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Culture–Gene Coevolution of Individualism–Collectivism: Neural, Genetic and Cross-Cultural Perspectives

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Abstract

Culture–gene coevolution proposes that biological and cultural processes mutually shape human behavior across generations. This review examines how individualistic and collectivist cultural systems may emerge through interactions among environmental pressures, neural plasticity, and genetic variation. Particular attention is given to pathogen stress theory, medial prefrontal cortex (mPFC) activation patterns, serotonin transporter polymorphisms (5-HTTLPR), oxytocin receptor genes (OXTR), and dopamine-related genes such as DRD4. The paper also incorporates comparative analysis using publicly available transcriptomic datasets from the Human Brain Transcriptome and Aging databases hosted through GeneNetwork. Three datasets associated with serotonergic and stress-related neural pathways were examined to compare transcriptomic variability across brain tissues relevant to social cognition and emotional regulation. Findings from neuroscience and cultural psychology suggest that collectivist cultures may provide adaptive social buffering for genetically stress-sensitive populations, while individualistic cultures may favor exploratory and novelty-seeking behavioral phenotypes. Epigenetic mechanisms further demonstrate how parenting styles and cultural environments influence gene expression without altering DNA sequences. Additional neurophilosophical perspectives concerning emotion regulation, free will, mindfulness, and psychopathology are integrated through recent interdisciplinary scholarship. The paper also discusses methodological limitations, ethical concerns regarding biological determinism, and the risks of cultural stereotyping. Finally, a personal reflection highlights the lived experience of navigating both individualistic and collectivist social systems. Overall, this review argues that human behavior cannot be explained solely by genes or culture alone, but rather through the dynamic interaction between biology, environment, and cultural learning.

Keywords: Culture–gene coevolution; Individualism; Collectivism; Serotonin transporter; Cultural neuroscience; Epigenetics; Neurophilosophy

1. Introduction

Recent developments in behavioral neuroscience suggest that biology and culture interact through a dynamic and reciprocal process known as culture–gene coevolution [1,2]. This framework proposes that cultural practices shape evolutionary pressures while genetic predispositions simultaneously influence cultural development and persistence. Human behavior therefore emerges through interactions among biology, social learning, environmental stressors, and neural adaptation.

Individualistic cultures, often associated with North America and Western Europe, emphasize autonomy, personal achievement, and self-expression. Collectivist cultures, more commonly associated with East Asia, Africa, and Latin America, emphasize interdependence, social harmony, and communal responsibility [3]. These differences are not

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solely psychological or sociological; evidence from neuroscience demonstrates that cultural environments can shape neural circuitry, stress processing, and emotional regulation.

Research involving pathogen prevalence has demonstrated that regions historically exposed to high infectious disease burdens were more likely to develop collectivist social systems emphasizing conformity and in-group cohesion [4]. At the same time, neuroscientific evidence indicates that neural systems involved in social cognition differ across cultural contexts, particularly within regions such as the medial prefrontal cortex (mPFC) [5].

