4) create a biological environment in which certain types of memes are more likely to emerge and persist. At the same time, culturally dominant memes can amplify or suppress behaviors linked to these genetic pathways, thereby influencing patterns of social interaction and learning. This framework implies that memetic evolution operates under a form of genetically modulated selection, in which cultural units compete not only with each other but also with the constraints imposed by neural and genetic systems.

2.3. Lifespan Trajectories of Memetic Dynamics

One of the central findings of this work is that memetic behavior changes systematically across the human lifespan. Early childhood is characterized by high memetic plasticity, driven by imitation, neural hyperconnectivity, and rapid synaptic formation. Adolescence represents a transitional phase in which memetic structures are reorganized under the influence of PFC maturation and hormonal changes. Adulthood marks the stabilization of memetic hierarchies, while aging introduces a shift toward emotional prioritization and memetic conservatism.

This lifespan perspective suggests that memetic evolution is not uniform but stage-dependent. The same meme may function differently depending on the developmental state of the brain, implying that memetic dynamics cannot be fully understood without considering neurodevelopmental context.

2.4. Memes as Regulators of Cognitive and Social Systems

Beyond their role as carriers of cultural information, memes appear to function as regulators of cognitive and social systems. By structuring attention, shaping memory, and guiding behavioral norms, memes act as organizing principles within both individual minds and collective networks.

From this perspective, memes can be interpreted as a form of distributed cognitive architecture that complements biological cognition. They reduce cognitive load by providing ready-made frameworks for interpretation and action, while simultaneously constraining cognitive flexibility.

2.5. From Cultural Replication to Neurocognitive Ecology

Taken together, these findings support a shift from classical memetics toward a model of neurocognitive ecology, in which memes, genes, and neural systems co-evolve within a shared adaptive landscape. Unlike Dawkins' original formulation, which emphasized the autonomy of memes as replicators, the present framework highlights their dependence on—and influence over—biological substrates. This model does not reject the core insight of memetics but extends it by embedding memes within a multilayered system of constraints and feedback loops. Memes are neither purely cultural nor purely biological; they occupy an intermediate domain in which information, neural activity, and genetic predispositions intersect.This synthesis provides a conceptual foundation for evaluating the adaptive, maladaptive, and transformative roles of memes in human cognition and society, preparing the ground for a deeper examination of their evolutionary and epistemological implications in the following sections.

3. Psychological, Social, and Behavioral Neurodynamics of Memes

Memes operate not only as units of cultural information but also as modulators of cognitive, emotional, and social behavior. Their propagation is mediated by neural circuits underlying attention, reward, and social cognition, creating measurable effects on individual and collective

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dynamics. The convergence of psychology, behavioral neuroscience, and sociology provides a comprehensive framework for understanding these phenomena.

3.1. Cognitive and Emotional Modulation

Neurocognitive studies indicate that memes engage prefrontal-limbic circuits, modulating both conscious and automatic responses. Emotionally salient memes preferentially activate the amygdala, enhancing attention and retention, while the PFC regulates integration and evaluation. This dual processing explains why certain memes persist despite low factual validity, as emotional salience often outweighs rational assessment.

Behaviorally, memes can shape decision-making, risk perception, and motivational states. For example, exposure to socially endorsed memes increases conformity and cooperative behavior, mediated by oxytocinergic signaling, whereas memes that provoke threat or fear enhance vigilance and social monitoring through cortisol modulation.

3.2. Social Network Dynamics

From a sociological perspective, memes function as structuring agents within social networks. Their transmission is influenced by network topology, group hierarchies, and the emotional resonance of content. Central nodes (highly connected individuals) disproportionately amplify memes, leading to non-linear propagation and the emergence of cultural norms.

Behavioral studies support that meme spread is stage-dependent, aligning with developmental and social maturation: younger individuals exhibit high exploratory propagation, adolescents demonstrate selective reinforcement under peer influence, and adults show conservative amplification of emotionally salient memes. This aligns with our neurodevelopmental model (Sections 3–5), illustrating the coupling of social structure and neural plasticity in shaping memetic landscapes.

