# Easy Alliances: The Methodology of Minimally Cognitive Behavior (MMCB) and Basal Cognition


**Abstract:**

Although the cognitive sciences produce abundant data, progress in understanding the fundamental aspects of cognition has been hindered by a proliferation of interpretive frameworks. Getting a better grasp of cognition requires that we have ways of concretizing claims and comparing and testing theories. The methodology of minimally cognitive behavior (Beer 1996, 2019, 2020a; Beer and Williams 2009) offers a strategy for evaluating specific cognitive behaviors that can accommodate the variety of explanatory strategies on offer (dynamical systems theory, information theory, autopoietic theory, adaptation, and so on) through the use of toy models. While the methodology itself does not specify a means of picking out which behaviors are cognitive, the nascent program of basal cognition (Lyon 2019, Lyon et al. 2021) offers a principled way to understand cognitive behaviors through its integration with biological functions. Using basal cognition and the MMCB in tandem thus provides both a principled way to carve out a domain of cognitive behaviors and a methodology for evaluation and comparison of the explanatory frameworks which cover that domain.


## I. Introduction

Frequent misunderstandings of the methodology of minimally cognitive behavior (hereafter MMCB) designed by Randall Beer (Beer 1996; Beer and Williams 2009; Beer 2019, 2020a) take this literature to offer a means of, or collection of claims about, pinpointing the minimal conditions under which we can claim that a system is cognitive (see Lyon 2019 for discussion). What the MMCB actually provides, as a methodology, is a means for evaluating specific cognitive behaviors that can accommodate the variety of explanatory strategies on offer (dynamical systems theory, information theory, autopoietic theory, adaptation, and so on), and whose models and data can be used to test conceptual frameworks and their adequacy for theory formation. As Beer points out, many efforts to draw strong demarcations between the cognitive and non-cognitive within the cognitive sciences have largely been led by intuition rather than concrete examples and experiments (Beer 2019). What MMCB offers are resources that can be useful in adjudicating between or integrating cognitive frameworks.

Likewise, the contemporary program of basal cognition (Lyon 2019; Lyon et al. 2021; Levin et al. 2021) offers a schematic toolkit for understanding cognition through foundational biological principles that could easily be mistaken as demarcating the baseline criteria of cognition. However, because it is a functional approach to cognition, where the function is grounded in the biological needs of the organism, the approach also promotes explanatory diversity and integration. The basal cognition framework is intended to offer a way to unite research on cognition and biology through an examination of the functions of organismic activities and their evolutionary origins, and is dedicated to a pluralism towards cognition rather than specific framework-championing.

This paper offers some initial thoughts on how the MMCB and basal cognition programs might form a productive partnership. It shows how the commitments of the basal cognition program and MMCB are complimentary, and how they both avoid the pitfalls of more specific framework-championing programs. Below, the central commitments of each are spelled out, showing how and where they diverge as projects, and then some thoughts are offered on how they might be integrated in future research.

## II. The Methodology of Minimally Cognitive Behavior (MMCB)

The overall aim behind Randall Beer's (1996, 2020; Beer and Williams 2009) methodological approach to what he calls *minimally cognitive behavior* is simple: create toy models to generate specific cognitive behaviors that would be of interest to cognitive science using minimal components. The methodology was developed when contemporaries such as van Gelder (1995) and Brooks ( 1991) were pushing back on the idea that all cognition required some kind of central processing of representational content in order for a system to be able to interact with the world; they developed dynamical systems theory (DST) and advocated for engineering AI through layered subsystems (respectively) to offer new resources for understanding the complex, non-centralized, and situated nature of cognition and intelligence. Building on this work, Beer developed the MMCB, now often referred to simply as 'minimal cognition' (though not by Beer himself), using toy models to reverse engineer behaviors that might indicate cognition in other kinds of systems while using very few internal components.

For example, Beer's early work in this area (1996) involved a simple two-dimensional agent with two motors, an "arm" and "hand", and a compact array of distance sensors. The agent, operating only with the internal components of a limited dynamic neural network, could navigate around and distinguish between objects in its environment. It was able to interact with these objects, moving some of them to build simple structures, and was able to orient itself towards gaps it could fit through and away from gaps it could not. This was all done without central processing, without building an internal model of the world, and without representational capacities.

