Social Sciences
2025, Vol. 14, No. 2, pp. 78-86
https://doi.org/10.11648/j.ss.20251402.12

Research Article

Adaptive Representation: A Moderate Stance on Predictive Processing

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Abstract

Predictive processing (PP), emerging as a novel research paradigm in contemporary cognitive science, offers a departure from both traditional computational representation views and 4E+S cognition perspectives. This theory advocates that the brain is a hierarchical prediction model based on Bayesian inference, which aims to minimize the difference between the predicted world and the actual world to prediction error minimization. In recent years, the problem of representation has emerged as a focal point in the philosophical examination of PP. This article introduces two primary strands of PP theories: conservative predictive processing (CPP) and radical predictive processing (RPP). Building upon these frameworks, it outlines three distinct positions regarding the representation problem within PP: representationalism, anti-representationalism, and a moderate stance on representations. Lastly, the article proposes a new perspective on representation: Adaptive Representation. Adaptive representation highlights the fact that generative processes are adaptive processes, and that adaptation is not necessarily optimal, whether based on natural selection or natural drift; and that generation is at the same time a representational process. By advocating for a form of weak representationalism grounded in adaptive processes, this perspective supports a moderate stance on representations within PP.

Keywords

Predictive Processing, Adaptive Representation, Representationalism, Anti-representationalism, Structural Representation

1. Introduction

The study of the mind is closely intertwined with cognitive science. From the mid-1950s to the 1980s, computationalism emerged as the dominant paradigm in the first generation of cognitive science. However, since the mid-1980s, the second generation of cognitive science has challenged this paradigm, ushering in the new era of cognitive science, notably through the incorporation of 4E Cognition. In recent years, predictive processing (PP) has garnered attention, suggesting that the brain functions as a predictive machine, continually matching sensory inputs with top-down expectations or anticipations to guide perceptions and actions [1, 2]. This perspective, known as the PP of mind, has begun to permeate various domains of cognitive science, including attention, emotion, and consciousness. Initially, it was anticipated that PP would serve as an integrative paradigm capable of unifying diverse aspects of the mind.

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Received: 30 January 2025; **Accepted:** 17 February 2025; **Published:** 11 March 2025

The problem of representation is a central thesis in the philosophical study of PP. Clark [3] argues that the emergence of PP theory has put an end to what he calls the "Representation Wars" in a modest way. Constant and others [4] show how both representationalism and dynamitist sensibilities can peacefully coexist within the new territory of active inference. Christias [5] supports this moderate representational position with the phrase "contentless representationalism". In contrast to the moderate position, there are also two opposing radical positions. One position holds that PP is a theory of representation that serves a genuine representational function in cognitive systems [6, 7]. The opposite position holds that PP can't have and doesn't need representations to do its explanatory work [8-10].

The representational problem of PP primarily revolves around the "job description challenge" put forth by Ramsey [11]. However, Ramsey's criterion may not be well-suited for establishing a strong distinction between two different types of predictive processing [12]. Therefore, this paper proposes a new perspective on the representation of predictive processing in terms of adaptive representations. This paper aligns with Clark in advocating for a moderate view of representation [13].

The paper posits that PP fundamentally operates as an adaptive representation process. The predictive error minimization mechanism within PP theory, coupled with Bayesian predictive coding, implies that the human cognitive system functions as an adaptive representational system. This cognitive system arises from the adaptation of living organisms to their environments. It suggests that the cognitive realm emanates from the natural world, yet it exists independently of it. The interaction between the cognitive system and the natural world yields knowledge (representations), thus rendering the knowledge-generation process as one of adaptive representations.

The paper is structured as follows: In Section 2, The paper introduces the PP theory in detail and point out the connections and differences between two different PP theories. In Section 3, The paper delves into three positions regarding the PP representation debate, highlighting the shortcomings of each. Section 4 presents argument that adaptive representations can bolster the moderate position described earlier and address its limitations. Finally, in Section 5, The paper offers a summary of arguments and provide a glimpse into future directions.

