Systematic Review Article

Barriers to Theoretical Convergence in Consciousness Research

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ABSTRACT

The field of consciousness research has shifted over the past decade from identifying neural correlates of consciousness toward developing and testing theories. However, rather than converging on a single theory, the field has seen a parallel progression of competing theories. To identify the structural factors behind this trajectory, this systematic meta-review examines 22 review articles published between 2010 and 2025 identified from PubMed and PsycNet which propose, evaluate, or compare one or more theories of consciousness, primarily focusing on Global Neuronal Workspace Theory (GNWT), Integrated Information Theory (IIT), Higher-Order Theory (HOT), Predictive Processing (PP), Orchestrated Objective Reduction (Orch-OR), and Recurrent Processing Theory (RPT). Three interconnected limitations were identified by comparison and critical analysis of the identified reviews: 1) definitional divergence, in which proponents of different theories embed their explanatory commitments directly into their definitions of consciousness; 2) context biased evaluation, in which theories are preferentially tested in experimental paradigms that reflect their own central commitments; and 3) the failure of integrative models to converge on a theory-independent model. Together, these factors help explain why empirical research has thus far produced theory-confirming rather than theory-discriminating evidence. Despite these challenges, the field shows signs of maturation: systematic and multi-theory reviews have become more common since 2020, and the introduction of adversarial collaboration represents a meaningful step toward bias-resistant theory evaluation. Future progress will require greater definitional transparency, increased use of theory-neutral experimental contexts, and broader adoption of preregistered, cross-theoretical research designs.

Keywords: Consciousness; GNWT; IIT; HOT; PP; Orch-OR; RPT; Adversarial Collaboration

INTRODUCTION

Following Francis Crick and Christof Koch's seminal work in 1990 which proposed the synchrony of gamma oscillations in the cerebral cortex as a neural basis for conscious experience, the field of consciousness saw a surge of activity (1). Researchers were determined to identify the neural correlates of consciousness—the minimal sets of neural processes required for specific conscious experiences—and in turn illuminate the location of consciousness within the brain (2–5). As the field matured, however, it became clear that the search for neural correlates had limited explanatory power for exactly how consciousness occurs (6, 7). Within the last decade, the field of consciousness has undergone a shift from identifying the neural correlates of consciousness toward developing and testing theories of consciousness (8, 9).

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The proposed theories of consciousness differ fundamentally, and a comparison of the various theories is valuable. Recurrent Processing Theory (RPT) attributes consciousness to recurrent feedback loops between brain regions (10), while Predictive Processing (PP) describes consciousness as a product of the brain's continuous effort to predict and explain incoming sensory information (11), and Higher-Order Theories (HOT) propose that phenomenal experience arises from the brain's meta-awareness of thought (12). Quantum theories of consciousness have also been proposed, with Orchestrated Objective Reduction (Orch-OR) being the most prominent (13). Orch-OR attempts to explain consciousness as a phenomenon caused by quantum effects such as entanglement and superposition in microtubules.

In a crowded field, two leading theories of consciousness have emerged: Global Neuronal Workspace Theory (GNWT) and Integrated Information Theory (IIT). GNWT proposes that phenomenal consciousness arises when information is globally broadcast across a widespread network of neurons in the brain in a sudden, non-linear process known as ignition, and it emphasizes the importance of the prefrontal cortex for consciousness (14, 15). In contrast, IIT asserts that consciousness is the capacity of a system to integrate information—in other words, the extent to which a system is irreducible to the sum of its parts—and proposes a posterior hot zone as the primary area responsible for consciousness (16). GNWT and IIT disagree over what can be considered conscious: GNWT solely describes the brain, while IIT suggests that any object may experience consciousness minimally given a sufficient amount of integrated information (17).

In recent years, attempts have been made both to reconcile these differences and to identify weaknesses in either theory (18, 19). Yet, much of the empirical evidence points to a concerning pattern: proponents of various theories often seem to introduce preconceived biases into research, to the point that a 2022 review by Yaron *et al.* was able to consistently identify which theories different consciousness studies supported purely from their experimental designs. Yaron *et al.* identify a "parallel progression of leading theories" rather than the gradual emergence of one individual theory (20).