The MMCB is now a well-known research program that creates minimal models "in which evolutionary algorithms are used to evolve models agents that can exhibit some cognitively interesting behavior, and these evolved agents are then subjected to a mathematical analysis to understand the mechanisms underlying their behavior (Beer 1996; Beer 2003; Harvey Di Paolo, Wood, Quinn, & Tucci 2005)" (Beer and Williams 2015). The current state of cognitive science shows that experiments alone do not settle some debates, as results can often be interpreted to fit one's preferred framework. Instead, we need a theory (or competing theories) through which we can make proposals about how to answer questions about cognition, and then those theories can be tested and put to work through toy models. Beer's recipe for theory creation (2019) involves a series of four steps. First, select a *conceptual framework* that establishes a perspective to be taken on the phenomena of interest, and can establish the guiding principles for subsequent steps. Second, create (or select) a toy model with which the answers provided by the conceptual framework towards a particular question can be tested in a concrete sense. Third, a theory is constructed, where a theory is "a rigorous mathematical interpretation of each of the framework's principles and concepts within the toy model" (Beer 2019, p. 2). The theory mathematically formalizes the terminology of the conceptual framework, which can then be applied and run through evolutionary algorithms. Lastly, the toy model is fine-tuned and repeatedly improved as the theory and the conceptual framework are refined.

Importantly, the mathematization aspect of the methodology (through e.g. information theory, dynamical systems theory, and so on) can be applied to any system without appealing to any specific underpinnings as delineating the "correct" type of cognitive system to be studied. The methodology is not intended to pick out the minimal components of a cognitive system, and is not committed to finding cognition only in a specific type or class of system. Beer himself has been clear that MMCB "was intended as a methodological strategy for bringing cognitive science into direct confrontation with situated, embodied, and dynamical ideas in the simplest and most concrete way possible" (Beer 2020, p. 2), and not to advocate for any one conceptual framework or explanatory strategy above others.

An example of the MMBC at work is seen in Beer's work on gliders in the Game of Life (Beer 2015). Beer starts by laying out the conceptual framework being used: the autopoietic approach to life provided by Maturana and Varela (1980), which sees living as a persisting organization of processes under precarity rather than a certain kind of material structure. The fundamental idea is that living involves a network of processes that satisfy two conditions: (1) boundary maintenance, or the individuation of the system from its environment through ongoing generation of a boundary, and (2) operational closure, or selective openness to the world to assimilate components (energy) that allow for the continued generation of the boundary (energy expenditure). While the materials constituting a cell, for example, change over time, the autopoietic "delimited spatiotemporal organization of processes" persists (Beer 2015, p. 2). Using autopoiesis as a conceptual framework provides a perspective that can be taken to answer questions about interacting processes and boundary closure. Conway's Game of Life is selected as a toy model, as the entities go through stages of decay and production analogous to the processes involved in the self-maintenance of cells. Briefly, through formalizing the set of autopoietic processes of production, destruction, and maintenance in terms of those used within the GoL model, and then mapping out the interdependencies between these processes into a formal network, the toy model is evaluated to see if the entities satisfy the boundary conditions of autopoietic theory. With this established, the self-maintenance of those boundaries can be tested against different kinds of perturbations within the model. The formalization of the framework and the model itself have afterwards been fine-tuned, and other phenomena of interest have been evaluated using the GoL model in subsequent work (Beer 2018; Beer 2016; Beer 2020b).

The MMCB is a useful resource for doing concrete evaluations of the claims made by advocates of differing conceptual frameworks within the cognitive sciences. The example shared above shows how processes thought to form the basis of cognition (boundary-production and self-maintenance) on a particular framework can be examined using the methodology. Some examples of the kinds of cognitive processes and behaviors the MMCB have been used to study are object discrimination (Beer 1996), chemotaxis and coordination in locomotion (Beer and Gallagher 1992), short-term memory (Phattanasri, Chiel, and Beer 2007), affordance perception and selective attention (Slocum, Downey, and Beer 2000), and associative learning (Williams and Beer 2013).

How, though, do we determine which *behaviors* and *processes* are cognitive? The methodology itself makes no claims on how we might carve out the domain of cognitive behaviors from the non-cognitive, taking what might be thought of as a "cognitive science knows it when it sees it" attitude towards the realm of cognitive behaviors. The remainder of this paper aims to show that one way to understand cognitive behaviors is through integration with the contemporary approach of basal cognition. Basal cognition is not itself a conceptual framework, but an approach to studying cognition through biological principles. Its integration with MMCB offers a functional way of carving out a realm of cognitive behaviors for biological systems.

## III. Basal Cognition & the MMCB

Basal cognition takes seriously the biological function of cognition for living organisms. The aim is to create a common approach to across disciplines studying biology and cognition, where cognition is understood as "compris[ing] the sensory and other information-processing mechanisms an organism has for becoming familiar with, valuing, and interacting productively with features of its environment [exploring, exploiting, evading] in order to meet existential needs, the most basic of which are survival/persistence, growth/thriving, and reproduction" (Lyon 2020, p. 416). The approach takes three steps: "First, start with the smallest and simplest organisms that display the phenomenon of interest (the function, the mechanism). Second, in those organisms identify principles from observed and measured patterns of genetic, epigenetic and behavioural interactions. Third, scale up to more complex organisms and observe where the similarities and differences actually lie, not simply where we think they must lie" (Lyon 2020, p. 1). The approach also holds that cognition exists on a continuum, where a firm grasp of evolutionary processes makes it clear that the mechanisms of cognition can be found to some degree in all living organisms.