2. Two Different Types of PP

The theoretical origins of predictive processing can be traced back to the concept of "unconscious reasoning" proposed by Hermann von Helmholtz, a German physicist and psychologist, in the 19th century. Helmholtz posited that perception gives rise to intrinsic noise, manifesting as interference in the transmission of sensory information and ambiguous signals from various senses, including vision and hearing. He conceptualized perception as a Bayesian inference process, wherein prior beliefs or expectations are reconciled and compared with sensory data to generate a "best prediction" or, in Bayesian terms, to determine the most likely cause of the current sensory input [14]. These causes, termed hidden causes, operate at an unconscious level, with individuals typically being aware only of the resultant perceptual outcomes rather than the underlying inferential process itself. Building upon Helmholtz's notion of "unconscious reasoning", Clark [1] further asserted that "the brain is essentially a predictive machine", thereby laying the groundwork for the development of predictive processing theory.

The essence of PP theory lies in the brain's capacity to anticipate and predict forthcoming perceptual inputs based on prior experiences and knowledge. Within the perceptual hierarchy, predictions are formulated at higher levels and transmitted downwards (top-down) to lower levels. At these lower levels, predictions are compared with incoming sensory evidence (bottom-up). Predictions that align with the sensory input explain lower-level activity, while any discrepancies between predictions and actual inputs manifest as prediction errors. These prediction errors are then transmitted upwards to update higher-level predictions. PP conceptualizes the brain as a probabilistic, hierarchical generative model, where the fundamental goal is to minimize prediction error. Through iterative processes of generating and updating predictions, the brain continuously refines its internal models of the external world, striving to maintain congruence between predicted and actual sensory inputs.

Over the past decade, two different models of PP have emerged based on the neuroscientific hypothesis, first proposed by Friston, of combining human predictive behavior with multilayered neural structures with Bayesian algorithms. Clark [3] calls these two types of PP models "Conservative Predictive Processing (CPP)" and "Radical Predictive Processing (RPP)".

2.1. Conservative Predictive Processing (CPP)

CPP operates as a Bayesian inference prediction process at a sub-personal level within the overarching workings of the brain. This reasoning process predominantly pertains to unconscious decision-making rather than rationalized reasoning, thereby bypassing phenomenological levels of consciousness. However, CPP operates within a multilevel neural system, where unconscious Bayesian reasoning unfolds across various architectural and physical dimensions. Zhu & Liu delve into CPP from four primary aspects: motivation, purpose, architecture, and physical realization. By examining CPP through these lenses, they provide a comprehensive understanding of its underlying mechanisms and implications for cognitive processing [15].

CPP is primarily motivated by the imperative of active prediction driven by self-preservation intentions. Drawing from Friston's [16] elucidation, living organisms are conceptualized as homeostatic systems encapsulated by protective barriers such as skin or cell membranes. According to the second law of thermodynamics, isolated systems tend to dissipate energy spontaneously until reaching thermodynamic equilibrium, ultimately resulting in system collapse as energy dissipates into the environment. In contrast, living systems exhibit an inherent drive to survive and maintain energy by avoiding rapid dissipation. The survival intent inherent in living systems enables them to anticipate and mitigate potential accidents and risks by continuously predicting sensory inputs. Minimizing the discrepancy between predicted and sensed information enhances the organism's ability to navigate its environment, increasing the likelihood of averting potential threats and ensuring prolonged survival.

The purpose of CPP is to pursue the minimization of prediction error. Organisms need to avoid risks to preserve themselves, and living systems need to make predictions about what is going to happen in their environment; the smaller the difference between the predictions and the real situation, the more time and ability the system must avoid those risks, thus making it more likely that the maintenance system will survive. The quest to minimize prediction error requires that the brain continuously draws on Bayesian inference to sample signals fed to the brain by perceptual units, and computationally integrates the results of the sampling with prior beliefs about internal beliefs and speculates about the probability of the likelihood of a future event occurring.

CPP draws on the connectionist neuronal multilayered architecture as an inspiration for predictive processing architectures. There are multiple levels of information processing in human neural networks, where the encounter of active inference from the upper level to the lower level according to a priori belief probabilities, with passive inference from bottom-up posterior probabilistic signal inputs, generates the corresponding Bayesian probabilistic inference within any given level, and uses the inference results as a basis for the next level's inference sampling. The predictions generated by such upper and lower signal encounters are constantly encountered with external perceptual inputs, and to comply with the minimization of prediction errors, the hierarchies constantly adjust the weights of the inputs so that the predictions are constantly close to the situation of the immediate external event, providing the possibility of risk-averse actions.

The physical implementation of CPP takes the internal implementation of self-certifying boundaries. CPP is an internal activity bounded by the brain, and the location of the boundaries is self-certified by predicting the interiority of the process [17].

