

Beyond the Neural Black Box

Affordances, Embodied Authorship, and the Emergence of Agency

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Abstract

Advances in neuroscience have illuminated the neural processes preceding and accompanying human decisions, yet questions remain concerning the explanatory sufficiency of these findings for understanding agency. This article examines evidence from neural preparation, perceptual organization, contextual attribution, embodied authorship, and cognitive invention, distinguishing the identification of neural constituents from conclusions about the determination of human action. It proposes neural, biocognitive, and contextual affordances as analytically distinguishable but reciprocally organized conditions through which possibilities become available, meaningful, and actionable. Within this framework, cognition is not regarded as an epiphenomenon of biology but as an inseparable constituent of co-emergent authorship. Lived duration further informs how possibilities are experienced within changing contexts. Drawing on second-order inquiry, the article examines the domains of meaning and epistemological premises through which empirical observations acquire explanatory significance, distinguishing scientific findings from philosophical interpretations without separating their reciprocal contributions. The central

argument is not that determinism has been disproven, but that neural antecedents alone do not provide sufficient evidence for the assertion that agency is illusory. An empirical research approach is proposed to investigate contextual relevance, novel alternatives, neural preparation, and experienced authorship through independently defined measures and testable predictions. The article concludes that scientific accounts of agency must distinguish necessary conditions from sufficient explanations, particularly when their interpretations carry implications for ethical judgment and human responsibility.

Keywords: agency; biocognition; contextual coemergence; neural affordances; second-order inquiry; explanatory sufficiency; embodied authorship; lived duration

Introduction

Scientific advances frequently generate questions that extend beyond the phenomena initially investigated. Neuroscience is no exception. The identification of neural processes associated with decisions has contributed substantially to understanding human action, while also generating interpretations concerning the existence of agency itself. Such interpretations invite examination of the relationship between what empirical observations establish, and the broader conclusions drawn from them. The issue is not whether neural findings are valid, but whether their explanatory significance has been adequately established.

This article approaches that question by examining the empirical and conceptual conditions under which human action becomes intelligible. Rather than treating neuroscience and philosophical inquiry as competing explanations, it investigates how their distinct contributions can inform one another without being conflated. The resulting inquiry considers not only the evidence associated with agency, but also the assumptions through which that evidence acquires meaning.

From the Behavioral Black Box to the Neural Black Box

The history of cognitive science offers an instructive example of how an empirically successful explanatory framework can nevertheless prove insufficient to account for the phenomena it seeks to explain. B. F. Skinner's work on operant conditioning demonstrated that behavior could be shaped systematically through reinforcement and environmental contingencies (Skinner, 1953). These findings established important principles of learning that remain scientifically relevant. Their validity, however, did not establish that observable contingencies provided a comprehensive explanation of cognition.

The emergence of cognitive science brought increasing attention to phenomena that could not be adequately characterized through behavioral contingencies alone. Learning involved not only changes in observable responses but also the organization of experience, the construction of meaning, memory, expectations, and the capacity to apply acquired knowledge in novel contexts (Bransford et al., 2000). The problem was not that conditioning had been demonstrated incorrectly. Rather, the explanatory framework was insufficient to accommodate the expanding empirical terrain.

John Bransford's contributions to research on learning exemplified this broader transition. Instead of dismissing established behavioral findings, his work investigated the cognitive processes necessary to explain understanding, knowledge organization, and the transfer of learning. The distinction was consequential: an experimental demonstration could be valid while remaining insufficient to support a comprehensive theory of cognition (Bransford et al., 2000).

A comparable explanatory question emerges in contemporary neuroscience. Research has demonstrated that measurable neural activity can precede the reported conscious awareness of an intention to perform certain voluntary movements (Libet et al., 1983). Such findings are important.

Yet the observation of neural antecedents does not, by itself, establish that those antecedents constitute the entirety of deciding, nor that the experience of agency is necessarily illusory.

The contemporary neural black box differs from its behavioral predecessor in an important respect. Rather than excluding internal processes from scientific investigation, neuroscience examines them with increasingly sophisticated methods. Nevertheless, a new explanatory limitation can arise when the identification of neural mechanisms is treated as sufficient to explain the cognitive phenomena associated with them.

The question, therefore, is not whether neural mechanisms participate in cognition. They unquestionably do. The question is whether identifying those mechanisms adequately explains how possibilities acquire contextual relevance, how individuals recognize themselves as authors of actions, and how cognition participates in constructing novel alternatives.

The present inquiry approaches these questions through converging empirical evidence from neuroscience, perceptual learning, cognitive attribution, psychophysiology, and embodied cognition. Rather than proposing a philosophical refutation of determinism, it examines the explanatory sufficiency of the scientific findings invoked in its support.

Neural Antecedents and Explanatory Insufficiency

One of the most consequential developments in contemporary neuroscience has been the capacity to identify neural activity associated with voluntary movement before individuals report becoming consciously aware of their intention to act. These findings have contributed to an important scientific debate concerning the relationship between neural preparation, conscious intention, and human agency. The empirical observations themselves are not in dispute merely because their philosophical implications remain contested. The central question is whether the observations are sufficient to establish the conclusions attributed to them.