This paper presents a meta-review, analyzing 22 review articles that propose, evaluate, or compare theories of consciousness. The six focal theories analyzed in this systematic meta-review (GNWT, IIT, HOT, PP, RPT, and Orch-OR) were pre-specified because they emerged as the most commonly discussed theories in a preliminary literature search. The study's objective is to evaluate how the included reviews variably present conceptual definitions, experimental contexts, and integrative models, while critically examining the methodological biases in the proposed models. The "theoretical convergence" of consciousness is considered, defined as the reconciliation of multiple competing theories of consciousness into a theory-independent model. Finally, to evaluate claims of theoretical convergence, this analysis distinguishes between alignment at the levels of mathematical formalism and biological mechanism.

METHODS AND MATERIALS

Records were identified from PubMed (n = 567) using the following search string, with the respective name of each theory as follows: ((“integrated information theory”[Title/Abstract] OR “IIT”[Title/Abstract]) AND (“consciousness”[Title/Abstract]) AND (“2010”[Date - Publication]:“3000”[Date - Publication]) AND (english[Language])); ((“global neuronal workspace theory”[Title/Abstract] OR “GNWT”[Title/Abstract]) AND (“consciousness”[Title/Abstract]) AND (“2010”[Date - Publication]:“3000”[Date - Publication]) AND (english[Language])); ((“higher-order theory”[Title/Abstract] OR “HOT”[Title/Abstract]) AND (“consciousness”[Title/Abstract]) AND (“2010”[Date - Publication]:“3000”[Date - Publication]) AND (english[Language])); ((“recurrent processing theory”[Title/Abstract] OR “RPT”[Title/Abstract]) AND (“consciousness”[Title/Abstract]) AND (“2010”[Date - Publication]:“3000”[Date - Publication]) AND (english[Language])); ((“predictive processing theory”[Title/Abstract] OR “PP”[Title/Abstract]) AND (“consciousness”[Title/Abstract]) AND (“2010”[Date - Publication]:“3000”[Date - Publication]) AND (english[Language])). Identical searches were conducted in PsycNet; however, all records identified through this database were duplicates of records already retrieved from PubMed. 2010 was chosen as a starting date to focus on recent work in the field. Included research papers were required to be reviews published in an English-speaking journal that addressed at least one theory of consciousness. Additionally, a supplementary citation search was conducted to identify additional high-impact papers (those with > 90 citations) (n = 5). Duplicates (n = 80) were removed by hand, and then the remaining records (n = 492) were screened for the proposal, evaluation, or comparison of one or more theories of consciousness, and all deficient papers (n =

282) were removed. The remaining reports (n = 210) were screened for type of paper, and only reviews (n = 22) were included. All non-reviews (n = 188) were excluded. While no protocol was registered, the PRISMA reporting guideline for reviews of reviews was otherwise followed. See PRISMA diagram in Figure 1.

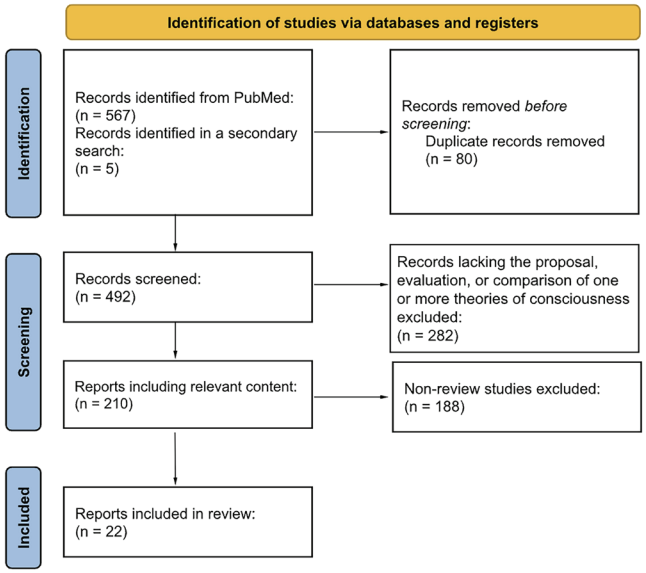

Figure 1. *PRISMA flow diagram showing the identification, screening, eligibility assessment, and final inclusion of review articles in this systematic meta-review. Records were retrieved from PubMed and PsycNet and supplemented through citation searching. After duplicate removal and screening, 22 review articles were included in the final synthesis.*

