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Liminality in the Brain

Neuroplasticity and Transformation

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Der Beitrag verbindet neurowissenschaftliche Forschung zur Neuroplastizität mit dem anthropologischen Konzept der Liminalität. Er argumentiert, dass transformative Erfahrungen durch Phasen produktiver Destabilisierung entstehen, in denen stabile Selbst- und Weltmodelle vorübergehend aufgelockert werden. Auf der Grundlage von Konzepten des Rituals, Psychedelika, Kunst und Ehrfurcht wird die Hypothese entwickelt, dass solche liminalen Zustände erhöhte neuronale Flexibilität ermöglichen und so nachhaltige Veränderungsprozesse begünstigen können.

The brain does not have it easy. It needs to offer a stable neural foundation for reliable models of the self and the world around it, while at the same time staying adaptable and enabling meaningful transformation. This tension sits at the center of modern neuroscience. While this field of research is well able to describe how the brain reorganizes, the conditions under which transformation manifests neurally are not yet fully explored. To get a deeper understanding of this process and of the conditions under which transformation is enabled, this text proposes to synthesize two bodies of thought that address the problem of transformation from different perspectives: the network neuroscience of plasticity and the anthropological concept of liminality, as developed by Arnold van Gennep (1909/1960) and Victor Turner (1969). Both bodies of thought operate at different levels of description. Together, however, they suggest a framework for thinking about transformation as a phenomenon on multiple levels with identifiable neural signatures, phenomenological characteristics, and cultural forms. In order to show this, the following lines review findings from anthropology, psychology, and neuroscience to combine converging evidence on topics such as ritual, pharmacology, and art. When combined, these hint at an underlying phenomenon in which the organized self is temporarily expanded into a more destabilized network state that makes transformation possible. Importantly, the convergence proposed here is structurally suggestive rather than mechanistically established:

liminality and neural network science operate at vastly different levels, and how they relate to each other is not yet clear.

This attempt at integration fits into the emerging field of neuroanthropology, which has begun to address precisely this intersection, arguing that cultural practices shape neural architecture in ways that go beyond individual learning (R. Turner, 2015; R. Turner & Whitehead, 2008). Robert Turner's work is especially relevant. Drawing on neuroscience and the anthropology of his father Victor Turner, he argues that liminal states induced by ritual remove the cultural feedbacks that maintain prior social identity, thereby enabling modification of brain connectivity through synaptic plasticity and myelination (R. Turner, 2015, 2019). The following text builds on this idea to offer a generative hypothesis and to organize scientific findings along the question of how and when transformation takes place.

The brain's ability to change

The understanding of neuroplasticity begins with Hebb (1949). His principle, later summarized as "neurons that fire together wire together," became a fundamental idea of neuroscience. However, this formulation also constrained how plasticity was conceptualized: as fundamentally local and incrementally synaptic. Contemporary neuroscience has revised and broadened this picture. Plasticity is now conceptualized as a property of distributed neural systems across multiple spatial and temporal scales, including synaptic modulation (Malenka & Bear, 2004), white matter remodeling (Zatorre et al., 2012), and large-scale reconfiguration of functional connectivity patterns (Bassett & Sporns, 2017).

A fairly recent development applies network science to brain organization, modelling it as a dynamic graph of nodes (i.e., anatomical regions) and edges (i.e., functional or structural connections) that form modules and

networks. Research employing functional magnetic resonance imaging (fMRI), which uses the blood-oxygen-level-dependent signal to indirectly measure brain activity under different conditions and tasks, has identified particularly relevant large-scale networks: The default mode network (DMN), implicated in self-referential processing and autobiographical memory (Buckner et al., 2008), is anti-correlated under task conditions with the executive control network. The salience network mediates switching between these networks. Within these networks, experience-dependent reorganization occurs, positioning the brain at a dynamic balance between stability and flexibility (Deco et al., 2011). This text uses the term "neural flexibility" to refer to this ability of the brain to shift between functional network configurations, moving from segregated modular organization toward more globally integrated states and back again. This experience-dependent reorganization is itself well established, e.g., in adolescent development (Baker et al., 2025), adversity (Michael et al., 2025), and skill learning (Zatorre et al., 2012). The brain retains its capacity for reorganization, even during adulthood, but the given examples share a largely gradual, cumulative character, driven by sustained practice, maturation, or repair. The question motivating this text is different: not whether experience reshapes the brain, but whether certain acute conditions can open transient windows of heightened reorganization, and what constitutes "the right kind" of disruption to trigger this. This is where anthropological literature has something unexpected to offer.