In their influential experiments, Libet and colleagues (1983) measured the readiness potential, an electrical signal associated with preparation for voluntary movement, and compared its onset with participants' retrospective reports of when they first became aware of an intention to move. On average, the readiness potential preceded reported conscious intention. This temporal relationship has frequently been interpreted as evidence that the brain initiates actions before conscious awareness enters the process. Yet the experiment did not directly establish that the entire process of deciding had been completed before awareness, nor did it demonstrate that conscious participation could have no subsequent role in the organization or execution of action.

Subsequent research extended the temporal horizon of neural prediction. Using functional magnetic resonance imaging, Soon et al. (2008) identified patterns of brain activity that predicted participants' eventual choices between simple motor responses several seconds before those choices entered reported awareness. These results demonstrated that information relevant to an impending response could be detected in preceding neural activity. However, prediction was probabilistic rather than certain, and the experimental task involved relatively simple, constrained alternatives. Detecting neural information associated with an eventual choice is not equivalent to demonstrating that the choice was irrevocably determined at the moment that information became measurable.

An additional explanatory issue concerns the interpretation of the readiness potential itself. Schurger et al. (2012) proposed that, in tasks involving spontaneous movement without an external imperative to act at a particular moment, the readiness potential could emerge from the averaging of ongoing neural fluctuations preceding movement. Their accumulator model offered an alternative account of how preparatory neural activity might arise without requiring the assumption that the onset of the averaged signal represents a discrete unconscious decision. This interpretation

does not eliminate the importance of neural antecedents; rather, it demonstrates that the same physiological observation may accommodate more than one explanatory model.

The methodological and conceptual limitations of drawing broad conclusions about free will from such experiments have also been examined by Brass et al. (2019). The distinction between predicting a simple motor response and explaining the broader capacities involved in human decision-making remains especially important. Everyday decisions frequently involve competing goals, learned values, anticipated consequences, social relationships, and the possibility of revising an intended course of action. These constituents are not adequately represented by treating all decisions as equivalent to selecting between two experimentally prescribed movements.

The explanatory distinction becomes clearer when neural antecedents are considered as *potential affordances* rather than as completed decisions. Neural activity may establish conditions, constraints, tendencies, or possibilities that participate in subsequent action. The presence of these antecedents is entirely compatible with the biological requirements of cognition. What remains to be demonstrated is whether identifying those antecedents is sufficient to explain the contextual selection, interpretation, and enactment through which an action becomes meaningful to the individual.

This distinction does not require the assumption that consciousness operates independently of the brain, nor does it establish that neural processes are exempt from causal organization. Rather, it questions whether the identification of an earlier neural event licenses the conclusion that later cognitive participation is explanatorily redundant. Temporal precedence, predictive association, and causal sufficiency are different scientific claims. Establishing one does not automatically establish the others.

Consequently, the central issue is not whether neural processes precede conscious awareness in particular experimental circumstances. The evidence indicates that they can. The issue is whether those findings establish the absence of agency or instead identify biological constituents that make agency possible. Resolving that question requires extending the inquiry beyond neural timing to examine how possibilities are organized, selected, and enacted within embodied and contextual experience.

Neural Affordances: Possibilities Are Not Decisions

Neural activity preceding voluntary movement establishes preparation for action, but it does not necessarily establish an irreversible commitment to that action. Subsequent investigations have examined what occurs when preparatory activity is followed by inhibition, changing awareness of intention, or revision of an emerging response. These findings extend the inquiry beyond the identification of neural antecedents to the organization of action itself.

Schultze-Kraft et al. (2016) investigated whether individuals could cancel a movement after preparatory neural activity had become detectable. Using electroencephalography and a brain–computer interface to identify patterns associated with impending movement, the researchers introduced signals instructing participants to stop. Movements could still be inhibited after preparatory activity had begun, provided the intervention occurred sufficiently early. Under the experimental conditions, successful cancellation became increasingly difficult approximately 200 milliseconds before movement onset. The findings demonstrate that detectable neural preparation does not necessarily constitute an irreversible commitment to action. They do not imply that inhibition operates independently of neural processes, nor does the observed temporal boundary establish a universal neurological point of no return.

A complementary investigation by Matsushashi and Hallett (2008) examined the timing of conscious intention using probes presented during the period preceding voluntary movement rather than relying exclusively on retrospective clock judgments. Their findings placed the emergence of reportable intention substantially earlier than estimates obtained through Libet's procedure. This difference indicates that the timing attributed to conscious intention depends partly on its operational definition and method of measurement. Neither estimate, by itself, establishes the precise moment at which a decision becomes complete.

Resulaj et al. (2009) investigated changes of mind during perceptual decision-making. Their experiments demonstrated that sensory evidence accumulated after an initial commitment could influence a subsequent reversal of the developing response. Although this paradigm differs from experiments involving self-initiated movement, it provides independent evidence that decision-related processing may continue after an initial commitment, allowing an action to be redirected. Together, these investigations identify distinguishable operations within voluntary behavior. Preparatory activity can precede a movement that is subsequently inhibited; the reported emergence of intention varies with the measurement procedure; and an initially selected response can undergo revision as additional evidence is processed. The findings do not establish a universal sequence governing human decisions or identify a single neural locus of agency. They demonstrate why neural preparation, commitment, inhibition, and revision should not be conflated merely because they participate in the production of an action.

