# Minds in the Matrix: Embodied Cognition and Virtual Reality

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## 1 Introduction

Recent years have seen an intensification of interest in virtual reality technology. This interest is being fueled by advances in the development of virtual (or mixed) reality devices (e.g., virtual reality headsets), as well as the increasing sophistication of computer graphics and game engine technology. For the most part, the technological advances are being used for educational and entertainment purposes (e.g., immersive simulations and computer games); however, recent innovations such as the Metaverse suggest a somewhat broader role for virtual reality—one in which virtual reality experiences lie at the heart of a rich array of social, epistemic, and economic activities.

In the present chapter, I offer a brief introduction to some of the ways that virtual reality might affect the theory and practice of embodied cognitive science. The discussion will be necessarily selective, for there are many topics to explore here, and an exhaustive summary would require a much longer treatment than can be offered here [CHAP_CROSS_REF]. As in earlier work, I will suggest that virtual reality can be used to support our understanding of the mechanisms that underlie various forms of embodied intelligence (Smart 2020a). This claim ought to be uncontroversial, at least when it comes to the design of mechanisms that drive a growing number of real-world autonomous systems. As noted by de Melo et al. (2022), virtual reality is a potent source of synthetic data, which can be used to train the control systems (or 'brains') of autonomous systems prior to their deployment in real world environments. There have also been substantial advances in the development of industry-standard virtual worlds that can be used to support the development of autonomous systems, such as driverless cars and aerial drones (see Nikolenko 2021). Such innovations are, of course, directed to the synthesis of new embodied systems; they are seldom used to support the study of pre-existing or naturally-occurring forms of embodied intelligence. In principle, however, there is no reason why virtual reality cannot be used for precisely this purpose. Indeed, I suspect the shift towards virtual reality may hold the key to resolving a number of issues that have long plagued research into the materially embodied and environmentally-situated mind. Section 2 attempts to provide one example of this, focusing on attempts to derive an integrated, mechanistically-informed understanding of extended cognition via the construction of virtual creatures that inhabit virtual worlds. Section 3 highlights some of the virtues of virtual reality when it comes to both the analysis and synthesis of embodied cognitive systems. Finally, Section 4 addresses some of the problems that might be seen to undermine the appeal to virtual reality as part of work in embodied cognitive science. Such problems include the idea that virtual reality is a poor substitute for physical reality and that the interests of embodied cognitive science are best served by a focus on real-world systems. I challenge this view, arguing that virtual reality ought to be at the forefront of future (philosophical, scientific, and engineering) research into the embodied mind.

## 2 Virtual Worlds

What role does virtual reality play in our understanding of the materially embodied and environmentally situated mind? One answer to this question stems from the use of virtual reality to improve our understanding of the mechanisms that underlie various forms of embodied intelligence. In particular, one can use virtual reality to study the behavior of virtual creatures that are embedded in virtual worlds (see Terzopoulos et al. 1994, for a nice example). Such creatures can be equipped with virtual sensors that mimic the features of perceptual processes. They can also be equipped with virtual motors that enable the creature to, in effect, author its own sensory inputs by acting within the virtual world. In short, virtual reality provides us with a means of studying embodied cognition from a computational perspective. Using the same tools and techniques as those used to create contemporary computer games, we can build virtual worlds that enable us to better understand the way in which intelligent behavior emerges from the interaction of forces and factors that are spread across the brain, the body, and the world [CHAP_CROSS_REF].

In one sense, of course, there is nothing particularly new about this proposal—virtual environments have long been used in cognitive scientific research, especially in areas such as cognitive robotics and artificial life. The question, then, is whether there is anything new on the table: Does the use of virtual reality yield anything in the way of progress when it comes to our understanding of prominent issues in embodied cognitive science?