RESULTS AND DISCUSSION

Characteristics of Included Reviews

The reviews studied were published between 2013 and 2025 and had a broad international distribution with 13 different countries represented (Table 1). The included reviews examined a wide range of theories of consciousness. This paper focuses on the six most prevalent theories (GNWT, IIT, HOT, PP, Orch-OR, & RPT). GNWT (n = 14) and IIT (n = 12) were the most represented theories, appearing in 14 and 12 papers out of 22 respectively. Orch-OR was the least frequently examined theory (n = 3) (21–23). Figure 2 presents the number of reviews considering each theory. Nine of the 22 included reviews examined multiple theories (n = 9). Only one paper considered all six theories (n = 1) (23). 13 of the 22 papers considered a single theory alone, with five papers considering solely GNWT, three considering solely IIT, four considering solely PP, one considering solely Orch-OR, and none considering HOT or RPT alone (Table 1). While these single-focus reviews can offer an in-depth analysis of the included theory, they may suffer from the absence of cross-theory examination, which has the potential to provide new insights.

Most of the included reviews were non-systematic (n = 19). Only two systematic reviews were identified (20, 22), along with one partially systematic review (24). All three of these reviews were relatively recent, being published in 2021, 2022 and 2024, suggesting that the field is moving toward a more systematic approach. The non-systematic nature of earlier reviews indicates a risk of bias in those studies.

Table 1. Characteristics of the included review articles by theory of consciousness and experimental or clinical context. *The table summarizes the 22 review articles included in this systematic meta-review, arranged by first author and publication year. The Theories column identifies the theories of consciousness examined in each review, while the Context column indicates the experimental or clinical setting in which consciousness was investigated. "Various" denotes reviews covering multiple contexts, and "N/A" indicates that no specific context was identified. GNWT = Global Neuronal Workspace Theory; IIT = Integrated Information Theory; HOT = Higher-Order Theory; PP = Predictive Processing; Orch-OR = Orchestrated Objective Reduction; RPT = Recurrent Processing Theory.*

First Author	Year	Country	Theories	Context
Tagliazucchi, E	2013	Germany	GNWT, IIT	Sleep
Bartolomei, F	2014	France	GNWT	Focal epilepsy
Michel, M	2017	France	GNWT	Anterior insular cortex
Havlik, M	2017	Czechia	PP	Mind-wandering
Pinto, Y	2017	The Netherlands	GNWT, IIT	Split brain

Continued Table 1. Characteristics of the included review articles by theory of consciousness and experimental or clinical context. *The table summarizes the 22 review articles included in this systematic meta-review, arranged by first author and publication year. The Theories column identifies the theories of consciousness examined in each review, while the Context column indicates the experimental or clinical setting in which consciousness was investigated. "Various" denotes reviews covering multiple contexts, and "N/A" indicates that no specific context was identified. GNWT = Global Neuronal Workspace Theory; IIT = Integrated Information Theory; HOT = Higher-Order Theory; PP = Predictive Processing; Orch-OR = Orchestrated Objective Reduction; RPT = Recurrent Processing Theory.*

First Author	Year	Country	Theories	Context
Fazekas, P	2018	Belgium	GNWT	Dreams
Hong, C	2018	USA	PP	Sleep
Olcese, U	2018	The Netherlands	PP	Conscious and nonconscious brain states
Li, T	2019	China	Orch-OR	N/A
Hutchinson, B	2019	Australia	GNWT	Inattentional blindness
Cofré, R	2020	Chile	IIT	Altered states of consciousness
Mashour, GA	2020	Various	GNWT	Various
Northoff, G	2020	Various	GNWT, HOT, IIT, PP, RPT	Various
Rorot, W	2021	Poland	PP	N/A
Sattin, D	2021	Italy	GNWT, HOT, IIT, RPT, Orch-OR	Various
Seth, A	2022	Canada	GNWT, HOT, IIT, PP, RPT, Orch-OR	Various
Yaron, I	2022	USA, Israel	GNWT, HOT, IIT, RPT	Various
Tse, PU	2024	USA	IIT	N/A
Cea, I	2024	Chile	IIT	N/A
Promet, L	2024	Germany	GNWT, IIT, PP	Various
Storm, JF	2024	Various	GNWT, IIT, PP, RPT	Various
Mudrik, L	2025	Various	GNWT, HOT, IIT, PP, RPT	Various