Within the present biocognitive framework, neural affordances are antecedent conditions that make particular actions possible or more probable without, by themselves, establishing that those actions have been selected or completed. This proposed extension of the concept of affordance distinguishes the availability of an action from its subsequent realization. The experiments do not

directly measure affordances in this theoretical sense; rather, their findings provide empirical grounds for investigating whether preparatory neural activity can be understood as enabling possibilities rather than constituting completed decisions.

This distinction also suggests a broader organization of action involving neural, cognitive, and contextual affordances. Neural affordances concern biological possibilities and constraints; cognitive affordances involve the interpretation, evaluation, modification, or invention of possible actions; and contextual affordances concern the relational conditions through which those possibilities acquire situational meaning and relevance. Behavior is the enacted outcome of their organization, not an additional category of affordance. These constituents are analytically distinguishable but contextually coemergent, rather than independent stages in a fixed causal sequence. An explanation moving directly from neural preparation to observable behavior may therefore leave the cognitive and contextual constituents of action insufficiently characterized.

The resulting question is not whether neural antecedents participate in behavior, but how their possibilities become organized into particular actions. Addressing that question requires examining how experience and environmental context influence what an organism perceives as possible, relevant, and actionable.

Perception, Learning, and Contextual Relevance

The investigation of voluntary action raises a question that cannot be resolved solely by identifying neural activity preceding movement: how do particular possibilities become available to perception in the first place? Before an individual can evaluate or act upon an alternative, the environment must be perceived in ways that make certain distinctions and responses possible. Research on perceptual development and cultural variation provides evidence that this

organization is influenced by experience rather than determined exclusively by the immediate sensory stimulus.

Held and Hein (1963) investigated the contribution of self-produced movement to the development of visually guided behavior. In their classic experiment, pairs of young kittens received comparable visual stimulation while differing in their opportunities for active movement. One kitten moved through the environment under its own control, while the other was transported passively through a corresponding visual experience. The actively moving animals subsequently demonstrated more effective visually guided responses than their passively transported counterparts. The experiment indicated that visual exposure alone was insufficient to account for the development of the tested sensorimotor capacities. The relationship between movement and its sensory consequences was a significant constituent of perceptual development.

The significance of this finding extends beyond the presence or absence of visual information. Both animals encountered visual stimulation, yet the conditions under which that stimulation was experienced differed. Self-produced movement provided a relationship between action and sensory change that passive exposure did not reproduce. The experiment does not establish that active movement is necessary for every form of visual learning, nor does it identify a mechanism independent of neural processes. It demonstrates that the organization of perceptually guided behavior cannot be adequately characterized by visual input alone.

A different dimension of perceptual organization emerges from cross-cultural investigations. Segall, Campbell, and Herskovits (1963) examined susceptibility to geometric visual illusions across populations with differing cultural and environmental experiences. Their findings revealed variation in responses to illusions, including the Müller-Lyer configuration, challenging the assumption that identical visual arrangements necessarily produce identical perceptual judgments

across populations. One influential interpretation associated some of these differences with exposure to environments containing particular architectural and spatial features, although the relative contributions of environmental experience, testing procedures, and other factors remain subjects of investigation.

These observations are relevant because they distinguish the physical properties of a stimulus from the perceptual organization through which it is encountered. The Müller–Lyer configuration may remain geometrically unchanged while judgments of its apparent dimensions vary across groups. The findings do not establish that culture determines perception in a simple or uniform manner. They do, however, provide evidence that perceptual responses are not fully specified by stimulus geometry alone.

Taken together, these investigations reveal complementary dimensions of perceptual organization: the contribution of sensorimotor experience to visually guided behavior and the variation of perceptual judgments across cultural environments. Their convergence supports examining perception as an activity shaped through an organism's history of engagement with its surroundings, rather than treating sensory stimulation as an exhaustive description of perceptual experience.

This empirical perspective is compatible with the enactive approach developed by Varela, Thompson, and Rosch (1991), in which cognition is understood through the ongoing relationship between an organism and its environment rather than as the passive construction of an internal representation from external inputs. Within that approach, perception and action are closely related aspects of embodied engagement. The enactive framework offers a conceptual interpretation of such relationships; it should not be confused with a direct experimental conclusion established by either of the preceding studies.

Within the present biocognitive framework, these findings support an inquiry into how experience contributes to the formation of perceptual possibilities. Neural processes remain indispensable, but what becomes perceptually salient, distinguishable, or actionable also depends on the organism's history of engagement with its environment. **A possibility may be physically available in the environment without being perceptually recognized as a possibility for action; its relevance emerges through the relationship between the perceiver and the circumstances encountered.**

The concept of contextual relevance therefore concerns not merely the presence of external conditions, but the relationship through which particular conditions become significant for perception and potential action.

The resulting distinction prepares the next stage of inquiry. If experience and context participate in organizing what is perceived, then the interpretation of experience may also have consequences beyond perceptual judgment. The question becomes whether cognitive attribution can influence physiological responses under otherwise comparable external conditions.

