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The mind's golden cage and cognition in the wild

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The mind has been traditionally conceived as a set of differentiated, compartmentalized cognitive elements. However, understanding everyday, naturalistic cognition across brain health and disease entails major challenges. How can mainstream approaches be extended to cognition in the wild? Pragmatic, methodological, disease-related, and theoretical turns are proposed for future scientific development.

The mind's golden cage

From its early philosophical origins, to cybernetics, to the computer metaphor, to the cognitive revolution, and finally to its current marriage with neuroscience, the cognitive sciences developed a powerful heuristic: *Divide cognition and conquer the mind*. The mind has generally been conceived as a set of specific, compartmentalized cognitive elements. Reified entities were initially proposed for reasoning, intelligence, and memory. Later theoretical developments (e.g., embodied, extended, enactive, distributed, situated cognition) and multilevel approaches strengthened our understanding of emotion, social interaction, body, and context [1]. The mind became situated although still compartmentalized.

Mainstream cognitive science has made progress by *domesticating cognition* (Figure 1, left), an approach following naturally from the conceptualization of the mind as a set of isolated mechanisms. In most experiments, participants are passively exposed to fixed stimuli. One or two cognitive processes are assessed via one or two modalities, with strict control over tasks and participants' behavior. This provides accurate correlates for fragments of methodically decomposed elements, such as bodiless faces, situation-independent words, or intention-blind interactions [2]. Most contemporary theories are based on applications of this analytic approach.

Although enormous knowledge about segregated phenomena that rarely manifest as such outside the laboratory has been accumulated, this success has become a golden cage. Domesticating cognition has yielded insights into fragments of the mind, but poses challenges to understanding cognition in everyday life.

Cognition in the wild, uncharted

Imagine a typical interaction with a parental figure and label your internal activity: you probably engaged in a blending of audiovisual attention, sensorimotor processing, memory, language comprehension/production, imaginary processing, body/face recognition, interoception, and mentalization. Even when internally simulated, processes traditionally classified as cognition, emotion, interoception, and so forth are spontaneously intertwined. Thus, although cognitive elements may be phenomenologically distinguished in the laboratory, this can obscure how different processes blend in the wild [2,3]. In this way, *cognition in the wild* differs critically from domesticated cognition. It involves synergetic blending and self- and environment-induced changes rather than instructions.

A trade-off between experimental control and ecological validity pervades the field. The greater the experimental control, the greater the distance from cognition in the wild. Similarly, associations between brain structure and function are complex and often nonlinear [3,4]. In complex phenomena, no single cognitive process seems uniquely related to a single brain area or process, and vice versa. Although network science provides a more dynamical view, the problem stands: is the salience or the executive network related to a particular process? [3,4]. Links between experimental and naturalistic cognition are fragile, limiting our understanding of brain–behavior associations.

Theories of isolated phenomena cannot adequately capture synergetic processes [3]. Generalist frameworks (i.e., predictive coding, dynamical system approaches to cognition [5]) have been applied to a variety of cognitive processes, but these 'theory of everything' [6] approaches are usually more successful as models of a specific (or a few) domain(s) than cognitive synergies. Similarly, neurocognitive theories have typically favored causal (linear) explanations, which are not well suited to assess individual differences and contextual dependencies under naturalistic settings [7]. Although multilevel explanations are encouraged in the field of embodiment and social neuroscience, in reality most cases are not truly multilevel (they involve simple associations between neural and cognitive measures). Cognitive science continues to create models of specific processes fit for observation in laboratory settings, but theories assessing cognitive synergies are rare.

Cognition in brain health and disease

Although brain health involves the appropriate coordination of cognitive, emotional, social, and behavioral functions, it is typically understood via disease models developed by clinical disciplines traditionally rooted in domesticated cognition.