Neither here nor there

Arnold van Gennep (1909/1960) proposed that rites of passage across many cultures share a common structure of three phases: separation, transition or liminality, and incorporation. Victor Turner (1969) explored the middle phase in his work and characterized the liminal subject as "neither here nor there; they are betwixt and between the positions assigned and arrayed by law, custom, convention, and ceremonial" (V. Turner, 1969, p. 95). This is not the absence of any structure, but has its own organization in the form of *communitas*, a mode of non-hierarchical boundary-dissolving sociality. The dissolution of prior identity is scaffolded and directed within a framework that manages instability and guides reintegration.

Evidence indicates that liminal states are induced through a consistent repertoire of practices: isolation from ordinary social life, altered food and sleep, rhythmic music, physical ordeal, and the suspension of normal social distinctions (Bell, 1997). All of them share the systematic alteration of the conditions that normally stabilize identity, such as social roles, routines, and interpretive frameworks through which a person maintains a coherent sense of self. Turner himself extended the concept beyond formal ritual, arguing that certain social movements, artistic practices, and periods of cultural transition share analogous structural characteristics (V. Turner, 1974). Nowadays, the term liminality has received widespread attention and is used in various manners: to describe a space or time, a short or long period, in psychotherapy, organizational theory and business consultation, societal and political crises, gender, and so on (Thomassen, 2009). This raises issues of overgeneralization and vagueness. Therefore, this text adopts a mechanistic definition of liminality as a temporary destabilization of stable self-organization followed by a directed reintegration process that offers procedural scaffolding to facilitate the emergence of a new stable organization.

The same shape at two scales?

It appears that liminality and neural flexibility describe similar phenomena on vastly different levels. Liminality, as inherently social and symbolic, constituted by cultural meaning and practice, might be supported on the level of the brain by the dynamics of neural flexibility, or liminal experiences might enable such dynamics within and between different brain networks, while the direction and nature of the relationship remain unclear. The following lines will explore possible explanations and examples of this structural resonance.

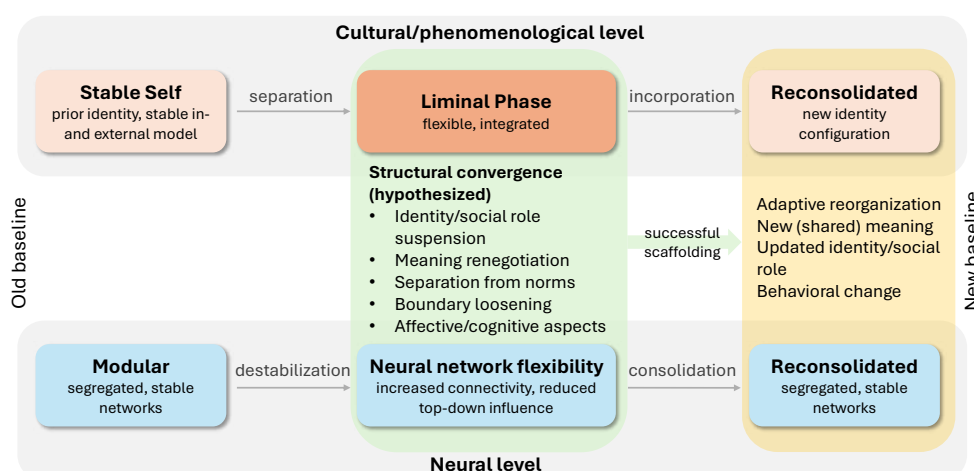
One framework that helps explain this convergence of liminality as neural flexibility comes from predictive processing accounts of brain organization (Friston, 2010; Clark, 2013). From this perspective, the brain operates as a hierarchical generative model, continuously generating predictions about incoming signals and updating itself on the basis of prediction errors. High-level predictions, including those constituting stable self- and world-models, are maintained with high confidence, exerting strong top-down influence on incoming sensory

input and remaining relatively resistant to revision. This prevents the self-model from being destabilized by every minor prediction error but also means that genuine reorganization requires conditions that temporarily reduce that top-down constraint. As mentioned, liminal conditions strip away top-down cultural and social feedback and thereby disrupt the stabilizing

frameworks normally maintaining identity in its current form to create windows in which the system becomes more receptive to reorganization.