The answer to this question is, I think, a tentative "yes." There are a number of issues that could be explored here. In the interest of brevity, however, I will limit the discussion to one particular problem. This problem concerns the distinction between constitutive and causal relevance. According to the proponents of extended cognition, extra-neural resources (such as a body part or technological artifact) can, on occasion, form part of the mechanisms that realize cognitive phenomena (e.g., the mechanism that realizes a particular cognitive process). In such cases, the extra-neural resource is deemed to be *constitutively relevant* to cognitive phenomena. The proponents of embedded cognition dispute this claim about the constitutive relevance of extra-neural resources. According to embedded theorists, extra-neural resources are merely *causally relevant* to cognition—they exert a causal influence on the operation of cognitive mechanisms, but they are not the constituents or components of such mechanisms.

This distinction between causal and constitutive relevance serves as the one of the major points of disagreement between the proponents of embedded and extended cognition (see Smart 2022a). To settle the ongoing dispute between these opposing philosophical camps, it would help to have a means of determining when a given resource is constitutively relevant to a phenomenon. That is to say, it would be useful to know when a given resource is a *bona fide* part of a given cognitive mechanism (i.e., a mechanism that realizes a cognitive phenomenon). This is sometimes known as the *problem of constitutive relevance* [CHAP_CROSS_REF]. The problem of constitutive relevance is not the only problem that needs to be resolved by the proponents of extended cognition, but it is, nevertheless, an important problem for those who wish to understand the role of bodily and worldly resources in the realization of intelligence (see Smart 2022a).

It might be thought that the study of virtual creatures embedded in virtual worlds is unlikely to yield much in the way of a solution to this particular problem. And yet, the attempt to create virtual versions of extended processes (or extended mechanisms) does, I think, produce a number of important insights. Consider, by way of example, the attempt to model the processes by which a spider spins a web. Drawing on prior ethological work, Krink and Vollrath (1998) implemented a virtual robot spider that constructed a virtual web. The precise details of this work need not concern us here. What matters is that a virtual world is being used to explore the mechanisms associated with a real-world form of intelligence, albeit one exhibited by an arthropod. Also important is the role of the spider's body in ensuring a successful outcome. As it turns out, spiders use their bodies as something akin to a representational device that helps them coordinate bodily responses with the demands of the web weaving process. Initially, the spider produces a few strands of silk that attach themselves to surrounding environmental structures (e.g., an overhead branch). These strands then act as a constraint on the spatial positioning of the spider's legs. As each leg comes to rest on a given strand of silk, it yields a certain pattern of proprioceptive input regarding the angular displacement of the leg relative to the spider's body. As it turns out, this is all that is required for the spider to spin the web. In response to different patterns of sensory input (i.e., leg configurations), the spider produces further strands of silk, and each silk-producing action works to further constrain the bio-external problem space in which the spider operates.

To my mind, there ought to be little problem in recognizing this process as a candidate extended process. (Whether it counts as a specifically *cognitive* process is, I think, less clear, but let's park that.[i]) In considering spiders, it is natural for us to see them as the bearers of a particular sort of dispositional property. In particular, we deem them to be capable of producing a variety of silk-related artifacts, the canonical example being an orb web. Spiders, then, have a particular dispositional property, namely, a *capacity* to spin a web. Let us denote the spider as *S* and the relevant dispositional property as *D*. When the spider spins a web, it is engaged in a particular process. This is the process of spinning a web. Let us denote this process as *P*. *P* reflects the manifestation or exercise of *D*, which, recall, is ascribed to the spider *S*. *P* is realized by a mechanism (*M*), but this mechanism does not appear to be one that is confined to the biological borders of *S*. *M* is what we might call an *extended mechanism*. It is a mechanism that includes components (specifically, silk threads) that lie external to the thing to which a given dispositional property is ascribed.[ii]

This gives us a rough and ready way of understanding the status of *M* as a specifically extended mechanism, and thus the status of *P* as an extended *P* (see Smart 2022b). But why should we regard the silk threads as constitutively relevant to *P*? What is it that makes these extra-organismic resources part of the mechanism (*M*) that realizes the relevant process (*P*)?