Like MMCB, the basal cognition approach is not meant to provide a minimal criteria for delineating cognitive from non-cognitive systems, though it is committed to using biological principles to understand cognition, meaning that for biological organisms we have to think of cognition as having a functional, biological basis. Lyon and others argue that a new theory of this nature is needed to move cognitive science forward, and similar to MMCB, points to the many intuition-based stalemates between conceptual frameworks as indicative of the need for a more interdisciplinary and principled approach.

The alignment in spirit between basal cognition and MMCB is quite clear. Both programs emerged amidst frustration with intuition-based framework-championing in cognitive science. Both programs point to prolific but unintegrated data-generation in the numerous disciplines of cognitive science as holding back rather than progressing our understanding of cognition. And both point to biology as the natural place to start a principled integration to study cognition without having the focus solely on the study of (and assumptions about) human cognition.

Broad agreements aside, though, can these programs somehow be put to work together? Basal cognition is a revolutionary approach to the study of cognition, and MMCB is a methodology for making concrete, testable claims about cognitive behaviors and processes through the use of toy models. The proposal here is that the basal approach to cognition offers a principled way to establish which behaviors and processes are cognitive for biological systems. For basal cognition, cognitive behavior indicative of cognition requires the ongoing ability to solve a number of cognitive tasks according to the (self-defined) needs of the system. The basal cognition toolkit proposed by Lyon et al. (2021) outlines a number of interrelated cognitive capacities needed for meeting the existential needs cognition has evolved to accomplish: orienting response, sensing/perception, valence, decision making, anticipation, and so forth. The approach is in line with other functional approaches to cognition that seek to have our studies guided by what a system *does* rather than what a system *uses* to do what it does. For instance, Goldstone and Theiner (2017) say that "although we wish to avoid proposing a criterial 'mark of the cognitive,' we find it increasingly attractive, perhaps even eventually unavoidable, to consider a system to be capable of cognition to the extent that it can flexibly achieve its goals despite imposed challenges" (p. 349). The basal cognition program takes goals to be the biological needs of the system, and makes no further claims on the necessary underpinnings or form of those goals. Any biological organism will have goals determined by its existential needs, and on different scales for multicellular organisms.

In the terminology of the MMCB, the basal cognition approach does not offer a conceptual framework nor a theory suited for formalization. However, the approach provides two things that are not included in the MMCB: (1) a way of establishing cognitive behaviors and processes through a functional approach grounded in biological principles, and (2) a biological basis for taking seriously that those minimally cognitive behaviors (and whatever is taken within the model as the minimal components or processes needed to achieve the behavior) scale up along a continuum. On this last point, we can also take seriously that cognitive mechanisms and processes do not just scale up between organisms, but also within multicellular organisms. To demonstrate, let's quickly look at an example of research utilizing the basal cognition approach.

Studying the mechanisms of learning in humans has often started with the retention of full-blown, conceptual information, leading decades of research to focus on the manipulation and retention of contentful representations and their content. Pamela Lyon (2006) has contrasted this kind of "top-down" *anthropogenic* approach to cognition with a *biogenic* approach that instead starts from biological fundamentals and then layers up by the biological complexity of the organism (which forms the basis of the basal cognition framework). Growing interest in the slime mould *Physarum polycephalum* has opened up new ways of thinking about the mechanisms at work in information-retention and learning. In recent work, Aurèle Boussard and colleagues (Boussard et al. 2021) have investigated how it is that slime moulds learn without the neural architecture that would support representational capacities. By studying the learning behaviors of slime moulds, and then honing in on the mechanisms that facilitated these behaviors, they were able to identify several types of oscillations that play an important role in the retention of information (see also Hanson 2021). Using the basal cognition approach, they first identified the learning behaviors in a simple system. They identified principles from observations of the patterns of learning behaviors, and studied the mechanisms at work. Third, they linked this research to the study of oscillations seen in human learning (theta and gamma oscillations) in order to identify similarities in pattern formation and dynamics when the mechanisms are scaled up. And lastly, they provide insights for pursuing future transdisciplinary work.