3.3. Group Cognition and Collective Behavior

Memes contribute to the emergence of collective cognition by providing shared symbolic structures and heuristics. They coordinate group behavior, stabilize social norms, and facilitate the transmission of complex cultural knowledge without direct instruction. Experimental evidence from twin studies, pidgin and creole language formation, and dialect emergence demonstrates that shared memes can scaffold novel communication systems, reinforcing both social cohesion and cultural innovation.

In this context, memes act as adaptive social regulators, aligning individual cognitive processes with group-level dynamics. Their persistence and selective amplification reflect both psychological biases and network effects, revealing a bidirectional influence between individual cognition and collective behavior.

3.4. Behavioral Implications in Aging and Neurocognitive Decline

Consistent with Sections 5 and 6, aging and neurodegenerative processes modulate memetic behavior. Older adults or individuals with PFC decline demonstrate increased reliance on emotionally resonant and previously reinforced memes, while integration of novel units is diminished. This shift alters group dynamics: meme-driven social influence becomes more conservative, emphasizing stability and emotional cohesion over innovation. At the behavioral level, this explains phenomena such as selective adoption of cultural narratives and resistance to new social information in older populations.

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3.5. Integrative Perspective

Taken together, these findings highlight that memes are multi-level behavioral regulators, simultaneously shaping cognition, emotion, and social organization. Their propagation reflects an interplay of neural architecture, psychological bias, and social structure, demonstrating that memetic dynamics are fundamentally embedded in both individual minds and collective systems. This synthesis reinforces the argument that memetic evolution must be analyzed through a neurobehavioral and sociocultural lens, bridging cognitive neuroscience, psychology, and sociology to explain both persistence and transformation of cultural information.

4. Limitations, Critical Perspectives, and Philosophical Considerations

While the present framework provides a comprehensive integration of neurobiology, genetics, and cultural transmission, several limitations warrant careful consideration. First, much of the evidence concerning memetic dynamics remains indirect, inferred from studies on memory, social cognition, and language acquisition. Direct empirical measurements of meme propagation at the neural or molecular level remain limited, and many proposed mechanisms, particularly the prenatal formation of proto-memes, are hypothetical and require targeted experimental validation.

Second, the interplay between memes and genetic pathways, though supported by correlations with genes such as FOXP2, ARHGAP11B, BDNF, and DRD4, is not yet fully causal. Behavioral and neuroimaging studies suggest strong associations, but disentangling cultural influence from innate predispositions remains challenging. Similarly, the precise mechanisms by which memes influence hormonal systems, modulate attention, or induce phenomena like the Mandela Effect require further neurophysiological and longitudinal research.

Third, the present framework emphasizes human universals, but cross-cultural variability in memetic propagation, social norms, and cognitive biases introduces complexities that are not fully captured. Memetic dynamics are likely contingent on cultural, historical, and environmental factors, limiting the generalizability of certain predictions.

A measured philosophical reflection may be warranted. Memes, as semi-autonomous cultural units, occupy an intermediate ontological status: neither purely material nor purely abstract. They operate through biological substrates yet retain a degree of independence, influencing thought and behavior in ways that challenge traditional notions of agency. This perspective invites a reconsideration of the boundaries between mind, culture, and biology, suggesting that human cognition is shaped not only by genes and neurons but also by persistent patterns of shared information.

Despite these limitations, the integration of neural, genetic, behavioral, and cultural evidence provides a novel conceptual scaffold for understanding memetic influence. By situating memes within neurogenetic and social contexts, this framework moves beyond metaphorical accounts toward testable hypotheses and mechanistic models, offering a foundation for future research in cognitive science, behavioral neuroscience, and cultural evolution.

5. Integrative Considerations and Transitional Synthesis

This section serves to consolidate key patterns emerging from previous analyses while subtly preparing for a comprehensive synthesis of memetic dynamics in the following section. The evidence suggests that memes function across multiple scales—neural, genetic, cognitive, and social—operating as adaptive yet partially autonomous units of information.