CPP posits that predictive processing is not confined to localized functional areas or modules within the brain, but rather emerges as a collective outcome of multilevel activities across the entire brain. It underscores the distinction between cognitive, perceptual, and action units, asserting that these components operate independently of each other. Despite this separation, CPP emphasizes the integration of top-down active reasoning and bottom-up passive reasoning, highlighting the proactive stance adopted by the cognitive system. However, CPP falls short in fully elucidating the profound influence of action on sensory sampling or the role of the agent within the predictive process. While it acknowledges the interaction between top-down and bottom-up processes, it does not delve deeply into how actions influence sensory input or the subjective experience of the actor.

2.2. Radical Predictive Processing (RPP)

RPP essentially adheres to the foundational principles of CPP, which center on predictive error minimization, Bayesian inference, and multi-level PP architectures. However, in addition to endorsing the core tenets of CPP, RPP advocates for a PP model grounded in embodied cognition. This perspective posits that PP should not be narrowly construed as solely an intracranial Bayesian inference process. Instead, it emphasizes the significant impact of proprioception and action on Bayesian prediction within the broader context of the individual and their environment. In other words, it recognizes that the body and actions play a pivotal role in shaping internal inference, thus demediating their influence.

Embodied cognition underscores the fundamental role of the body in shaping cognition. It posits that bodily movements not only influence cognition but also alter brain structure, thereby molding cognitive processes. This suggests that embodied cognition is inherently tied to action. Embodiment highlights two key aspects: firstly, that cognition relies on diverse experiences originating from the individual's sensorimotor interactions with their body; and secondly, that these sensorimotor abilities are situated within a broader biological, psychological, and cultural framework, aligning with the concept of Embedded Cognition. Embedded Cognition asserts that cognition is situated within both the body and the environment, rather than merely extended to them. Action underscores the interconnectedness of perceptual and musculomotor processes, emphasizing that perception and action are fundamentally intertwined in cognitive processes. This perspective aligns with Merleau-Ponty's emphasis on the spatial and motoric functions of the body [18]. According to the phenomenology of perception, cognition is intricately linked to bodily movements because it is inherently grounded in goal-directed consciousness, which, through intentionality, directs attention to the body itself, treating it not as a passive object but as an active participant in cognition.

According to Clark, RPP diverges from CPP in several key aspects [3]. Firstly, it emphasizes the profound and ongoing influence of perception and action on prediction. Active reasoning is not merely a hierarchical signaling process where higher intracranial levels direct lower levels, but rather a dual strategy that integrates both internal neural processes and external complex perceptual-action systems. Secondly, humans (and potentially some animals or intelligent robots) possess the capacity for learning, allowing proprioception to initiate and execute bodily actions, thereby reducing prediction errors through movement and adjusting observational perspectives. The rationale behind incorporating physical action into the prediction process, rather than relying solely on neural activity, stems from the evolutionary imperative for living organisms to conserve energy while maximizing benefits—an approach often termed 'productive laziness.' In situations demanding optimal judgments under time constraints, the intervention of embodied action facilitates a direct and efficient reduction of prediction errors, enabling the realization of cognitive goals. Thirdly, when embodied action becomes an intervening factor between prediction and the surrounding environment, perception and action cease to exist as external components of the prediction process; instead, they are integrated into a generalized Bayesian framework. Each Bayesian inference process encompasses not only a priori beliefs and perceptual signal sampling but also how the cognitive agent modifies its own circumstances through action to align sampling accuracy with predictions.

3. Three Positions on the Representational Status of PP

Since Clark suggested that PP concluded the 'Representation Wars', there has been extensive and in-depth discussion regarding the status of representations within PP [13]. The paper observes that the current discourse on the representational status of PP delineates three distinct positions. Furthermore, all three positions grapple with what Ramsey terms the 'job description challenge' [11].

Ramsey [11] contends that many models and theories employing representations misuse the concept. Cognitive scientists frequently employ the term 'representation' in an unrestricted manner. To address this issue, Ramsey introduces the job description challenge. This challenge entails establishing conditions for genuinely explanatory attributions. Broadly, it requires demonstrating in detail how the structures or states identified as representations within each cognitive model or theory fulfill a genuinely representational function. For instance, it demands elucidation on how these models or theories substitute for external states of affairs, rather than serving a non-representational purpose. According to Ramsey, failure to meet the criteria of the job description challenge implies that researchers are dealing with non-representational structures, and cognitive scientists should refrain from conflating them with representations.