So where might the MMCB fit in? The basal cognition approach helps provide a principled way of identifying a cognitive behavior, and in locating the minimal mechanisms or processes that might be modeled to facilitate evaluation and comparison amongst competing frameworks of interpretation. In this way, basal cognition and the MMCB can be more than allies–they are complementary programs that can be used in tandem to integrate disciplines and concretize claims in the cognitive sciences. The last section will briefly cover two possible concerns with using the basal cognition approach to support MMCB.

## IV. Concerns

This final section takes up two issues that might be of concern in using these programs together to investigate cognition. First is the functional approach of basal cognition itself (Lyon et al.

2020) and its grounding in meeting the existential needs of the organism. The advantages of using a (principled) functional approach in tandem with the MMCB have been discussed in the previous section, but there are additional reasons for thinking that the deflated sense of goals involved in the basal approach, as "implicit" and "arising from existential conditions" (Lyon 2021, p. 5), are more beneficial and appropriate for helping us pick out cognitive phenomena than using conceptual frameworks with anthropogenic leanings and more robust demands.

Matt Sims (2021) has recently taken up a detailed defense of the basal approach to intentionality to demonstrate the advantages of treating intentionality as a continuum, against Fred Adams' (2018) claim that basal approaches are overly permissive. For Adams, intentionality needs to contain conceptual content to be *bona fide* cognition, as he claims this content is what sets apart meaning-bearing intentions (the putative quarry of cognitive scientists) from the mere processing of information and automatic sensory responses. In contrast, Sims adopts the basal approach to intentionality because in "understanding cognitive capacities in terms of their biological function to guide adaptive behaviour from the very start, biogenic theorists are not constrained by human-centred demarcation criteria" (p. 50). The details are beyond the scope of this short paper, but the important aspect is what we *get* from each approach. On Adams' account, the study of cognition would be limited to those phenomena involving a certain kind of intentionality, and other kinds of behavior would be relegated to study by other fields. However, we are not provided with a *principle* to support distinguishing this kind of intentionality from the intentionality of single-celled organisms. Researchers of cognition would thus be precluded from investigating how we get ontogenetically and phylogenetically from the mechanisms of single-cell intentionality to meaning-bearing intentionality, which biology tells us would be supported by the former.

The second concern is that the study of cognition must extend beyond the study of organisms, and thus using the basal cognition approach is not helpful in examining sub-cellular, non-biological, and artificial intelligence systems. Using organisms as the basis of comparison for other kinds of cognitive systems does not seem appropriate if the cognition of these other systems cannot be evaluated in the same way–by looking at them functionally. This is a fair concern, but not one that needs to be handled by basal cognition as a foundation for studying biological cognition. If biological cognition is not to be held as the paradigm of cognition, and other kinds of (non-biological) cognition should be evaluated differently, then the onus is on these researchers to provide a principled way to carve out the domain of cognitive processes and cognitive behaviors for these systems–and to do so without simply falling back on intuitions about what constitutes the underpinnings of 'real' cognition.

Another option is, of course, to alter our idea of functionality in line with the systems being studied, and without expecting them to have similar existential needs that will scale up with complexity in the same way. This is the approach seen in Hanczyc and colleagues' work on motile oil droplets (Hanczyc 2011; Hanczyc and Ikegami 2010; Hanczyc 2020), in which self-production and self-organization along the lines of the autopoietic organization of biological systems is employed in studying the abiotic mechanisms, structures, and processes that might scaffold cognition in biological systems (or might be taken as an evolutionary pre-cursor to biological systems). In these systems, we might appeal to the organization of the system, and thus to the function of its behaviors as supporting its organizational structure, as explanatory (in a causal sense). For example, using this kind of functional anchor, the behaviors of these systems have been explored and tested through MMBC by computer scientists such as Matthew Egbert (2020, 2021).

One other way of handling this second concern might be instead to say that maybe cognition isn't the right terminology to use for these latter systems (Brancazio & Meyer 2022). This is a viable option, though out of scope for discussion here. Again, neither the MMCB nor basal cognition offers a conceptual framework that determines or delineates what can and can not be cognitive. The former offers a means of comparison between frameworks based on their formalization, and the latter offers a principled means of picking out cognitive processes and behaviors in biological systems. Principles that might be similarly applied to other systems are certainly possible.

## V. Conclusion

This paper has offered some preliminary thoughts on how the MMCB and the basal cognition approach might be used together. Neither should be taken as offering a minimal criteria for cognition or cognitive behaviors. Neither ought to be thought of as a theory or framework (they both support explanatory pluralism), and neither restricts the study of cognition to specific kinds of underlying mechanisms or implementations. Instead, basal cognition and the MMCB can work in complementary ways to identify cognitive behaviors, locate underlying mechanisms or processes, and then compare or evaluate conceptual frameworks through the use of minimal models.

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