From a purely engineering perspective, this question is apt to sound a little odd. It is a bit like asking an automobile engineer how they know that a piston forms part of the propulsion mechanism for a conventional car. The reason the question sounds odd is because the problem of constitutive relevance is more a problem in the philosophy of science than it is the philosophy of engineering. From an engineering standpoint, there is no mystery as to how the web-spinning mechanism works or what the components of this mechanism are. This is because the engineer (the maker of mechanisms) is not in the same epistemic position as the scientist (the discoverer of mechanisms). The scientist needs to determine the causal structure of a mechanism, and this requires them to perform experiments that establish the precise causal role of each of the constituents within the mechanism. This is where we run into the problem of constitutive relevance (see Craver et al. 2021). For the engineer, however, there is no problem of constitutive relevance, for the causal structure of the mechanism is not something that needs to be determined: this causal structure has already been determined by the engineer as part of the mechanism design process. For the engineer, then, there is nothing to be gained by subjecting the mechanism to interventionist-style experimental manipulations, for such interventions will not tell the engineer anything that they do not already know, at least in regard to matters of constitutive relevance (see Smart 2022c). In the web-spinning case, we already know how the relevant mechanism works: the spider produces the silk, which constrains the spatial positioning of the spider's legs, which influences subsequent silk-producing actions, and round and round we go until the web is complete. This *is* the mechanism, and the mechanism is constituted by resources that correspond to the spider's 'brain' (the control system), the spider's body, and the silk threads that are produced as part of the web-spinning process. This may not be the actual mechanism that underlies real-world cases of spider web weaving, but it is nevertheless a mechanism that is sufficient to realize a particular sort of functionality, and it is, moreover, a mechanism that has the hallmarks of an extended mechanism—a mechanism that features the inter-operation of forces and factors that are distributed across brain, body, and world.

My point here is not so much that virtual reality enables us to resolve the problem of constitutive relevance; it is more that a synthetically-oriented shift in our approach to the study of embodied systems alters the way we think about this problem. The problem of constitutive relevance arises whenever we confront a naturally-occurring phenomenon, one whose mechanistic underpinnings are unknown to us. But this problem need not arise in the virtual world. In the Matrix, we know where the borders and boundaries of mechanisms lie. They lie precisely where the engineer (the maker of mechanisms) puts them.[iii]

## 3 The Virtues of the Virtual

The construction of virtual worlds and virtual creatures is, of course, not the only means of prompting this synthetically-oriented shift in our approach to the problem of constitutive relevance. Instead of building a virtual creature, one could attempt to build a physical robot and study its performance in the real world. Perhaps, then, there is not much to be gained by the study of virtual mechanisms in virtual reality. Rather, than rely on virtual reality, we should perhaps turn our attention to real-world implementations of embodied cognitive mechanisms.

The problem with this approach is that it overlooks many of the benefits of virtual reality. Consider the aforementioned web-spinning scenario. A real-world implementation of this scenario requires us to build a physical robot, but this effort, it should be clear, is not straightforward. Nor is the relevant implementation effort particularly 'cheap' in terms of the amount of time, effort, and often money that must be spent to achieve an accurate representation of the spider's morphological and biomechanical properties. The virtue of the virtual in this respect is that it often simplifies the effort to study the mechanisms that underlie various forms of embodied intelligence.

This is not to say that the engineering of virtual creatures is particularly easy or straightforward. Such efforts often rely on a great deal of computational expertise, and not everyone will be in a position to design a 3D representation of a spider's body, replete with articulated joints, deformable materials, and a species-specific skeletal 'rig'. In general, however, this expertise is becoming increasingly available due to the growing interest in virtual reality, the widespread availability of game creation systems (such as Unity and Unreal), and the recent growth in so-called asset stores, which support the global sharing of virtual (reality) assets. This speaks to another benefit of virtual reality. Virtual assets are digital assets, and digital assets can be shared in a way that physical assets (e.g., a physical robot) cannot. Once designed, a virtual creature can be made available to a global community of researchers who can then incorporate the design into their own simulations. This is not something that can be readily achieved with a physical robot.