Cognitive Attribution and Physiological Consequences

An organism's capacity to act does not, by itself, establish the significance of an action. Available possibilities differ in the resources they require and in the relevance they acquire within a particular context. Two distinctions are useful here. Cost refers to the quantitative expenditure of resources, including energetic, metabolic, attentional, and temporal resources. Value refers to the qualitative contextual relevance of an action, constituted through considerations of survival and meaning. Value is not simply a subjective reward assigned to a predetermined cost. It may influence the conditions under which resources are mobilized and expended.

Experimental investigations of effort and reward provide an instructive starting point. Pessiglione et al. (2007) asked participants to exert physical force on a handgrip in exchange for monetary

incentives of differing magnitudes. Participants generated greater force for larger rewards, including under conditions in which they could not consciously report the incentive amount. Croxson et al. (2009), using functional magnetic resonance imaging during an effort-and-reward task, identified neural activity associated with anticipated effort, expected reward, and their interaction. Together, these studies demonstrate that expenditure and its neural correlates vary with anticipated consequences, rather than reflecting the physical demands of an action alone.

The Pessiglione findings introduce an additional question. Money acquires motivational significance through learning and participation in systems of social exchange. An individual who responds to a monetary incentive without consciously identifying its magnitude nevertheless brings an acquired history of meaning to the experimental encounter. The absence of conscious report does not imply the absence of culturally established propensities. Although the experiment did not independently manipulate cultural history, it invites consideration of how previously acquired significance participates in the physiological response to an immediate incentive.

Other investigations extend the relationship between attributed meaning and physiology. Crum and Langer (2007) informed hotel room attendants that their ordinary occupational activities constituted exercise consistent with public-health recommendations. Four weeks later, the informed group exhibited changes in several health indicators relative to a control group, despite reporting no corresponding increase in exercise. These findings suggest an influence of mindset, although the study does not establish that attribution alone accounted for the physiological differences. In another experiment, Crum et al. (2011) presented participants with descriptions portraying a milkshake as either indulgent or sensible, although the milkshake's actual nutritional composition was the same across the two labeling conditions. Ghrelin responses differed according to the descriptions under which the milkshake was consumed. The manipulation concerned the

attributed nutritional significance of the milkshake rather than a difference in its actual nutritional composition.

The distinction between cost and value becomes especially important when an anticipated expenditure is considered in relation to what an action means. Imagine an individual observing a child struggling in shark-infested water. Entering the water entails substantial anticipated cost, potentially including the loss of one's life. The child's survival may acquire overriding contextual relevance through the observer's relationships, cultural history, obligations, or conception of self. One might interpret the rescue in evolutionary terms, emphasizing the child's reproductive future or contribution to subsequent generations. But suppose the person struggling in the same water is 90 years old. The anticipated danger to the rescuer remains, and the older person's life may be valued just as strongly. An appeal to reproductive potential no longer provides the same explanation, although broader evolutionary accounts of altruism and cooperation remain possible. What becomes apparent is the distinction between explaining the possible origins of a propensity to protect others and explaining the contextual significance of the particular human life being protected. The danger has not disappeared, nor has the anticipated expenditure necessarily diminished. Rather, contextual value has altered the significance of undertaking the action. The example is illustrative, but it distinguishes the quantitative demands of an action from the qualitative relevance through which those demands are encountered.

Value may also influence realized cost. By modifying attention, physiological mobilization, effort, and behavioral organization, contextual valuation may alter the resources actually expended, whether increasing or decreasing expenditure under particular conditions. Anticipated cost and realized cost therefore need not coincide. Establishing when and how valuation changes actual expenditure remains an empirical question, but the studies reviewed here provide evidence that

incentive significance and attribution can influence measurable behavioral and physiological outcomes.

If the expenditure associated with an action can vary with its attributed significance, what constitutes an adequate explanation of that expenditure: the resources measured, the neural processes accompanying them, or also the contextual conditions through which the action acquires value?

Penfield and the Recognition of Embodied Authorship

The distinction between producing a movement and experiencing oneself as its author introduces a further challenge for explanations of agency. Wilder Penfield's investigations of conscious patients undergoing cortical stimulation demonstrated that electrical intervention could elicit bodily movements (Penfield & Rasmussen, 1950). His observations helped establish the importance of distinguishing experimentally induced motor activity from the broader experience of voluntary action. They did not, however, establish that agency exists independently of neural activity.

Subsequent stimulation research made these distinctions more precise. Desmurget et al. (2009) reported that stimulation of particular parietal regions could produce a conscious intention or desire to move without corresponding movement. At higher stimulation intensities, some patients reported having moved despite the absence of observable movement. Stimulation of premotor regions, by contrast, could elicit movements without a corresponding conscious experience of intending them. These findings demonstrate that movement execution, experienced intention, and awareness of movement can be experimentally dissociated.

Embodied authorship refers to the individual's experienced recognition of themselves as initiating and participating in an action, rather than merely observing a bodily movement. This

recognition can be investigated through reports of agency considered alongside motor behavior and neural activity, without assuming that subjective authorship establishes causal control. Contemporary examinations of electrically evoked movement likewise distinguish externally induced motor activity from patients' interpretations of its origin (Mazurek & Schieber, 2019).