On the network level, this corresponds to a shift in functional organization: a move away from segregated, modular network structure toward greater global integration (Cohen & D'Esposito, 2016). This means that the normally more segregated functional networks of the brain become more broadly interconnected. Metastability, understood as the delicate balance between local independence and global integration, captures this capacity for transition between configurations (Tognoli & Kelso, 2014). Recent research on psychedelics has provided an experimentally measurable model of this dynamic. Psychedelic conditions are associated with reduced functional modularity (Girn et al., 2023), increased global connectivity and reduced top-down influence (Carhart-Harris & Friston, 2019). Evidence of long-term changes in functional connectivity (Daws et al., 2022) is consistent with the view that temporary increases in neural flexibility can consolidate into lasting reorganization. Users of psychedelic substances describe ego dissolution and loosened self-boundaries (Nour et al., 2016), reflecting phenomenological similarities to the liminal condition. The psychedelic case differs from anthropological liminality in that it is missing cultural scaffolding and meaning-making, but its quantifiability makes it useful as a model system. Further, the therapeutic setting of clinical psychedelic use might function as substitute scaffolding that guides the liminal experience.

It is worth noting that Robert Turner (2015, 2019) comes to a similar conclusion through a different route. While



Schematic overview of structural parallels between liminality and neuroplasticity and their hypothesized convergence during liminal states.

he describes synaptic modification and myelination as the neural correlates of liminality, network neuroscience emphasizes large-scale changes in functional connectivity, modularity, and metastability. These approaches operate at different levels but come together on the same core claim that the liminal phase creates neurobiological conditions for transformation that ordinary experience does not.

The liminal in art and awe

Ritual and psychedelics are the most tractable cases, but also the most extreme. If the proposed convergence reflects something genuinely fundamental, some version of it should appear in more ordinary encounters with the world. Art and awe are candidates for this because they share liminality's defining feature as they may challenge existing self-models and, under some conditions, even motivate their revision. The framework becomes more speculative here, but also more generative.

Theoretical models (Pelowski et al., 2017) and a recent systematic literature review (Pizzolante et al., 2024) show that art encounters can indeed lead to what is called a "transformative experience". In their art perception model, Pelowski et al. (2017) describe the possibility of a transformative outcome occurring when felt discrepancy (i.e., how well one can integrate sensory input, meaning, emotion and embodied experience of the artwork with the existing self-model) and metacognitive self-awareness are high, motivating change in a schema relevant to the self. The evidence regarding neural correlates of this experience is still fragmentary,

but suggestive. Neuroimaging research has documented that peak aesthetic experiences not only recruit reward and attentional systems, but regions associated with self-referential processing, especially when the experience is felt as deeply moving rather than just beautiful (Vessel et al., 2012). More broadly, aesthetic experience systematically engages networks associated with self-referential and social cognition (Chatterjee & Vartanian, 2014). The most deeply moving encounters with art appear to activate the DMN and implicate the self-model directly. An aesthetic encounter that cannot be integrated without reorganization is, in this reading, a structurally related instance of the liminal dynamic.

One metacognitive and affective dimension often associated with transformative experiences, in art but also beyond, is awe. Awe has been shown to affect the self-concept (Shiota et al., 2007) and to diminish self-focused cognition, described by Piff et al. (2015) as a sense of the "small self." At the neural level, Guan et al. (2018) found that dispositional awe is negatively correlated with regional gray matter volume in areas associated with self-reflective cognitive control and self-regulation, which the authors interpret as the propensity to process self-relevant information more outward facing in relation to others. Similarly to aesthetic experience, the unsettling and expansive affective quality of awe may reflect what happens when incoming experience is too discrepant from existing self-models to be resolved by reinterpreting the input, requiring instead some revision of the model itself. In this sense, awe could be hypothesized as a signature of a self-model encountering something it cannot assimilate without changing. Indeed, awe has been documented as a correlate of transformative experience and changes in self-perception (Piff et al., 2015), consistent with the proposal that it produces temporary reductions in self-salience with downstream behavioral effects.

Insight and genuine conceptual learning might follow a related structural logic, albeit at a much smaller scale. The moment when an existing framework becomes inadequate, but a new one has not yet consolidated is phenomenologically uncomfortable: productive disorientation precedes understanding. While there is some evidence for neural markers of sudden insight (Kounios & Beeman, 2014), neuroscientific research in this domain has not yet focused on large-scale network dynamics. Conceptually, the "aha" moment may be understood as

the transition out of the liminal state, that is, the consolidation of a new configuration, though the timescales and neural magnitudes involved are substantially smaller than those operative in ritual or pharmacological contexts.