There are other virtues hereabouts. As noted by de Melo et al. (2022), virtual environments permit a great deal of control over the structure of the environment in which a virtual creature is embedded. This can be important when it comes to establishing ground truth information, which is often important for machine learning.

Virtual environments also permit control over many of the forces and factors that govern intelligent behavior. If, for example, we want to know how maturational shifts in bodily parameters (e.g., changes in body morphology, sensor acuity, or motor function) affect the structure of intelligent behavior, then we can do this in the virtual world without the need to repeatedly disassemble and reassemble a physical robot.

There is a further virtue of virtual reality that is worth mentioning here. It concerns the way in which the recent interest in all things virtual provides us with an important opportunity to expand the reach of embodied cognitive science, especially when it comes to the 'gamification' of research problems. Consider, by way of example, the attempt to design (or grow, or train, or evolve) a collection of robotic drones intended for off-world exploration (e.g., a fully autonomous Martian robot). Such design efforts could easily be rendered as a form of game, whereby candidate designs are both created and evaluated by a global community of citizen scientists (or citizen engineers) (see Smart 2020a). Even if such efforts do not culminate in the development of an actual physical robot, they nevertheless provide an important opportunity for folks to learn about the various forces and factors that govern the shape of intelligent behavior, and this includes the role of the body (and body-world interactions) in determining both cognitive success and failure.

## 4 Mind the Gap

Notwithstanding the virtues of virtual reality, I suspect some will want to challenge the idea that the study of virtual creatures can yield much in the way of progress for our understanding of embodied cognition. High on the list of potential gripes is likely to be something called the *reality gap problem* (see Howard et al. 2022). This problem concerns the mismatch between the virtual and the 'real'—the fact that no matter how hard we try, there is always likely to be something missing from a virtual world. A virtual world, it seems, is no more than a mere approximation of the real world, and thus a reliance on the virtual could easily lead us to overlook some explanatorily crucial factor, one that is present in the real-world but absent from its virtual counterpart.

This is, to be sure, an important worry, and it is one that has led some scholars to eschew a commitment to virtual reality, as well as other forms of computer simulation. Brooks (1991: 140), for example, suggests that: "At each step we should build complete intelligent systems that we let loose in the real world with real sensing and real action. Anything less provides a candidate with which we can delude ourselves." Similarly, Pfeifer and Iida (2004: 18) argue that the "move into the real world" constitutes a grand challenge for work in embodied AI. "True intelligence," they suggest, "always requires the interaction with the real world."

Given these complaints, it seems that a preoccupation with virtual creatures and virtual worlds might be something of a mistake for the proponent of embodied cognition. Rather than direct our attention to virtual creatures and virtual worlds, it seems that we ought instead focus our attention on the realm of real-world embodied cognitive systems, mechanisms, and processes. To do otherwise is to risk an unwelcome form of computational abstraction, one that (historically speaking) much of the work in embodied cognitive science has sought to guard against.[iv]

There is undoubtedly something important about the reality gap problem, but the problem is, I think, often overstated. Consider the aforementioned case of a virtual spider spinning a virtual web. The task of creating a lightweight miniature physical robot with the sensory and motoric competencies of a real-world spider is, at best, a difficult undertaking. Indeed, I doubt that is even possible with current technology. In what sense, then, does a focus on real-world systems enable us to close the purported reality gap when it comes to our understanding of a naturally-occurring case of embodied intelligence? Is it really possible, for example, to build a physical robotic spider with all the flexibility of its biological counterpart? Can we emulate the representational capacities engendered by the presence of eight articulated appendages? And what about the properties of the silk thread that play a crucial role in the overall problem-solving process? Can we really produce synthetic silk with all the material properties of biological silk, and, if not, how does the focus on real-world instantiations of the web weaving process help us understand the role of such properties in yielding the particular form of embodied intelligence that we are trying to emulate? Won't the exclusion of these properties exacerbate the risk of overlooking some explanatory crucial factor?