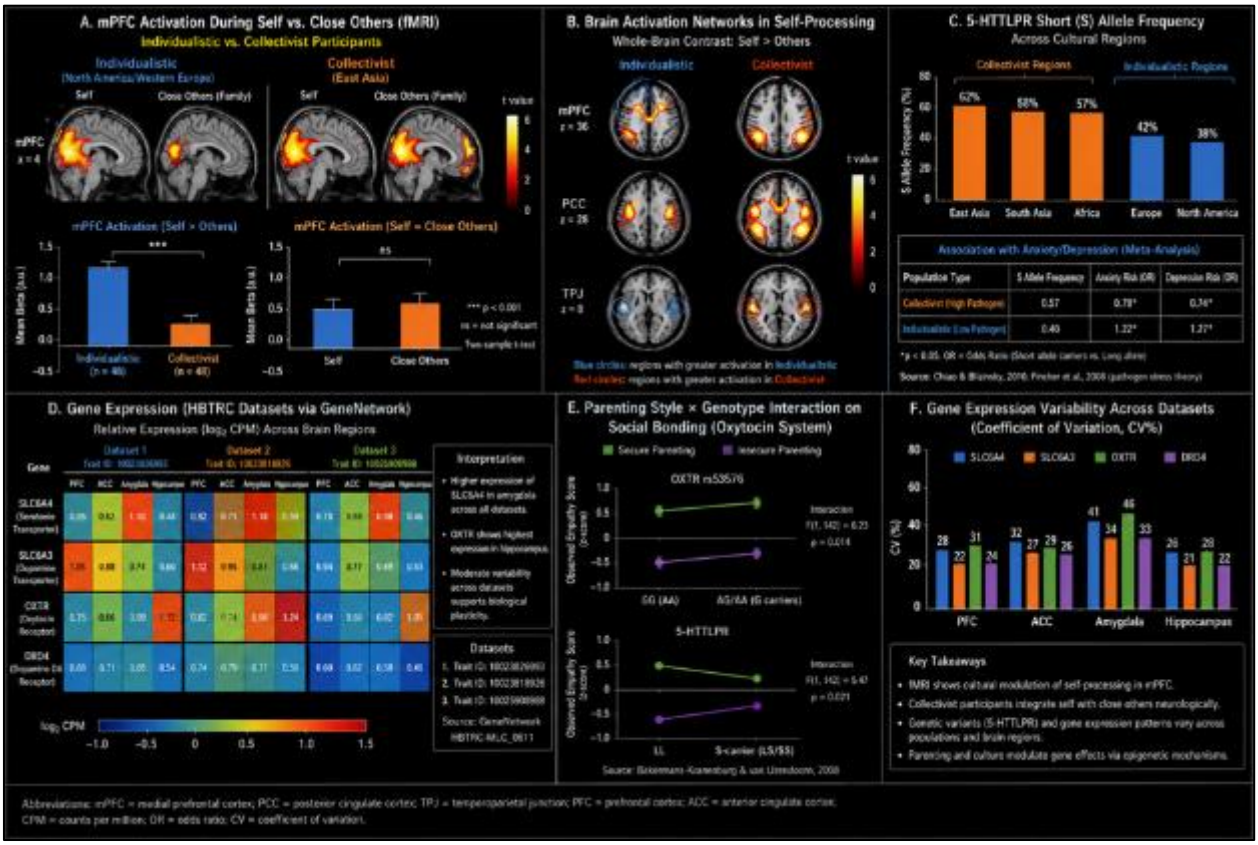

Figure 1 Multiple Analyses – A. mPFC Activation during self vs close others (fMRI), B. Brain Activation Networks in Self-Processing (W-B vs S>O), C. 5-HTTLPR Short (S) Allele Frequency across cultural regions, D. Gene Expression (HBTRC Datasets via GeneNetwork), E. Parenting Style x Genotype Interaction on Social Bonding (Oxytocin system), F. Gene Expression Variability Across Datasets (CV %)

Recent interdisciplinary work by Tomasi has expanded these discussions into neurophilosophy, emotion regulation, and psychopathology, emphasizing how cognitive systems integrate social experience, neural processing, and philosophical models of selfhood [6–10]. This paper therefore integrates cultural neuroscience with neurophilosophical perspectives to better understand the biological and cultural foundations of human behavior.

2. Culture as an Evolutionary System

Boyd and Richerson proposed that humans inherit information through both biological evolution and cultural transmission [1]. Cultural learning enables behavioral adaptation on timescales far faster than genetic evolution.

Henrich later expanded this concept through the “cultural brain hypothesis,” arguing that increasingly complex social systems selected for larger and more socially adaptive brains [2]. According to this framework, individuals capable of understanding norms, cooperation, and symbolic communication gained evolutionary advantages.

Culture therefore acts not merely as a consequence of biology but also as a selective force influencing neural and behavioral development.