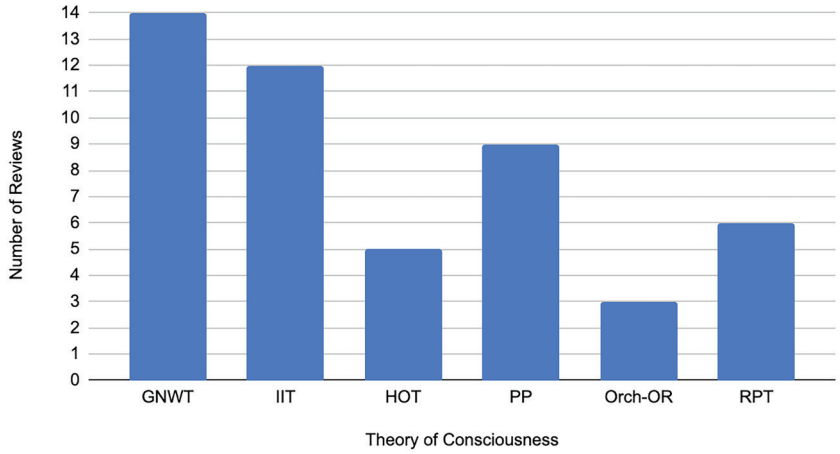

Figure 2. Number of included review articles addressing each focal theory of consciousness. *The six focal theories were Global Neuronal Workspace Theory (GNWT), Integrated Information Theory (IIT), Higher-Order Theory (HOT), Predictive Processing (PP), Orchestrated Objective Reduction (Orch-OR), and Recurrent Processing Theory (RPT). Because some review articles examined more than one theory, the total number of theory counts (49) exceeds the number of included reviews (n = 22).*

Defining Consciousness

One of the contributing factors to the "parallel progression of leading theories" is a lack of agreement regarding the definition of consciousness. While theories of consciousness ultimately aim to explain consciousness rather than merely describe it, the field is overloaded with distinct operational definitions. One of the included papers was a scoping review analyzing 29 theories of consciousness from 68 records published between 2007–2017 (22). The authors identified one or more frequent definitions used by proponents of each theory, and found that over 20 new terms relating to the sub-categorization of consciousness were proposed. As an example, Yu and Blumenfeld described consciousness as "the ability to maintain an alert state, attention, and awareness of self and environment," emphasizing its behavioral and clinical dimensions (25). In contrast, Georgiev defined consciousness as "the subjective character of our mental states," aligning consciousness with phenomenality rather than functional capacity (26).

Across the included reviews, proponents of different theories often embed their explanatory commitments directly into their definitions of consciousness. A comparison of definitions from studies advocating for IIT and GNWT reveals this. IIT defines consciousness in terms of integrated information, proposing that consciousness can be quantified based on the number and availability of conscious experiences and the "unity" of each conscious experience. In their 2020 review, Tse *et al.* state that "a physical system of interacting parts is conscious if it has a maximum of integrated information" (27), referring directly to the mathematical framework established by IIT (16). In their 2014 review of alteration of consciousness in the context of GNWT, which claims that consciousness arises when information is broadcast globally across a network, Bartolomei *et al.* define consciousness as "global availability of information through the workspace" (28). This trend, where each theory is accompanied by a congruent definition of consciousness, suggests underlying confirmation bias in consciousness research.

Definitional pluralism in consciousness research is not inherently problematic but becomes an obstacle when definitions are treated as theory-neutral or exhaustive. Different definitional approaches may be appropriate for distinct explanatory aims, such as clinical assessment, phenomenological description, or formal modeling, but future progress will require greater transparency regarding which aspect of consciousness a given definition is intended to capture, and which aspects it necessarily leaves unaddressed.

Contexts for Studying Consciousness

The studies included in this review investigated consciousness across a diverse range of experimental and clinical contexts. These included sleep (29, 30), focal epilepsy (28), mind-wandering (31), split-brain patients (32), dreams (33), inattentional blindness (34), and altered states of consciousness (35). While this variety represents the breadth of research on different aspects of consciousness, it also complicates theory comparison. A theory that takes dreaming as a conceptual starting point may not adequately explain split-brain phenomena, for example. Support for a theory within a particular context of consciousness does not necessarily indicate explanatory success across consciousness as a whole.