Neurological and psychiatric disorders are generally associated with specific cognitive deficits, although most brain diseases do not entail a single cognitive deficit linked to one specific dysfunction (Box 1). For instance, mentalization deficits present in autism are accompanied by impairments

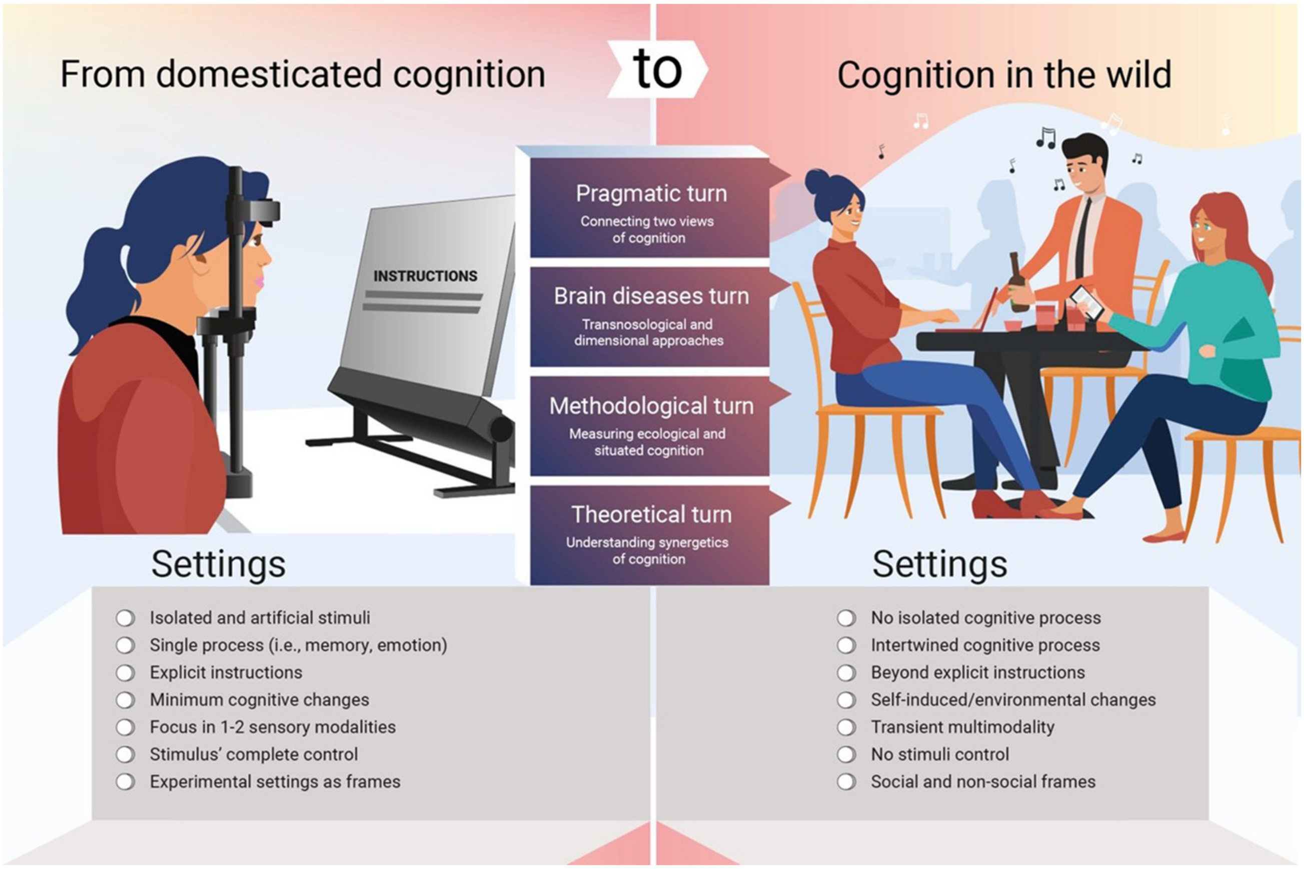

Figure 1. From domesticated cognition to cognition in the wild. Domesticated cognition (left panel) as observed in standard experiments. Participants passively respond to a specific, predetermined set of stimuli. Explicit instructions include to focus on the task and stimuli, to not move, and to avoid thinking or doing anything unrelated to the task. Typically, a single process (i.e., memory) is being evaluated. Stimuli entangle one or two modalities with strict control of stimulus properties. Isolated cognitive processes are being measured. Conversely, cognition in the wild (right panel) involves multiple processes spontaneously intertwined, unrestricted by explicit instructions, and with undetermined internal (cognitive) and external (environment) changes. The stream of cognitive processes is usually multimodal and multidimensional, and the environment does not provide a fixed stimulus control or an invariable social/nonsocial frame. Connecting domesticated cognition with cognition in the wild (center panel) may involve systematic and progressive pragmatic, brain-disease, methodological, and theoretical turns.