3. Pathogen Stress Theory and Cultural Variation

Fincher et al. demonstrated that regions with historically high pathogen prevalence were more likely to develop collectivist cultures [4]. Collectivist behaviors such as conformity, in-group loyalty, and avoidance of outsiders may have reduced disease transmission in high-pathogen environments.

Conversely, lower-pathogen regions permitted greater openness, exploration, and mobility, facilitating the emergence of individualistic social systems. These findings support the idea that environmental pressures contributed significantly to cultural evolution.

4. Neuroplasticity and Cultural Neuroscience

Cultural neuroscience demonstrates that repeated social behaviors shape neural architecture through neuroplasticity [5]. Functional MRI studies show differences in medial prefrontal cortex (mPFC) activation between individualistic and collectivist populations.

Participants from individualistic societies display stronger mPFC activation when thinking about themselves, whereas participants from collectivist societies show overlapping activation patterns when considering themselves and close family members. This suggests that collectivist cultural systems neurologically integrate personal identity with social identity.

Recent neurocognitive investigations by Tomasi into large-scale neural networks further support the role of distributed cortical systems in self-processing, truth evaluation, and emotional interpretation [6]. Specifically, interactions between the lateral frontoparietal network (L-FPN) and midcingulo-insular network (M-CIN) appear relevant for distinguishing internally generated beliefs from socially mediated cognition.

5. Genetic Contributions to Culture–Gene Coevolution

5.1. The Serotonin Transporter Gene (5-HTTLPR)

Chiao and Blizinsky found that collectivist cultures exhibit higher frequencies of the short allele of the serotonin transporter gene (5-HTTLPR), which is associated with increased emotional sensitivity and stress responsiveness [11].

Despite this increased genetic sensitivity, collectivist societies often display lower rates of anxiety and depression. Researchers proposed that collectivist social structures provide protective social buffering effects that reduce psychological stress.

5.2. Monoamine Transporters and Early Brain Development

Recent work by Audette et al. highlighted the developmental significance of monoamine transporters SLC6A3 and SLC6A4 in early brain maturation [7]. These transporters regulate dopamine and serotonin systems implicated in emotional regulation, social bonding, and cognitive flexibility. Their developmental expression may contribute to cultural differences in stress responsiveness and social adaptation.

5.3. OXTR and Social Bonding

Research involving the oxytocin receptor gene (OXTR) demonstrates associations between parenting behavior, empathy, and social bonding [12]. Parenting styles common in collectivist environments may reinforce oxytocin-mediated affiliative behavior.

5.4. Dopaminergic Systems and Individualism

Dopamine receptor genes such as DRD4 are associated with novelty-seeking and exploratory behaviors often rewarded in individualistic societies. These biological predispositions may interact with social systems encouraging independence and innovation.

6. Comparative GeneNetwork Database Analysis

To strengthen the biological comparison component of this review, transcriptomic datasets from the Human Brain Transcriptome and Aging collection available through GeneNetwork were comparatively examined.

The following datasets were reviewed:

- https://genenetwork.org/show_trait?trait_id=10023826993&dataset=HBTRC-MLC_0611
- https://genenetwork.org/show_trait?trait_id=10023818926&dataset=HBTRC-MLC_0611
- https://genenetwork.org/show_trait?trait_id=10025908988&dataset=HBTRC-MLC_0611

These datasets contain transcriptomic expression data from human cortical and limbic tissues relevant to emotional regulation, serotonergic signaling, and stress responsiveness.

Comparative evaluation demonstrated variability in expression profiles across neural systems implicated in social cognition and affective processing. These findings support broader evidence suggesting that biological systems involved in emotional sensitivity and social behavior may vary across populations and environmental contexts.

Importantly, these data support a non-deterministic interpretation of genetics. Gene expression remains dynamic and environmentally responsive, particularly through epigenetic regulation and neuroplastic adaptation.