In the papers analyzed, each theory of consciousness was evaluated in a different set of contexts. For example, GNWT was frequently examined in contexts involving large-scale information sharing, such as focal epilepsy, split-brain patients, and inattentional blindness (28, 32, 34). IIT was studied through altered states of consciousness and split-brain phenomena, contexts that directly investigate the integration and unity of conscious experience (32, 35). Predictive processing was examined through mind-wandering and changes between conscious and nonconscious brain states, which naturally emphasize predictive inference (31, 36). This pattern suggests that theories are often evaluated in contexts that reflect their central explanatory commitments, potentially limiting opportunities for genuinely theory-neutral comparison. These results support the findings of Yaron *et al.*, who analyzed studies from 2001 to 2019 and found that support for major theories of consciousness was often highly dependent on experimental design and methodological choices (20). Across all of the papers published before 2020, sleep was the only context that all three of these theories were studied in, suggesting that sleep might be a viable theory-neutral background for investigation.

This challenge has recently begun to be addressed in the field. Whereas many reviews published before 2020 (including the papers analyzed by Yaron *et al.*) focus on a single context of consciousness (20), those published after 2020 tend to compare results across various contexts and theories of consciousness or focus on broader theoretical synthesis (9, 15, 18, 22–24, 37).

Criteria for an Accepted Theory of Consciousness

A viable theory of consciousness must explain not only what consciousness is, but also how it arises. Successful theories should differentiate between conscious and

unconscious systems and identify the factors responsible for this distinction. They must also address both the functional purposes and the phenomenal character of consciousness. Finally, any successful theories must provide a satisfactory answer to the "hard problem of consciousness," namely how and why physical brain processes give rise to subjective experiences, such as the redness of red (38). In the reviews analyzed, several different integration attempts have been proposed, which are not necessarily equivalent.

Wanja Wiese formalized the idea of a minimal unifying model (MUM), which aims to unify common assumptions across existing theories of consciousness (39). A MUM is minimal in that it identifies only the fundamental characteristics of consciousness and does so with limited specificity and explanatory commitment.

However, while a MUM purports to capture common ground among theories, in several of the papers reviewed theories of consciousness were found to share a conceptual core (23, 40). Consequently, it becomes difficult to determine whether agreement among theories may not represent independent convergence on minimal truths about consciousness. Instead, it may reflect the recurrence of assumptions and concepts that are already widespread in the theoretical landscape.

While the Minimal Unifying Model approach and similar integrative strategies aim to synthesize the most robust, universally supported mechanisms across theories of consciousness, they paradoxically yield disparate conclusions. For instance, the MUM approach has been applied within predictive processing and Bayesian contexts by Rorot (40). By remaining comparatively non-committal about specific biological mechanisms, this formulation leans heavily toward computational measures like precision and complexity. Conversely, other integrative efforts reject this biological minimalism in favor of concrete mechanisms. In their review searching for a convergence of theories, Northoff and Lamme propose temporo-spatial dynamics as a possible link or "common currency" between neuronal and phenomenal states, ultimately highlighting Northoff's Temporo-spatial Theory of Consciousness (TTC) (9). In another of the papers analyzed, Storm *et al.* propose Dendritic Integration Theory (DIT) for how it seemingly bridges gaps between other leading theories like GNWT, IIT, and RPT (18).

Ultimately, if these integrative models were strictly capturing a single, theory-independent set of minimal truths, they would theoretically converge. Instead, the several non-equivalent attempts to integrate the models of consciousness, such as computational measures and Bayesian inference, temporo-spatial dynamics, and dendritic hardware illustrates that "unifying" models remain deeply shaped by the specific methodological lenses through which they are constructed.

Adversarial Collaboration

Recently, a new research approach, called adversarial collaboration, has entered the field of consciousness. Adversarial collaboration is a research method where researchers of conflicting viewpoints collaborate in the formation and implementation of an experiment in order to fairly test a variety of perspectives, reduce bias, and jointly advance knowledge. Adversarial collaborations in other fields have helped break stalemates similar to the state of consciousness research. Coles *et al.* performed an adversarial collaboration that tested the facial feedback hypothesis, which claims that facial expressions not only express emotional experiences but can in fact influence them (41). Some collaborators were advocates of the hypothesis, some were critics, and some were neutral. The study found both supporting and conflicting evidence for the hypothesis. These results are especially valuable as their validity is agreed upon by all collaborators, bringing new mutually accepted evidence into the field.