Throughout development, memes demonstrate both plasticity and conservatism. Early-life memetic acquisition exhibits high flexibility, supporting rapid learning, social imitation, and cultural innovation. With age, memetic structures become increasingly stable, interacting with the prefrontal cortex and limbic system to reinforce emotionally salient and frequently repeated units. In aging and neurodegeneration, older memes dominate cognitive and social processes, whereas novel or complex cultural information becomes less influential. This trend highlights the stage-dependent modulation

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of memetic influence, a phenomenon that emerges consistently across neural, behavioral, and sociocultural data.

Furthermore, the interplay between memes and biological systems underscores a reciprocal dynamic: memes are shaped by neural architecture and genetic predispositions while simultaneously influencing behavior, social interaction, and cultural evolution. Hormonal modulation, attentional allocation, and emotional salience all contribute to memetic propagation, illustrating that memes operate as biologically instantiated regulators of cognition and social organization.

This section also emphasizes the continuity across lifespan and systems, preparing the conceptual bridge for the concluding synthesis. The recurring themes—neurodevelopmental emergence, adolescent stabilization, adult propagation, and age-related conservatism—highlight a consistent pattern of memetic integration. By framing these dynamics systematically, we are positioned to consider their combined implications for cognition, culture, and the adaptive landscape of human society in the final discussion.

6. Synthesis and Integrative Conclusions

The cumulative evidence presented across the previous sections demonstrates that memes function as multiscale agents, influencing cognition, neural processes, behavior, and social organization. From prenatal proto-memes shaped by genetic and neural substrates, through early-life acquisition and adolescent stabilization, to age-related conservatism and neurocognitive integration, memes exhibit a lifespan trajectory that mirrors both biological and cultural evolution. Neurogenetic mechanisms—including the coordinated activity of genes such as FOXP2, ARHGAP11B, BDNF, DRD4, and SLC6A4—establish the substrate for memetic integration, while the prefrontal cortex and limbic system mediate both the propagation and modulation of cultural units. Emotional salience, attentional priority, and hormonal responses amplify certain memes, facilitating selective reinforcement and long-term retention. Aging and neurodegenerative processes shift the balance toward conservatism and emotional weighting, resulting in the persistence of well-established memes and the reduced influence of novel units.

Behaviorally and socially, memes operate as regulators of individual cognition and collective dynamics, shaping learning, cooperation, conformity, and cultural transmission. Network structures and social hierarchies further modulate their propagation, producing non-linear effects that reinforce collective memory, social norms, and shared identity. These interactions create a reciprocal system in which memes, neural substrates, and genetic predispositions co-evolve, continuously shaping and reshaping human cognition and culture. This integrated framework illustrates that memes are neither purely informational nor purely biological; they exist within an intermediate domain in which cultural, neural, and genetic factors intersect. By embedding memes in this multilayered system, we can reconcile classical memetic theory with empirical findings from neuroscience, psychology, behavioral genetics, and sociology.

In conclusion, the present synthesis supports a neurogenetic-cultural model of memetic dynamics, wherein memes act as active, semi-autonomous agents that: Influence memory, cognition, and emotion, Interact with genetic and neural systems to shape developmental trajectories, Modulate social behavior and cultural evolution, Persist adaptively across the lifespan, exhibiting both plasticity and conservatism.

By providing a unified conceptual scaffold, this framework offers a foundation for future empirical research and theoretical development. It underscores the importance of integrating biological, cognitive, and social perspectives to fully understand how cultural information propagates, evolves, and influences human life. Moreover, this synthesis establishes a logical transition to the Conclusion, where the broader implications for science, society, and the study of human cognition can be drawn.

Conclusions

This study presents an integrated framework for understanding memes as dynamic, multiscale agents embedded within neurogenetic, cognitive, and social systems. From prenatal formation through adolescence, adulthood, and aging, memes interact with neural circuits, genetic pathways, and behavioral mechanisms to shape cognition, emotion, and social behavior.

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By synthesizing evidence across neuroscience, psychology, genetics, and sociology, the work demonstrates that memes are neither purely cultural nor purely biological but occupy an intermediate domain in which information, brain, and social environment converge. This framework offers a foundation for future empirical studies, providing mechanistic hypotheses on how memes influence memory, social organization, and cultural evolution. In sum, memes function as adaptive yet semi-autonomous units, shaping human thought and behavior across the lifespan and highlighting the complex interplay between biology and culture.

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