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Why Children Don't Have to Solve the Frame Problems: Cognitive Representations Are Not Encodings

Mark H. Bickhard

Lehigh University

Psychology and developmental psychology alike are dominated by a core assumption concerning the nature of representation, an assumption that representation has the nature of an encoding. I argue that this assumption is false and offer an alternative model of representation based on the pragmatics of action. Encodingism yields multitudinous and multifarious problems, problems which I have addressed in detail elsewhere. One of the central problems of encodingism, however, is that it creates a class of fatal problems collectively called "the frame problems." I argue that the frame problems originate in the inherent requirement that encoding representations carry explicit content—if the content were not explicit, then the encoding would not encode anything and would not be a representation at all. These problems—and others, such that encodings cannot emerge, and, therefore, render development impossible—visit themselves on theories that are constructed within an encodingist set of presuppositions. Conversely, the interactive alternative model of representation that I offer has its own powerful consequences for development—the issues at stake are not trivial. © 2001 Academic Press

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We all believe an unbounded number of things about the way the world is and about the way the world works. For example, I believe that if I move this book into the other room, it will not change color—unless there is a paint shower on the way, unless I carry an umbrella through that shower, and so on; I believe that large red trucks moving at high speeds can hurt me, that trucks with polka dots can hurt me, and so on; that if I move this book, the room will stay in place—unless there is a pressure switch under the book attached to a bomb, unless the switch communicates to the bomb by radio and there is shielding in the way, and so on; that the moon is not made of green cheese, that the moon is not made of caviar, that the moon

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Address reprint requests to Mark H. Bickhard, Department of Psychology, 17 Memorial Drive East, Lehigh University, Bethlehem, PA 18015. E-mail: mark.bickhard@lehigh.edu.

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is not made of gold, and so on. The problems involved in accounting for such infinite proliferations of beliefs—and the computations and inferences that take them into account and that determine which are *relevant* to take into account—are collectively called the Frame Problems, and are considered by some to constitute a major discovery of a new philosophical problem (Amarel, 1981; Ford & Hayes, 1991; Ford & Pylyshyn, 1996; Genesereth & Nilsson, 1987; McCarthy & Hayes, 1969; Pylyshyn, 1987; Toth, 1995).

How could we possibly learn them all? How could the brain possibly instantiate them all? How could we possibly take them all into account? The problems appear insoluble, impossible. Yet we all learn and hold such unbounded numbers of beliefs; in particular, children do. Something must be wrong.[1]

I argue that the frame problems arise from a fundamental presupposition about the nature of representation—a false presupposition. That is, I argue that the frame problems are artifactual: they arise *only* as consequences of this false presupposition and disappear when that presupposition is corrected. Yet, it is a presupposition that dominates contemporary developmental psychology (and psychology more broadly, as well as cognitive science, artificial intelligence, philosophy of mind, and so on). Roughly, it is the presupposition that representation—*all* representation—is constituted as encodings. In contrast, I will offer an alternative model of the nature of representation within which the frame problem does not arise—within which such unboundedness is natural—and I will illustrate how the impossibilities of the frame problem visit themselves on a contemporary developmental model (Perner, 1991).

The alternative model of representation that I offer is called interactivism. It is part of the general historical development of pragmatism, of the emergence of representation out of action and interaction. This tradition is historically quite recent: it is known best in psychology through the work of Piaget, but its descent is roughly from Peirce and James to Baldwin to Piaget. I will not argue a specifically Piagetian model of representation, because in fact I think he got it wrong (Bickhard, 1988a,b; Bickhard & Campbell, 1989), but I will present a generally pragmatist model, that, though developed independently (e.g., Bickhard, 1973, 1980), happens to be somewhat more similar to Peirce's than to Piaget's (Hookway, 1985; Hoopes, 1991; Houser & Kloesel, 1992; Mounce, 1997; Murphy, 1990; Rosenthal, 1983; Smith, 1987).[2]

[1] Chomsky showed that the age of the universe is not long enough for children to learn all of the associative connections that would be involved if language were associative (Chomsky, 1964). Clearly, there is also insufficient time since the origin of the universe for children to learn all of these beliefs—insufficient time for children to solve the frame problems—yet children seem to manage this task quite well. Why do children not have to solve the frame problems? The solution to this problem turns out to be very un-Chomskyan.