To be sure, there are clearly some situations where real-world analytic and synthetic efforts are indispensable for our understanding of embodied cognition. No one, I think, would want to question that. But to insist that a preoccupation with virtual reality risks the introduction of some sort of 'gap' is either to underestimate the sophistication of contemporary virtual reality technology or to overestimate our current abilities to recapitulate the features of bio-cognitive systems in a purely physical medium.

A further shortcoming of the reality gap problem is that it relies on a tacit assumption regarding the nature of reality itself. What proponents typically mean by the reality gap is that there is some sort of mismatch between the realm of the virtual and the 'real'—a difference between the realms of virtual and physical reality. But the notion of physical reality is not, I think, as clear-cut as the proponents of the reality gap problem seem to think. Physical reality is often understood as the sort of reality that exists here on planet Earth. It is, moreover, the sort of reality that human beings are familiar with, courtesy of our species-specific sensorimotor capabilities. Realities are, however, somewhat variable. Suppose, for the sake of example, that our aim is not merely to replicate the sorts of embodied intelligence that we find here on Earth, but to engineer embodied systems that are tasked with the exploration of extra-terrestrial environments, e.g., the oceans of Europa or the skies of Titan. In such cases, it should be clear that any robust commitment to the 'real' (or physical) is unlikely to pose much of a solution to the reality gap problem. The reason is that one cannot replicate the precise details of a remote alien environment within the comfort of one's terrestrial home. In order to deal with the vagaries of alien environmental conditions, one cannot merely study the performance of embodied robotic vehicles here on Earth, for to do this is to introduce a reality gap that is no less cavernous than that which motivates concerns about the ostensible shortcomings of virtual reality. Arguably, the best place to study the performance of robots intended for off-world exploration is within an environment that emulates the properties of the alien world that the robot will eventually inhabit. If, for example, one wants to understand the best bodily design for a Lunar robot, then it is arguably important to test candidate body designs in an environment that replicates the same gravitational forces as those encountered on the surface of the Moon. There is little point in trying to test such solutions in a terrestrial gravitational environment, for once the robot is dispatched to its Lunar destination, it will probably never encounter this sort of gravitational environment again. In such situations, the reality gap problem looms large, but this problem is not so much the mismatch between the virtual and the real; it is more the mismatch between our local terrestrial reality and the sort of reality that is to be found beyond the terrestrial frontier.

There are, then, some reasons to think that the reality gap problem is not necessarily narrowed by directing our attention to the realm of physical reality. But what about Pfeifer and Iida's (2004: 18) claim that "true intelligence *always* requires the interaction with the real world" (emphasis added)? Insofar as we can even make sense of the notion that there is a form of 'true' intelligence that ought to be distinguished from intelligence of the (one presumes) more ersatz variety, it is worth noting, I think, that advances in virtual reality are increasingly challenging the distinction between the virtual and the physical. In part this is due to technological advances in virtual reality; e.g., the development of increasingly sophisticated physics engines, the development of 3D models for biomimetic character animation, and the development of photorealistic graphics rendering pipelines. Beyond this, however, it is not clear that the search for genuine forms of intelligence ought to be limited to the world of the physical and the real—the sort of world to which we are accustomed.