These observations leave open whether the experience of authorship arises prospectively, retrospectively, or through interacting processes. They establish a more limited but consequential point: an adequate account of agency must explain how movement, intention, bodily experience, and recognition of oneself as an acting individual become related.

The empirical question, then, is not whether the brain participates in action, but whether the neural mechanisms sufficient to elicit movement also constitute a sufficient explanation of embodied authorship.

Contextual Coemergence and the Constituents of Agency

The empirical distinctions examined thus far invite consideration of how neural, biocognitive, and contextual processes participate in the organization of human action. A bottom-up explanation typically proceeds from relatively simpler levels of organization toward more complex relationships, while a top-down explanation examines how broader organizational conditions influence the activity of their constituents. Simplicity and complexity here refer to relative levels of organization rather than intrinsic properties of the processes themselves. Neither explanatory direction, considered independently, necessarily captures the reciprocal relationships through which action becomes possible and meaningful.

Contextual coemergence offers a complementary interpretation. Rather than treating neural mechanisms, cognition, and context as separate systems acting upon one another, it examines their reciprocal constitution within an unfolding situation. The distinction is not between biological

causation and an additional nonbiological force. Neural processes remain indispensable, while their functional significance is examined within the embodied, experiential, and relational conditions in which they participate. Contextual coemergence therefore concerns the organization of relationships rather than the introduction of an independent causal agent.

Within this framework, neural, biocognitive, and contextual affordances identify analytically distinguishable domains of possibility. Neural affordances concern biological conditions and constraints through which actions become possible. Biocognitive affordances concern the interpretation, evaluation, and reorganization of possibilities within embodied experience. Contextual affordances concern the relational circumstances through which possibilities acquire situational relevance. These distinctions do not imply an ontic separation or a fixed sequence in which one domain produces the next. They provide complementary descriptions of constituents that participate reciprocally in the emergence of action.

Research on cultural variation in attention and perception offers empirical grounds for examining such relationships. Masuda and Nisbett (2001) found differences in the extent to which participants from Japanese and American cultural backgrounds attended to focal objects and surrounding contextual information when describing visual scenes. Miyamoto, Nisbett, and Masuda (2006) further investigated how culturally characteristic perceptual environments and immediate environmental exposure were associated with differences in attention to contextual relationships. These findings do not independently establish contextual coemergence as a causal theory. They demonstrate, however, that perceptual organization can vary with experiential and environmental conditions, supporting inquiry into how contextual relationships participate in what becomes salient and actionable.

The implications for agency extend beyond the selection of responses from a predetermined inventory. If the significance of a possibility emerges through changing relationships among biological capacities, experience, and context, then the organization of those relationships may also alter which possibilities become recognizable. Agency may therefore involve not only responding to available alternatives but participating in the reorganization of the conditions through which alternatives become conceivable. This proposition leads to a further question: whether human action includes the invention of possibilities that were not previously represented within the individual's recognized options.

Cognitive Invention and Lived Duration

Agency need not be confined to selecting among alternatives already available to an individual. A distinction can be made between choosing an existing possibility and constructing one that was not previously represented within the person's recognized options. Selecting among alternatives requires evaluation; invention additionally involves reorganizing the conditions through which alternatives become conceivable. This distinction does not imply that invention occurs independently of neural processes. It identifies a cognitive operation that cannot be adequately described as selection among a fixed inventory of responses.

Research on insight and problem restructuring provides an empirical foundation for this distinction. Ohlsson (1992) described how impasses in problem solving can be overcome through changes in the representation of a problem. Kounios and Beeman (2014) reviewed behavioral and neuroscientific findings showing that insight involves identifiable cognitive and neural processes associated with the emergence of solutions not previously apparent to the problem solver. Such findings distinguish the generation or recognition of a new solution from the evaluation of

alternatives already under consideration. Novelty here refers to what becomes newly available to the individual, not necessarily to an unprecedented invention in the world.

The distinction becomes particularly consequential when invention changes the context of the problem itself. An individual may not simply discover another response to an existing question but reformulate the question, altering what counts as a relevant possibility. The resulting action is then organized within conditions partly transformed by the individual's participation. Invention, in this sense, can modify the field of affordances rather than merely select from it.

The experience of these possibilities also unfolds within lived duration. Clock time measures intervals, but lived duration concerns the experienced continuity and significance of events as they unfold. Two individuals may encounter comparable measured intervals while experiencing different degrees of urgency, openness, or opportunity. Duration is therefore not treated here as an alternative physical clock, but as a constituent of how possibilities are experienced and organized within an unfolding situation.

The relationship between invention and duration is especially relevant when a previously unrecognized possibility changes an individual's experience of what remains possible. A situation initially experienced as constrained may become open to reconsideration through a new interpretation or course of action. Conversely, perceived urgency may restrict the possibilities an individual recognizes or pursues. These relationships are proposed as biocognitive hypotheses rather than established causal effects of lived duration on invention.