in working memory and executive functions. Meanwhile, motor disorders [i.e., Parkinson's disease (PD), amyotrophic lateral sclerosis] present deficits in social cognition. In dementia, disruptions of the orchestrating dynamics lead to disintegration of cognition and identity. Cognitive deficits across diseases are not only transdiagnostic but transcognitive.

Furthermore, a clinical neuropsychological setting provides an unchanged, structured, and highly predictive scenario. Consequently, cognitive performance does not always replicate cognition in the wild [8] and we do not know whether neuropsychological assessments have real-life significance for the patients.

Freeing cognition

Continuing on the aforementioned trajectories risks the accumulation of knowledge that does not capture naturalistic cognition [9]. How can the limits of the domesticated mind be surpassed to better assess cognition in the wild? I propose four avenues for progressive development (Figure 1, center).

Pragmatic turn

A first modest step is to better connect current experimental advances with naturalistic cognition. This necessitates the expansion of classical internal validation processes (control of stimulus, conditions, confounding) towards the identification of specific cognitive tasks (i.e., *bona fide* cases of compartmentalized cognition) that predict naturalistic cognition. External confirmation via double validation (in the laboratory and the field) may underscore the relevance of certain experimental approaches. Controlled results (i.e., different

Box 1. Nonlinear mapping of brain and cognition across diseases

Brain diseases provide links between unique cognitive impairments and structural brain(dys)function. However, revisited evidence of one-to-one mappings is more challenging than initially anticipated (Table I). The 'lesion model' surpasses correlative evidence of neuroimaging, although these models have accentuated simple associations between one cognitive deficit and specific damage [2]. Present evidence supports the degeneracy principle [10], where similarly impaired cognition across diseases is related to disparate cellular, molecular, regional, and network heterogeneity. For instance, moral cognition deficits are observed in patients with localized ventromedial prefrontal cortex (vmPFC) damage, diffuse frontotemporal neurodegeneration, white-matter abnormalities, or mesolimbic dopaminergic or serotonergic dysfunctions. The opposite is also true: disparate cognitive deficits are observed with similar biological impairments. The same mutation (*C9orf72*) can lead either to systematic social impairments (i.e., behavioral variant frontotemporal dementia) or to a predominantly motor disease (i.e., amyotrophic lateral sclerosis). Insular lesions are related to deficits of gustatory, olfactory, auditory, somatosensory, and multimodal perception, but also mood, action, language, empathy, emotion, executive functions, or addiction. Assessing one-to-one mappings is required to address domesticated cognition. Conversely, cognition in the wild calls for a dynamic and synergetic assessment of brain and behavior.

Table I. Reconsideration of classical mappings of brain structure and function[a]

Patient/condition	Structural damage	Domain	Structure or domain revisited
H.M.	Hippocampus (bilateral resection)	Memory deficits	Partially preserved hippocampus, other diffuse pathology, and lesions in distant regions (orbitofrontal cortex)
bvFTD	FTI degeneration	Social cognition deficits	Cognitive (memory, executive functions), mood (depression, apathy), and behavioral (disinhibition) impairments
SS lesions	SS cortex lesions	SS sensing deficits	SS cortex involved in body modeling, contextual updating, memory, motor output, and body simulations
Split brain	Callosotomy	Verbal vs. perception deficits	Left–right modularity has become outdated due to dynamical whole-brain interactions
PD	Basal ganglia neurodegeneration	Motor skill impairment	Brain systemic disease and cognitive deficits (action language, executive functions, social cognition, mood)
Phineas Gage	Ventromedial prefrontal lesion	Decision-making deficits	Extensive damage of gray matter and connections beyond the vmPFC
Tan	Broca lesion	Language production deficits	Additional damage to insular areas and disruption of connections projecting to distant regions