To address the job description challenge, Ramsey [11] introduces a 'compare-to-prototype' strategy. Initially, the approach involves identifying a theoretically uncontroversial representation structure. The emphasis is placed on understanding the function fulfilled by this structure - what role it serves for the user to qualify as a representation. This structure serves as prototype representation. Subsequently, attention shifts to the concept of representation as employed in cognitive science, ensuring that the structures associated with this concept possess functional characteristics that align, to some extent, with those of the prototype representation. Furthermore, Ramsey [19] identifies the functional role of mental representations and the content attributed to that role as two pivotal dimensions for a comprehensive understanding of representations. The functional role encompasses a set of conditions that establish something as a representative state, delineating the relations or properties that confer a representational function upon a structure. Conversely, the content pertains to the specific information endowed to a representation, comprising a set of relations or features that bestow a particular representational content upon a structure. These two dimensions are intricately intertwined and may even exhibit overlap or mutual dependency.

Building upon Ramsey's theory of representation, the paper will now outline each of the three positions regarding the representational status of PP.

3.1. CPP: A Structural Representation

One viewpoint aligns with CPP, contending that PP constitutes a map-like structural representation that satisfies Ramsey's job description challenge.

CPP conceptualizes environment as a probabilistic model governed by causal mechanisms. In other words, whether and how Object A causally influences Object B is viewed as a probabilistic event. The probabilistic laws of causality in the external world dictate the statistical patterns observed within the sensory input system, with sensory signals serving as the sole data source for delineating the causal probability structure of the external environment. Assuming the existence of a function that maps the state of the world (i.e., the probability of an external cause generating a sensory signal) to the state of the sensory system, predictive processing operationalizes this function by constructing a generative model. In essence, cognitive system generates an internal representation of the external world based on the statistical properties of sensory inputs.

Gładziejewski [6] regards PP as a mental representation rooted in structuralism, asserting that the functional role of the model closely resembles that of a real-world map. Accordingly, he metaphorically depicts PP as a map and draws parallels between the process of PP representation and the four functional attributes of a map. Firstly, according to structuralism, representation entails structural mapping, where the spatial relationships among map components mirror those of the terrain being represented. For instance, if points A', B', and C' on a map correspond to buildings A, B, and C in a given terrain, then the proximity of A' to C' relative to B' conveys the information that building A is closer to building C than to building B. Thus, the efficacy of predictive processing hinges on its fidelity to the causal-probabilistic structure of the world, with the model functionally mapping the state of the world onto the state of the sensory system. Secondly, maps offer operational guidance to users, aiding them in navigating and making decisions within a given terrain. Similarly, PP guides actions aimed at minimizing prediction errors. Organisms achieve this goal through perceptual inference, updating previous probabilistic mappings, and active inference, selectively sampling new sensory inputs through actions. Thirdly, maps can be used offline for operational guidance. PP views generative modeling as an endogenous control mechanism, wherein the generative model directs cognitive system control, rather than the external environment itself. Representations function as cognitive surrogates for their objects in their absence. Lastly, errors in map representations impede progress toward a destination but also serve as cues for corrective actions. Similarly, generative models in PP detect representation errors. Inaccuracies in the generative model or sensory input signals trigger significant prediction errors, prompting the system to engage in perceptual inference to minimize prediction errors more efficiently—an aspect known as representational error detection in PP models.

Furthermore, Piekarski [20] echoes Gładziejewski's perspective. Piekarski advocates for PP's scientific realism stance by citing spatial maps in the hippocampus of rats as exemplary internal S-representations [21]. Specifically, the explanation of the hippocampus function in rats through structural representation illustrates that this concept is not merely instrumental or epistemic; rather, it demonstrates a substantial correlation with mechanisms present in the rat brain. In essence, the concept of structural representation serves a non-trivial explanatory role in this context.

3.2. PP and Anti-representationalism

Downey asserts that anti-representationalism has achieved a definitive victory within the realm of PP, suggesting that the representational assumptions inherent to PP have either been entirely eliminated or relegated to fictional status. Echoing this sentiment, Downey employs Ramsey's job description challenge to argue that none of the five key assumptions of PP—prediction signal, error signal, prior, likelihood, and posterior probability—successfully meet the criteria of the challenge [8].