Agency can thus involve more than the execution of a prepared response or selection among existing alternatives. It may include the construction of possibilities and their organization within lived duration. The empirical challenge is to investigate how these processes relate to neural

preparation, contextual conditions, and enacted behavior without assuming that any one description exhausts the phenomenon.

Empirical Convergence and Explanatory Sufficiency

The empirical findings examined throughout this article arise from different research traditions, yet they converge on a common explanatory challenge. Neural preparation can precede reported intention; perception is shaped by active engagement and cultural experience; contextual attribution can influence physiological expenditure; stimulation can dissociate bodily movement from experienced authorship; and problem restructuring can make previously unrecognized possibilities available for action. None of these findings independently establishes a comprehensive theory of agency. Considered together, however, they raise questions about whether neural antecedents alone constitute a sufficient explanation of the phenomena they enable. The relevant distinction is not between neural causation and an alternative source of causation. Neural processes remain indispensable constituents of action. However, the complexity of biocognitive processing, particularly the emergence of novel possibilities and their changing contextual relevance, presents explanatory demands that cannot be considered resolved merely by identifying neural antecedents or correlates. Caution is therefore warranted against ad hoc interpretations in which neural activity is retrospectively invoked to explain whichever outcome occurs, without independently specifying how the proposed mechanism accounts for that outcome or what evidence could challenge the interpretation. The question is not whether neural processes participate in these phenomena, but whether a strictly bottom-up account has demonstrated sufficient explanatory power to encompass their contextual organization, novelty, and significance.

The convergence therefore supports an empirical research strategy rather than a predetermined metaphysical conclusion. Neural, biocognitive, and contextual descriptions can be investigated as distinguishable but reciprocally organized constituents of agency. The adequacy of an explanation depends not on the level at which it begins, but on whether its premises and evidence account for the phenomenon under investigation.

Second-Order Inquiry: When the Premise Becomes the Explanation

Second-order inquiry examines not only scientific evidence but also the domain of meaning informing its interpretation. First-order inquiry identifies the constituents and observable relationships of a phenomenon; second-order inquiry examines the conceptual premises, theoretical histories, and epistemological assumptions through which those observations acquire explanatory significance. As developed in Martinez's (2026) second-order framework, the initial purpose is not to establish whether a first-order interpretation is right or wrong, but to discover what informs its construction. Because scientists are human observers, empirical findings do not contain their interpretations intrinsically. Second-order inquiry makes these informing conditions available for examination without presupposing the validity or invalidity of the resulting assertion. The present article applies this distinction to empirical science and philosophical interpretation, recognizing that each can inform and constrain the other without substituting for its methods of justification. This relationship is epistemological rather than an additional causal mechanism. An illustration outside neuroscience appears in popular interpretations of quantum complementarity, where experimentally established relationships among preparation, measurement arrangements, and observable outcomes are sometimes extended into claims that conscious observation itself changes physical reality. Such claims introduce a meaning of *observer* not established by the experimental findings. The second-order question concerns the conceptual transition from

measurement to conscious observation, rather than an immediate judgment about the interpretation's correctness.

The distinction also applies to cognition and biology. Within the biocognitive framework, cognition is neither an epiphenomenon of biology nor an independent system acting upon it. Cognition and biology are inseparable constituents of co-emergent authorship, through which living processes participate in the construction of meaning and action. Their analytical differentiation may serve empirical investigation without establishing an **ontic separation**. This biocognitive proposition remains open to second-order examination and empirical investigation under the same standards applied to competing explanations.

Applied to agency, the inquiry examines what neural antecedents demonstrate and what additional premises permit assertions about the presence or absence of agency. Neural activity preceding a decision, accompanying its revision, or participating in the invention of a novel alternative does not automatically establish a single philosophical conclusion. Radder and Meynen (2013) illustrate the importance of distinguishing temporal precedence, correlation, necessary conditions, and causal initiation when interpreting neural events. The methodological challenge is to identify when an interpretation has become self-confirming and what evidence could challenge it. This examination opens empirical questions capable of refining, challenging, or extending explanations of agency without prematurely declaring any one account sufficient.

Toward an Empirical Science of Agency

An empirical science of agency requires operational distinctions among neural preparation, selection, invention, and embodied authorship. Neural preparation can be examined through electrophysiological and neuroimaging measures; selection through observable choices and response timing; invention through the generation of alternatives not initially presented; and

embodied authorship through reports of experienced initiation considered alongside behavioral and neural measures. These observations need not be treated as independent processes. Their differentiation allows investigators to examine how they relate without presupposing that any one measure constitutes agency in its entirety.

One experimental approach would compare decisions across situations that differ in contextual relevance while maintaining comparable task demands. Participants could encounter scenarios in which the available alternatives, their personal significance, or opportunities to construct new responses are systematically varied. Neural preparation, behavioral choices, physiological expenditure, and reported authorship could then be examined together. Crucially, contextual relevance would be assessed independently of the neural activity it is proposed to help explain, avoiding circular interpretations in which context is inferred solely from the observed neural outcome.