What the synthesis can and cannot claim

The examined cases share the structural pattern of a period of productive instability during which stable configurations are temporarily loosened, followed, when conditions are right, by the consolidation of new ones. While the scale and socio-cultural role of these cases vary enormously, the underlying pattern appears consistent. However, the evidence collected here comes mostly from separate lines of research and it has not yet comprehensively been shown that they reflect a single shared mechanism linked to liminality. Nonetheless, drawing on the presented literature, the extended understanding of liminality in social sciences, and the network properties of the brain, it is plausible to propose that transformation represents a multi-level process linking culturally structured disruption, alterations in neural organization, and the consolidation of new functional states. In this view, identity is neither fixed nor arbitrarily plastic, but continuously reconstituted through interactions between environmental structure, neural dynamics, and lived experience (Gallagher, 2013).

A key implication concerns the role of scaffolding. Liminality alone does not guarantee adaptive reorganization. Without appropriate structure, it may produce disintegration instead of transformation. Such structure is provided by the scaffolding of ritual liminality, the therapeutic frame, or the shared cultural meaning of aesthetic encounter, emphasizing its necessity and constitutive role for a successful liminal transition. This is in line with clinical findings that therapeutic outcomes following psilocybin-assisted therapy correlate not only with the intensity of the acute experience but with the quality of preparation and post-session integration (Haijen et al., 2018). Just as important are cases of failed destabilization. Szokolczai (2009) describes chronic conditions in which the reintegration phase never occurs, leaving an individual or community in unresolved instability. Destabilization needs to be embedded in a guiding setting to be successful. To assess what determines whether liminality consolidates into transformation or into collapse

requires an appropriate operationalization of "successful scaffolding" and remains an open empirical question.

Two further challenges require explicit acknowledgment: the level-of-analysis problem and the problem of causal inference. First, ritual liminality and neural metastability describe phenomena on different levels, ranging from social-symbolic to neurobiological. Translating between them leaves gaps and risks confounding variables, unclear causal chains, and oversimplification. Second, the causal inference problem refers to the fact that the association between liminal contexts and neural flexibility does not establish the causality of neural reorganization being necessary for liminality, nor of the causal direction running from experience to neural state rather than the reverse. These questions could only be resolved through longitudinal, controlled empirical research. Thus, the most defensible claim is that liminal contexts as culturally engineered conditions of structured instability reliably produce the experiential and environmental inputs that neuroscience associates with increased neural flexibility. Understanding transformation requires both levels of description simultaneously rather than reducing them to one level of explanation.

Where to look next

This claim leads to testable predictions. If liminal states are characterized by temporary increases in neural flexibility, contexts identified as liminal should produce measurable shifts in network dynamics such as decreased modularity, increased global efficiency, or increased metastability. Longitudinal designs are necessary, and cross-cultural comparisons could assess whether convergent neural signatures emerge across different cultural patterns. Comparisons across different liminal contexts could test for mechanistic equivalence. Further, identifying boundary conditions under which liminal conditions fail to produce adaptive reorganization is crucial. A complete account of transformation will need to specify the factors that determine whether the system successfully reconsolidates.

To go back to the beginning: the brain does indeed not have it easy. The tension of constantly balancing stability and flexibility remains. This essay has argued that to understand how our brains master this task, we perhaps need to look not only inside the brain but around it: at

the conditions that open windows of liminality. Across different phenomenological settings, a neural logic of productive destabilization seems to emerge. Whether this reflects a single underlying mechanism is a question that only cross-disciplinary empirical work can answer. For now, the synthesis proposed here is a hypothesis about where to look rather than a claim about what will be found.

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Zum Cover

Ein Schmetterling als Sinnbild für Metamorphose und Transformation: Auf seinen Flügeln trägt er symbolische Ausschnitte der vielfältigen wissenschaftlichen und künstlerischen Disziplinen, die PRO SCIENTIA ausmachen und die sich in einem stetigen Wandel befinden. Die mechanische Gestaltung des Schmetterlings greift diese Dynamik auf und verweist auf die gegenwärtigen Transformationsprozesse in Wissenschaft, Kunst und Gesellschaft. Dem Entwurf liegt eine handgemachte Collage mit Bleistiftzeichnung zugrunde, als Zeichen menschlichen, künstlerischen Schaffens im Kontrast zur immer mehr dominierenden Verwendung von "KI".

Francesca-Maria Raffler, Wien