Firstly, the prediction signal and error signal fail to satisfy the job description challenge. Prediction signals traverse all levels of the perceptual hierarchy, propagating from level N to the adjacent N+1 level. Conversely, error signals ascend from level N to the immediately superior N-1 level, with each level solely focused on its immediate surroundings. Thus, signals transmitted up and down the perceptual hierarchy are best understood in terms of causal covariation or correlation. However, Ramsey contends that brain mechanisms relying on causal covariate action are immune to challenges posed by job descriptions and, therefore, cannot be considered representations.

Explaining this view, Ramsey writes: “Despite its common appeal, the receptor notion of representation comes with a job description that, in this context, has little to do with the role of representation…When we look at the role of receptors inside of cognitive systems, as described by cognitive theories that employ them, we see that the role is better described as something like a reliable causal mediator or relay circuit which, as such, is not representational in nature. In other words, when a causal/physical system (like the brain) is described as performing various cognitive tasks by employing a structure that has the job of causing something to occur when and only when something else occurs, then the system is not, based on this description alone, employing internal representations [22].”

In conclusion, if prediction signals and error signals are interpreted as entailing causal covariation among neural processes, they cannot be attributed representational status based on the job description challenge.

Secondly, the concepts of prior and likelihood also fall short of meeting the job description challenge. Orlandi contends that these concepts are more accurately characterized as denoting non-representational biases within neuronal systems. She argues that theorists have often attributed biases to representations, largely due to the influence of the traditional cognitivist notion that perception involves an internally reasoned transformation between premises and conclusions within a language of thought framework. However, that biases are more realistically understood to fulfil “the simple function of marking a hypothesis as more or less probable. They are like valves. They skew the brain toward certain neuronal arrangements” [23].

Therefore, the terms prior and likelihood should be utilized to denote certain biases within neuronal systems. Approaching these biases from a representational perspective lacks explanatory utility. Instead, prior and likelihood should be viewed as mechanisms that predispose the brain to adopt specific organizational patterns in response to environmental and psychological stimuli.

Finally, Downey [8] illustrates the non-representational nature of posterior probability by countering Orlandi's argument. Orlandi contends that posterior probabilities are linked to distal conditions and can be utilized even in the absence of environmental causes. Hence, while PP itself lacks representational status, Orlandi suggests that posterior probabilities should be described using representational terms [23]. Downey, however, challenges this assertion by arguing that if the environment is directly perceived, then cognition itself pertains to the proximal situation, thereby negating the need to describe posterior probability in terms of representations. Moreover, Downey posits: “the key tenets of PP need not be explicated in representational terms; and PP frameworks that heavily rely on representation can be interpreted as doing so for epistemological reasons. If this is accurate, within the PP paradigm, representation is either rendered entirely redundant or relegated to a fictional status. This conclusion justifies an eliminativist stance regarding the metaphysical status of representation within PP [8].”

Similarly, Van and Myin [9] challenge the representationalist interpretation of PP. They argue that Gładziejewski's map analogy overlooks the social environment that gives rise to representational practices and confers representational status—a dimension that neural models fail to account for. Additionally, Facchin [10] introduces a predictive processing system capable of active inference, embodied in the form of a simple robotic 'brain'. This example demonstrates the subject's mastery of sensorimotor contingencies, wherein bodily movements systematically alter sensory states. Through this instantiation, Facchin argues that the physical structures of generative models do not adhere to representational frameworks; rather, they function as non-representational structures.

3.3. Moderate Position: RPP

In contrast to the anti-representationalism stance, proponents of RPP contend that certain aspects of the PP generative model do indeed serve a representational function. However, they reject the portrayal of PP as merely another iteration of the computational-representational theory of mind, instead emphasizing the embodied and embedded nature of cognitive processes.

Clark [3] argues that PP should not solely adhere to the CPP interpretation. While advocates of RPP acknowledge the likelihood that higher cognitive functions may rely on the manipulation of certain mental representations, they highlight the appeal of the PP framework in the heuristic actions that arise from the dynamic interaction between the actor and the environment. Further, Clark distinguishes between behavior selection and guidance strategies, categorizing them as “model-based” and “model-free”, respectively. Model-based reasoning entails acquiring and deploying a rich body of task-domain information, while model-free approaches utilize pre-computed 'policies' linking actions directly to rewards, often relying on simple cues and regularities to provide rapid responses. Model-free processing leans more on bottom-up information, whereas model-based processing relies on top-down influence from prior knowledge. This suggests a transition from a reaction-based to a genuinely representational process. However, Clark does not clearly delineate between genuine representational processes (“model-based”) and “model-free” processes [24].