The central empirical question is whether models incorporating contextual relevance and the emergence of novel alternatives explain or predict aspects of behavior and experienced authorship that explicitly specified neural models do not adequately capture. This comparison requires matched experimental conditions, independently defined variables, and prospective predictions rather than retrospective explanations of whichever result occurs. Findings that consistently provide no additional explanatory value for the proposed contextual measures, under appropriately sensitive tests, would challenge the framework or require its revision. Conversely, reliable improvements in prediction would support the usefulness of these distinctions without establishing an independent causal force or proving that neural mechanisms are insufficient in principle.

The aim of this inquiry is not to disprove determinism or establish its opposite, but to examine whether the evidence warrants the conclusions drawn from it. An explanatory account must

identify the relevant necessary conditions and provide sufficient evidence for the particular conclusion asserted. Neural antecedents may constitute necessary conditions for particular actions without providing sufficient evidence for the broader assertion that agency is illusory. On the evidence examined here, that assertion remains insufficiently established. The same standard applies to the biocognitive framework: its propositions must generate testable distinctions and remain open to revision. An empirical science of agency advances by establishing what its evidence warrants, rather than declaring an explanatory premise complete before its sufficiency has been demonstrated.

Conclusion: Beyond the Neural Black Box

The history of scientific inquiry demonstrates that identifying the constituents of a phenomenon does not necessarily establish the sufficiency of an explanation. The behavioral black box yielded important discoveries about learning while leaving essential biocognitive processes insufficiently characterized. Contemporary neuroscience has opened the biological black box with extraordinary precision, identifying neural activity associated with preparation, intention, movement, and decision. Yet the identification of these mechanisms does not, by itself, establish that the phenomena they accompany have been comprehensively explained. The neural black box emerges not because neural processes remain inaccessible, but because their identification can be mistaken for explanatory completion.

The empirical evidence examined in this article suggests that neural preparation, perceptual learning, contextual valuation, embodied authorship, and cognitive invention cannot be adequately understood by treating them as interchangeable descriptions of a single operation. Neural antecedents establish conditions through which possibilities become available, but their temporal precedence does not demonstrate that those possibilities have already been selected, enacted, or

experienced as authored. Cognition and biology are not competing sources of action. Within the biocognitive framework, they are inseparable constituents of contextual coemergence, through which possibilities acquire relevance and actions become meaningful.

This distinction carries consequences beyond theoretical neuroscience. Scientific interpretations of agency influence how human beings understand responsibility, intentionality, and their capacities to change. When empirical findings are extended into assertions that agency is illusory, the implications reach ethical judgment, legal responsibility, education, and clinical practice. Such consequences do not establish whether an interpretation is scientifically correct. They do, however, increase the responsibility to distinguish what experimental evidence demonstrates from what philosophical premises contribute to its interpretation. The scientific responsibility is not to protect agency from investigation, but to avoid declaring it absent before the evidence has established that conclusion.

The constructive contribution of this inquiry is therefore not a demonstration that determinism is false or that agency has been proven. It is the identification of explanatory distinctions and empirical questions that remain open. Neural affordances, contextual relevance, cognitive invention, lived duration, and embodied authorship offer domains for investigation through independently defined measures and testable predictions. Second-order inquiry provides a complementary epistemological discipline by examining the premises through which findings acquire explanatory meaning. Neither approach is exempt from scrutiny. Their value depends upon their capacity to generate distinctions that can be investigated, challenged, and refined.

Moving beyond the neural black box does not require abandoning neuroscience. It requires extending the explanatory terrain without confusing biological necessity with explanatory sufficiency. A science of agency capable of examining how possibilities emerge, acquire

significance, undergo revision, and become enacted may offer a more comprehensive understanding of human action while remaining fully accountable to empirical evidence. The question is not whether the brain participates in agency, but whether the explanations presently offered have established everything that participation entails.

And if we are determined to conclude that agency is an illusion, perhaps we should first determine whether the evidence has made that decision for us.

References

Bohr, N. (1928). The quantum postulate and the recent development of atomic theory. *Nature*, 121, 580–590. <https://doi.org/10.1038/121580a0>

Bransford, J. D., Brown, A. L., & Cocking, R. R. (Eds.). (2000). *How people learn: Brain, mind, experience, and school* (Expanded ed.). National Academy Press. <https://doi.org/10.17226/9853>

Brass, M., Furstenberg, A., & Mele, A. R. (2019). Why neuroscience does not disprove free will. *Neuroscience & Biobehavioral Reviews*, 102, 251–263. <https://doi.org/10.1016/j.neubiorev.2019.04.024>

Croxson, P. L., Walton, M. E., O'Reilly, J. X., Behrens, T. E. J., & Rushworth, M. F. S. (2009). Effort-based cost–benefit valuation and the human brain. *The Journal of Neuroscience*, 29(14), 4531–4541. <https://doi.org/10.1523/JNEUROSCI.4515-08.2009>

Crum, A. J., Corbin, W. R., Brownell, K. D., & Salovey, P. (2011). Mind over milkshakes: Mindsets, not just nutrients, determine ghrelin response. *Health Psychology*, 30(4), 424–429. <https://doi.org/10.1037/a0023467>

Crum, A. J., & Langer, E. J. (2007). Mind-set matters: Exercise and the placebo effect. *Psychological Science*, 18(2), 165–171. <https://doi.org/10.1111/j.1467-9280.2007.01867.x>