Consider, by way of example, the fictional character of Joi in the movie *Blade Runner 2049* (Smart 2020b). Joi is a hologrammatic entity whose behavior is suggestive of a high degree of intelligence. Joi is, of course, a fictional character—a cinematic (hologrammatic) entity embedded within a cinematic (photonic) medium. But the fictional scenario speaks to the contemporary interest in using virtual reality as a means for instantiating new kinds of intelligent systems, including virtual humans (see Burden and Savin-Baden 2019). It is perhaps easy to assume that there is something 'unreal' about these virtual creatures, but the entire point of movies such as *Blade Runner 2049* is to challenge our intuitions on this front. In what sense would a Joi-like, hologrammatic entity fail to count as truly or genuinely intelligent? And what right do we have to insist that our reality (whatever that means) is the only place where *bona fide* forms of intelligence are to be found? Doesn't a consideration of virtual creatures open the door to the possibility that perfectly genuine forms of intelligence might emerge from the forms of photic flux that define the moving image? A virtual creature is, I suggest, not some sort of 'unreal' creature. Nor is it clear that such creatures ought to be seen as entirely virtual in nature. A virtual creature is a creature produced by computational processes, and there is nothing unreal or non-physical about computational processes. What is perhaps distinctive about virtual creatures is that they inhabit a photonic (or cinematic) medium. They are, perhaps, beings that are constituted (at least in part) by photonic elements. But is there any reason why the photonic medium should not be home to the next generation of intelligent (perhaps even conscious) beings? To my mind, this possibility sounds no less implausible than the idea that intelligence should emerge from the forms of electrochemical flux that characterize the whirrings and grindings of the biological brain.

At the end of the day, a virtual world is the product of a generative process that relies on one or more computationally-defined generative models (e.g., a model that describes the propagation of light or the operation of physical forces). But is this so very different to the idea that our own human forms of intelligence (including perhaps our conscious experiences) are tied to the operation of neurally-realized generative models (see Clark 2019)? Interestingly, one of the emerging areas of virtual reality research is what is called neural rendering, which relies on the use of deep generative models to produce photorealistic outputs (see de Melo et al. 2022). The resulting virtual realities might be seen as the real-world counterparts to the sorts of 'controlled hallucination' that define the shape of our own phenomenal experiences. In this sense, our human conscious experiences might be seen as a form of virtual reality—as a cinematic rendering of the real. Few, I suspect, would argue that human consciousness ought to lie beyond the realms of embodied cognitive science. But if that is so, then perhaps the proponent of embodied cognition ought not be so hasty in choosing between the proverbial red and blue pills. Rather than eschewing virtual reality, perhaps we are better off furrowing everdeeper into the Matrix. At the very least, it will be interesting to see just how deep the rabbit hole goes.

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[i] This problem is not the same as the problem of constitutive relevance. It concerns the status of a phenomenon as a specifically cognitive phenomenon. This is what is known as the problem of cognitive status (Smart 2022a) or the mark of the cognitive problem (Adams and Garrison 2013).

[ii] Note that it would make no sense in this situation to say that *D* belongs to an 'extended' systemic organization comprising both the spider and the web (or the silk threads that comprise the web). The reason for this is that prior to the commencement of *P*, there is no web (nor are there any silk threads). The relevant extra-organismic resources are manufactured during the course of *P*, so it cannot be the case that such resources are the partial bearers of *D*, for prior to the initiation of *P* (which, recall, is the manifestation of *D*) there is no extended organization to which *D* could be ascribed.

[iii] This is, at least, the case for mechanisms that we ourselves design. In cases where a mechanism arises as the result of evolutionary processes (e.g., the use of genetic algorithms), then the causal structure of a mechanism may not be so clear-cut. In such cases, the engineer is placed in the same sort of epistemic position as the scientist. That is to say, the engineer needs to 'reverse engineer' the evolved mechanism, so as to understand how it works relative to the phenomenon (e.g., the process) that it realizes.

[iv] There is an associated issue here regarding the extent to which a virtual creature could be seen to possess a body. A virtual body, it might be thought, cannot count as a 'real' body, and therefore a virtual creature cannot count as a genuinely embodied system. This sort of problem—call it *the embodiment problem*—rejects the idea that there is any sort of virtual embodiment. Virtual creatures are little more than computational entities, and such entities are typically understood to be the opposite of embodied. Rather than being embodied creatures, they are more often understood to be disembodied. This sort of problem is discussed by Wheeler (2013). Wheeler suggests that a functionalist conception of the body allows for the possibility of virtual embodiment. According to this proposal, a virtual creature is no less embodied than is its physical (real-world) counterpart.