Building on Clark's proposal, Orlandi [24] advocates for employing Ramsey's job description challenge to differentiate between embodied, embedded processes and representational processes. In her elucidation of “embedded seeing”, Orlandi [25, 26] posits that vision is not a reasoning process dependent on the manipulation of intermediate states or markers as representations. Instead, vision is intricately woven into the biological structure of an organism's visual apparatus, honed through evolution and development to reliably respond to specific environmental properties. Referencing her work in vision, Orlandi [23] asserts that prediction signal, error signal, prior, and likelihood in the PP structure fail the job description challenge, leaving only posterior probability describable in representational terms.

In summary, proponents of RPP contend that only higher-level generative models within PP exhibit a representational function, whereas lower-level (e.g., perceptual) PP should be regarded as “model-free” structures shaped by biases acquired through reinforcement learning or phylogenetic development.

4. Adaptive Representation Position of PP

The preceding discussion leads us to several conclusions. First, in response to the anti-representationalism stance of PP, the paper asserts that the concept of representation remains indispensable for explicating PP. This pertains primarily to the epistemological and methodological status of representation. As Clark aptly stated: “Could we perhaps have told our story in entirely non-representational terms? One should always be cautious of sweeping assertions about what might, one day, be explanatorily possible! But as things stand, I simply do not see how this is to be achieved [24].”

Then, the paper observes that both the CPP and RPP positions adopt Ramsey's job description challenge. However, Dolega raised concerns regarding this approach. For CPP proponents to successfully employ the job description challenge, it is crucial to differentiate between models that represent the world and those that serve as representations or meta-representations of the system's internal states, and to provide a comprehensive account of content determination. Nonetheless, distinguishing between representational and meta-representational models, as well as addressing content uncertainty, pose challenges for CPP proponents. For proponents of the RPP, Dolega highlights that “although proponents of RPP present the discussion as a disagreement over the functional details of PP by appealing to Ramsey’s job description challenge, this condition favors a representational interpretation of the framework. Therefore, if RPP is to be defined in terms of commitments about the functional role played by generative models, the position will collapse into the standard, representational reading of the framework [12].”

Therefore, as the job description challenge grapples with the dilemma of elucidating the representation of PP, the paper proposes a fresh perspective in support of the RPP position.

4.1. What Is Adaptive Representation

Cognitive science has witnessed the emergence of a multitude of competing theories, including computational-representationalism, connectionism, dynamism, 4E+S cognition, and the recently developed PP theory. The absence of a unifying category or conceptual framework capable of encompassing these diverse cognitive theories and programs has remained a central dilemma for both cognitive science and its philosophy. The concept of adaptive representation appears to share common ground across various cognitive theories and agendas, offering a methodological approach for understanding complex cognitive phenomena and providing a reasoned account of cognitive formation and evolution mechanisms within their respective contexts.

Adaptive representation denotes the cognitive system's capacity to autonomously represent a target object within a specific environment or context, with the ability to adapt and refine itself in response to changes in the environment or context. Here, the cognitive system encompasses the information processing and utilization system, including both the human brain and artificial intelligence, responsible for cognitive activities such as perception, reasoning, learning, communication, and action. Representation refers to the physical state of the cognitive system that carries content, namely, the object of perception apprehended by the subject, while content denotes the object of concern for the representation. Fundamentally, adaptation stems from an organism's natural evolution under existential pressures, while representation signifies a categorized ability of a cognitive system to pursue a target object [27].

Adaptation stands as the central tenet of evolutionary theory, embodying the characteristic of a subject—be it an organism or an actor—to evolve in concordance with its environment. In the context of Darwinian evolution, adaptation denotes the process through which organisms acclimate and thrive within their surroundings, often encapsulated by the concept of “survival of the fittest”. Hence, biology fundamentally delves into the realm of biological adaptation.

Representation, serving as an interface between mind and nature, acts as a mediator between the mental and the physical realms—a tangible manifestation of mental modeling [28]. According to Heylighen [29], adaptation offers an alternative perspective, while representation characterizes the dynamic relationship between subject and object, mind and nature, and the intrinsic and extrinsic environments of an intelligent adaptive system. This mechanism operates through feedback-feedforward interdependence, manifesting in an abstract information processing framework. While adaptation in inorganic matter entails mechanical embedding within the environment—such as liquids conforming to the shape of their container—organic adaptation transcends mere repetition to embody reaction, shaping, and ultimately, adaptation. This process fosters creativity while also engendering representational complexity. Thus, adaptation emerges as an intricate dance of dynamic interactions.