Desmurget, M., Reilly, K. T., Richard, N., Szathmari, A., Mottolese, C., & Sirigu, A. (2009). Movement intention after parietal cortex stimulation in humans. *Science*, 324(5928), 811–813. <https://doi.org/10.1126/science.1169896>

Held, R., & Hein, A. (1963). Movement-produced stimulation in the development of visually guided behavior. *Journal of Comparative and Physiological Psychology*, 56(5), 872–876. <https://doi.org/10.1037/h0040546>

Kounios, J., & Beeman, M. (2014). The cognitive neuroscience of insight. *Annual Review of Psychology*, 65, 71–93. <https://doi.org/10.1146/annurev-psych-010213-115154>

Libet, B., Gleason, C. A., Wright, E. W., & Pearl, D. K. (1983). Time of conscious intention to act in relation to onset of cerebral activity (readiness-potential): The unconscious initiation of a freely voluntary act. *Brain*, 106(3), 623–642. <https://doi.org/10.1093/brain/106.3.623>

Martinez, M. E. (2026). *Changing the epistemology of spacetime: Toward a second-order science* (Biocognitive Monographs Series, BM-2026-10). Biocognitive Science Institute. <https://www.biocognitiveculture.com/working-papers-archive>

Masuda, T., & Nisbett, R. E. (2001). Attending holistically versus analytically: Comparing the context sensitivity of Japanese and Americans. *Journal of Personality and Social Psychology*, 81(5), 922–934. <https://doi.org/10.1037/0022-3514.81.5.922>

Matsushashi, M., & Hallett, M. (2008). The timing of the conscious intention to move. *European Journal of Neuroscience*, 28(11), 2344–2351. <https://doi.org/10.1111/j.1460-9568.2008.06525.x>

Mazurek, K. A., & Schieber, M. H. (2019). How is electrical stimulation of the brain experienced, and how can we tell? Selected considerations on sensorimotor function and speech. *Cognitive Neuropsychology*, 36(3–4), 103–116. <https://doi.org/10.1080/02643294.2019.1609918>

Miyamoto, Y., Nisbett, R. E., & Masuda, T. (2006). Culture and the physical environment: Holistic versus analytic perceptual affordances. *Psychological Science*, 17(2), 113–119. <https://doi.org/10.1111/j.1467-9280.2006.01673.x>

Ohlsson, S. (1992). Information-processing explanations of insight and related phenomena. In M. T. Keane & K. J. Gilhooly (Eds.), *Advances in the psychology of thinking* (pp. 1–44). Harvester Wheatsheaf.

Penfield, W., & Rasmussen, T. (1950). *The cerebral cortex of man: A clinical study of localization of function*. Macmillan.

- Pessiglione, M., Schmidt, L., Draganski, B., Kalisch, R., Lau, H., Dolan, R. J., & Frith, C. D. (2007). How the brain translates money into force: A neuroimaging study of subliminal motivation. *Science*, 316(5826), 904–906. <https://doi.org/10.1126/science.1140459>
- Radder, H., & Meynen, G. (2013). Does the brain “initiate” freely willed processes? A philosophy of science critique of Libet-type experiments and their interpretation. *Theory & Psychology*, 23(1), 3–21. <https://doi.org/10.1177/0959354312460926>
- Resulaj, A., Kiani, R., Wolpert, D. M., & Shadlen, M. N. (2009). Changes of mind in decision-making. *Nature*, 461, 263–266. <https://doi.org/10.1038/nature08275>
- Schindler, S. (2018). A coherentist conception of ad hoc hypotheses. *Studies in History and Philosophy of Science Part A*, 67, 54–64. <https://doi.org/10.1016/j.shpsa.2017.11.011>
- Schultze-Kraft, M., Birman, D., Rusconi, M., Allefeld, C., Görgen, K., Dähne, S., Blankertz, B., & Haynes, J.-D. (2016). The point of no return in vetoing self-initiated movements. *Proceedings of the National Academy of Sciences*, 113(4), 1080–1085. <https://doi.org/10.1073/pnas.1513569112>
- Schurger, A., Sitt, J. D., & Dehaene, S. (2012). An accumulator model for spontaneous neural activity prior to self-initiated movement. *Proceedings of the National Academy of Sciences*, 109(42), E2904–E2913. <https://doi.org/10.1073/pnas.1210467109>
- Segall, M. H., Campbell, D. T., & Herskovits, M. J. (1963). Cultural differences in the perception of geometric illusions. *Science*, 139(3556), 769–771. <https://doi.org/10.1126/science.139.3556.769>
- Skinner, B. F. (1953). *Science and human behavior*. Macmillan.
- Soon, C. S., Brass, M., Heinze, H.-J., & Haynes, J.-D. (2008). Unconscious determinants of free decisions in the human brain. *Nature Neuroscience*, 11(5), 543–545. <https://doi.org/10.1038/nn.2112>
- Varela, F. J., Thompson, E., & Rosch, E. (1991). *The embodied mind: Cognitive science and human experience*. MIT Press. <https://doi.org/10.7551/mitpress/6730.001.0001>