In 2025, the leading proponents of IIT and GNWT, as well as a theory-neutral consortium, published the first adversarial collaboration in the field of consciousness (19). The study directly compared conflicting predictions of IIT and GNWT. Researchers were required to preregister both their predictions and their interpretation of possible results, helping eliminate confirmation bias. The collaboration identified challenges in both IIT and GNWT, some of which are relevant to other theories of consciousness. The study is significant in consciousness research because it produces points of agreement between proponents of different theories.

Limitations of this Meta-Review

Several limitations must be considered when interpreting the findings of this meta-review. First, there is method heterogeneity among the included reviews, which vary in design, scope, theory coverage, and experimental context. Additionally, since these reviews likely synthesize many of the same primary studies, there is a risk of evidentiary dependence. This overlap introduces the risk of double-counting, where a single influential finding may be disproportionately amplified across multiple reviews, artificially inflating

the perceived consensus for a given theory. Furthermore, there is an unequal representation of theories within the analyzed literature. Theories such as GNWT and IIT are heavily represented while theories such as Orch-OR are sparsely covered. This imbalance may skew this meta-review's overarching conclusions toward the most dominant models, potentially obscuring insights from less prominent theories. These interpretative limitations are compounded by the predominantly non-systematic nature of the included reviews, which often lack the standardized search protocols necessary to prevent selective sampling and bias.

Additional methodological limitations must be acknowledged as well. Literature searches were limited to the PubMed and PsycNet databases, and only papers published in English were considered. Various interdisciplinary topics such as philosophy and computer science were omitted. The supplemental sources found in the second round of searches needed to meet a threshold of 90 citations, potentially leaving out further significant sources. Next, while this meta-review generally followed PRISMA guidelines, no protocol was registered, which increases the possibility of bias in the analysis. Finally, the three themes identified and examined in this meta-review were subjectively determined by the author, which introduces another potential source of bias. Because they are highly interpretive, these themes may exclude meaningful differences across the reviews analyzed.

CONCLUSION

This meta-review of 22 reviews published between 2013 and 2025 identified three limitations that help explain the field's "parallel progression of leading theories" rather than convergence on a single theory. The most pervasive was definitional divergence: different theories of consciousness define the phenomenon across different explanatory commitments. IIT defines consciousness in terms of integrated information, whereas GNWT defines it as the global availability of information. These definitions do not only describe consciousness differently; rather, they establish different explanatory targets and standards of evidence. Compounding this issue, theories are frequently evaluated in contexts that reflect their own central commitments, making genuinely disconfirmatory evidence difficult to obtain. This may help explain why Yaron *et al.* were able to predict which theories various studies supported based solely on their experimental designs (20). Integrative efforts such as Minimal Unifying Models have not fully resolved this pattern. Rather than aiding convergence on a theory-independent model, they often reproduce the methodological assumptions of their authors.

However, it is important to acknowledge that the three identified limitations should be viewed as themes interpreted from the literature. They must be considered in light of the meta-review's limitations, particularly the significant method heterogeneity, the predominantly non-systematic nature of the analyzed reviews, and the limited databases used to search for sources.

Despite these limitations, the analysis conducted in this meta-review indicates that the field shows signs of maturation. Systematic and multi-theory reviews have become markedly more common since 2020, and the 2025 Cogitate Consortium adversarial collaboration—which included preregistration of both predictions and interpretive criteria—directly addressed forms of confirmation bias that have long complicated theory evaluation. Future progress will likely depend on expanding such approaches, increasing the use of cross-context and theory-comparative research, and achieving greater transparency regarding what each definition of consciousness is intended to explain. Few questions in science and philosophy are as fundamental as understanding the nature of conscious experience. While a definitive answer remains elusive, recent methodological developments provide a credible path toward more rigorous and cumulative progress.

CONFLICT OF INTEREST

The author declares that there are no conflicts of interest related to this work.

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