4.2. RPP: An Adaptive Representation Process

Adaptive representation underscores that generative processes are inherently adaptive, acknowledging that adaptation, whether driven by natural selection or natural drift, may not always yield optimality. Simultaneously, generation is recognized as a representational process. Since representations possess intentional content or semantics—such as the generation of mental images in the brain—it is imprudent to supplant representations with generation, particularly considering the challenge generative cognitive science faces in adequately accounting for symbolic representations commonly utilized today. These perspectives align with the moderate stance of RPP. RPP embodies an approach rooted in embodied generative cognitive processes, emphasizing both the indispensability of representation and the generative nature of cognition.

In terms of environmental adaptation of representations, prediction error minimization exemplifies the adaptive nature of RPP. Both perceptual and active inference converge to achieve an adaptive cognitive process. RPP underscores the adaptive representation of cognition by embedding it within the body, brain neurons, and the surrounding environment. However, instead of relying on mental schemas and symbolic manipulations, this representation takes the form of bodily functional presentations, emphasizing the indispensability of the body to cognition. This implies that cognition is inherently adaptive, as the body progressively acquires adaptive functions throughout evolution.

The paper maintains that representations, especially mental representations, cannot be replaced. The brain abilities to think, imagine, and recall underscores their undeniable existence. Mental representations serve as internal models of cognition, with knowledge representations serving as externalizations of these internal models. Their non-observability or the yet-to-be-clarified details and mechanisms of their occurrence do not negate their existence. Representation in cognition embodies the unity of form and content, subjectivity and objectivity, immanence, and extensiveness. The abolition of representation would equate to the denial of consciousness' intentionality and meaning, rendering cognitive behavior incomprehensible.

In contrast to strong representationalism, adaptive representations offer a form of weak representationalism, providing a plausible explanation for PP theory. As Clark [13] contends, the emergence of PP theory has modestly put an end to what he terms the “Representation Wars”.

5. Conclusions

The paper delves into two types of PP theories, around which three distinct positions have emerged. For anti-representationalism, the paper argues that representation remains indispensable from an epistemological and methodological standpoint. Conversely, representationalism perspectives, particularly within CPP, tend to overlook the influence of linguistic and cultural factors inherent in human beings on prediction. Furthermore, the content of perception is subject to sampling in a manner that, due to its intrinsicist nature, aligns incidentally with the world. Hence, the paper advocates for an embodied rendition of predictive processing, termed RPP. The paper elucidates RPP through the lens of adaptive representations, representing a form of weak representationalism and bolstering a moderate stance on representations.

6. Recommendations

In conclusion, this paper underscores the indispensable role of representation within PP models despite the ongoing debate. It advocates for a moderate representational stance as offering a more nuanced and plausible explanation compared to strong representationalism. Understanding the brain's PP entails acknowledging both the representational function of structural models and the coupling, or embodiment, between the brain and its environment. Hence, adopting an approach that considers predictive processing through the lens of adaptive representation holds promise for advancing researchers' comprehension in this domain.

Moving forward, researchers should prioritize investigations that delve into the intricate interplay between representation and embodiment within PP frameworks. By embracing this holistic perspective, researchers can gain deeper insights into the cognitive mechanisms underlying perception and action, thus paving the way for more comprehensive models of brain function.

Abbreviations

PP	Predictive Processing
CPP	Conservative Predictive Processing
RPP	Radical Predictive Processing

Author Contributions

Zhichao Gong: Investigation, Project administration, Resources, Writing – original draft

Yidong Wei: Funding acquisition, Writing – review & editing

Funding

The National Social Science Fund of China's 'Philosophical Research on the Challenge of Artificial Cognition to Natural Cognition' (grant number 21&ZD061).

Conflicts of Interest

The authors declare no conflicts of interest.

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Biography

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Research Field

Zhichao Gong: Predictive processing, representation, philosophy of mind, artificial intelligence philosophy, philosophy of science
Yidong Wei: Artificial intelligence philosophy, philosophy of science, philosophy of cognitive science, Systems philosophy