[a]Abbreviations: bvFTD, behavioral variant frontotemporal dementia; FTI, frontotemporo-insular; SS, somatosensory.

experiments on working memory performance) can be used to predict performance in naturalistic settings (i.e., multitasking during social–ecological interactions). Well-powered designs combining controlled and naturalistic experiments are needed to assess individual and contextual differences and to estimate generalizability from controlled to naturalistic scenarios.

Brain-disease turn

Both clinical and cognitive sciences can benefit from more dimensional (transdiagnostic) approaches to brain diseases. For the clinical sciences, cognitive commonalities across and within psychiatric and neurological disorders may better reflect the biology of disease. The Research Domain Criteria represents an initial attempt in psychiatry to promote the dimensional study of cognitive deficits across conditions, but it is still based on compartmentalized processes. Accordingly, physiopathological models based on the degeneracy principle (Box 1 [10]) that assess fuzzy, noncategorical, and transnosological cognitive deficits are better positioned to tackle the large disease heterogeneity. Although preliminary, synergetic models of allostasis and neurodegeneration capture multiple neural (molecular pathways, atrophy, connectivity) and cognitive (executive, social, interoceptive, inhibitory) dynamics. For cognitive science, the (i) combination of dimensional physiopathology with novel data science approaches, (ii) ecological assessments of cognitive dynamics, and (iii) development of more complex methods connecting different mechanisms can bring synergetic cognition into the context of brain diseases.

Methodological turn

The design of tasks resembling everyday cognition is critical. Various methods have started to avoid using repetitive, artificial stimuli and oversimplified scenarios [11]. Examples include natural speech analysis, multisensory evoked responses, hyperscanning of interacting individuals, citizen science large-scale data designs using naturalistic settings, and virtual reality. Future research should parametrically incorporate spontaneous cognitive changes and environmental demands, which modify settings in natural contexts. Technical developments such as machine learning of multivariate data, decoding of naturalistic actions, or self-organizing network analysis will help to progressively approach ecological phenomena [2,3]. Finally, advances in naturalistic designs, including wearable, remote, multisource recording technologies, and digital cognition may favor a better understanding of cognition in the wild.

Theoretical turn

Theorization on synergic cognitive phenomena should avoid strict cognitive categories in favor of transient, dynamic, anticipatory processes shaped by neural, bodily, and environmental architectures. This requires moving beyond current embodied and situated approaches based on compartmentalized processes. Although it is presently challenging, future theorization may assess cross-phenomenological synergies [2]. Each cognitive element must truly be considered a *process* that: (i) emerges from the interaction with other cognitive processes, (ii) is transient and dynamical according to contextual backgrounds, and (iii) presents high heterogeneity depending on (i) and (ii).

Behaviorally informed emergentist approaches may also help move us beyond a reflexive–passive view of cognitive processes [7]. Assessing synergetic phenomena [3] with whole-brain dynamical modeling and theorization can be a good starting point. In some models [12], the orchestration of widely distributed (cognitive and brain) states is supported by transient and emergent integrations of intermixed processes. The self-organization of multiple cognitive processes during naturalistic tasks can be modeled with global transient dynamics [2,3].

Finally, boundaries between disciplines require reconsideration. Transdisciplinary approaches combat academic compartmentalization and may lead to more holistic insights into the mind. The cognitive revolution developed such an approach, although based on the metaphor of the mind as a computer. A transdisciplinary approach based around cognition in the wild may better resemble naturalistic cognition.

Concluding remarks

Although shifts have already begun in some areas, a systematic fourfold turn towards naturalistic cognition as outlined here may bring the mainstream of cognitive science to the doorstep of cognition in the wild. Doing so may help science transcend the mind's golden cage.

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Declaration of interests

The author has no interests to declare.

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