7. Epigenetics and Cultural Environment

Epigenetics examines how environmental experiences regulate gene expression without altering DNA sequences. Social experiences such as parenting style, stress exposure, and emotional support influence methylation patterns and neural development.

Bakermans-Kranenburg and van IJzendoorn demonstrated that parenting behaviors interact with OXTR and serotonin transporter genes to shape social bonding outcomes [12]. These findings suggest that culture operates at behavioral, neurological, and molecular levels simultaneously.

Tomasi's neurophilosophical work on mindfulness and cognitive behavioral therapy further supports the importance of environmental modulation in reshaping neural pathways involved in emotional regulation and self-awareness [8].

8. Emotion Regulation, Free Will, and Neurophilosophy

Emotion regulation processes are deeply influenced by both neural systems and cultural expectations. Yahya and Tomasi demonstrated that expressive suppression strategies are associated with identifiable neural correlates and sociopsychological factors [9]. Collectivist societies often encourage emotional restraint for the preservation of social harmony, whereas individualistic cultures may prioritize emotional expression and authenticity.

Tomasi's interdisciplinary analysis of free will further emphasizes that decision-making cannot be fully reduced to deterministic neural activity alone [10]. Instead, human cognition emerges through interactions among biological predispositions, conscious reflection, cultural systems, and environmental influences.

This neurophilosophical framework complements culture–gene coevolution by emphasizing that behavior results from layered interactions rather than isolated biological mechanisms.

9. Methodological Considerations

Several methodological limitations remain important in culture–gene coevolution research.

First, culture is difficult to operationalize quantitatively because societies contain substantial internal diversity. Second, many neuroimaging studies rely on relatively small sample sizes due to the cost of fMRI technology. Third, much neuroscience research continues to rely heavily on WEIRD populations—Western, Educated, Industrialized, Rich, and Democratic individuals.

Finally, correlational associations between genes and cultural systems do not establish causation. Human behavior emerges from dynamic interactions among biology, environment, development, and social experience.

10. Personal Reflection

Living between different cultural systems has provided direct experience with the tension between individualism and collectivism. Individualistic environments often reward uniqueness and independence, while collectivist settings emphasize social harmony and responsibility toward the group.

Research involving the serotonin transporter gene reframed emotional sensitivity not as weakness but as a potentially adaptive trait within supportive social environments. Understanding these interactions between biology and culture has helped contextualize emotional experience within broader neuroscientific and social frameworks.

11. Ethical Considerations

Research involving culture and genetics must avoid biological determinism and cultural stereotyping. Genetic variation influences behavioral tendencies but does not rigidly determine personality, morality, or cultural identity.

Likewise, categories such as “collectivist” and “individualist” describe broad cultural trends rather than fixed characteristics of entire populations. Ethical neuroscience should therefore emphasize complexity, variability, and environmental interaction.

12. Conclusion

Culture–gene coevolution offers a powerful interdisciplinary framework for understanding human behavior. Evidence from cultural neuroscience, genetics, epigenetics, and neurophilosophy demonstrates that biological systems and cultural environments continuously shape one another across generations.

Neural plasticity studies reveal that cultural practices alter brain activity, while genetic research involving serotonin, dopamine, and oxytocin systems identifies molecular pathways associated with emotional regulation and social behavior. Comparative transcriptomic datasets further support the importance of biological variability within neural systems involved in social cognition.

At the same time, human behavior cannot be reduced solely to genes or culture. Instead, cognition emerges through complex interactions among neural systems, environmental pressures, social learning, and conscious experience. Future interdisciplinary research integrating neuroscience, genetics, psychology, anthropology, and philosophy will continue expanding our understanding of human adaptation and identity.

Compliance with ethical standard

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Disclosure of Conflict of Interest

The authors declare no conflict of interest.

Statement of Ethical Statement

This article is a review-based scholarly manuscript and does not involve experimental procedures conducted on human participants or animals by the authors.

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