[2] The interactive model also has strong convergences with Dewey, both with respect to Dewey's notions of knowing and his model of language (Tiles, 1990). It differs, however,

Pragmatist conceptions of representation are in strong contrast to standard notions of representation that have dominated Western thought since the Greeks (Bickhard, 1987, 1993, 1995b). Those dominant assumptions turn on the notion that representations are in some sort of correspondence—causal, informational, isomorphic, and so on—with what is represented. Picture or statue representations are the basic analogy; presumed visual sensory ''encodings'' are paradigmatic (see Bickhard & Richie, 1983, for a critique of this notion). In general, these assumptions hold that representations encode what they represent. Such notions are still dominant, and, with the decline of Piagetian developmentalism in favor of computer and information processing (including connectionist) models, they have become reascendant in developmental psychology as well.

This paper is a part of the logical and conceptual conflict between these two traditions about representation. In particular, I will argue that the frame problems are problems for, and only for, the dominant correspondence or encoding models of representation. That is, the frame problems are *derivative* from encoding conceptions of representation, and do not arise for the interactive model of representation. Children, and adults, do *not* have difficulties with the frame problems because they are not problems of cognition and development—they are problems only for encodingist *models* of cognition and development. Conversely, the consequences of the alternative pragmatist model of representation that I propose ramify throughout developmental theory—and psychology and philosophy more broadly.

The frame problems, then, are not unique to developmental psychology: they visit themselves on all domains involved in the study of the mind, throughout psychology and beyond. The frame problems do have a special impact on developmental psychology, however, in that the *computational* intractabilities that are at the core of the frame problems are enhanced by impossibilities of *learning* or developing all the representations and all of the understandings of relevance among them that are involved. The frame problems would seem to make development impossible.

The frame problems constitute a fatal counterargument to encoding correspondence notions of representation, and, therefore, to much of contemporary developmental psychology (for many other problematics, see: Bickhard, 1993, 1996; Bickhard & Richie, 1983; Bickhard & Terveen, 1995; Campbell & Bickhard, 1986, 1992b; Levine & Bickhard, 1999).[3] If the basic presuppositions that provide the foundations for work on child development

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from Dewey's subsumption of ''truth'' into ''warranted assertability''—in this, the interactive model is again closer to Peirce (Mounce, 1997).

[3] In the context of the many other problematics of encodingism discussed in these references, the frame problems provide *another* fatal counterargument. One should be enough, but there are plenty more for the morbidly curious. Nevertheless, although encodingism is dead, encodingists dominate.

cannot even in principle account for a clear fact about development—the unbounded growth of beliefs—then it clearly cannot serve as a valid foundation for understanding development. Such false presuppositions can render an entire field of study nugatory and doom it to historical sterility, such as happened to the field of ''verbal learning'' when its associationistic presuppositions were rejected.

So, the stakes at hand are both the particular ones of how children, and adults, could possibly solve these seemingly impossible problems, and, more broadly and deeply, the theoretical validity of the view of representation in developmental psychology today. Although the frame problems do not constitute a problem that is specific to developmental psychology, they do constitute a deeply serious problem that impacts developmental psychology, and does so with a double force: developmental psychology faces not only the *computational* intractabilities of the frame problems, but also the impossibility of *learning* or *developing* such unbounded classes of beliefs.

THE FRAME PROBLEMS

The (first) frame problem was first discovered in an exploration of how a robot could keep track of the consequences of its actions, of what changes, and of what does not change (McCarthy & Hayes, 1969).[4] Some of those consequences seem obvious and easy to program, such as, if I move this book, then its location will change. Other issues involved in updating the robot's representational frame, however, proved to be not so easily addressed—for example, if I move this book, its color will not change, and the walls will not move, and so on. At first, such examples seem like a merely technical problem that should have a relatively simple technical fix. However, the decades since then have shown that the original problem is just the first recognition of a much more general and deep class of problems.

The general problem emerges from the fact that it is not a priori determinable what relevancies there are, or are not, between various actions or events and the multiple parts and aspects of the world (Glymour, 1987). Instead, any assumptions about such relevancies seem to be defeatable by appropriate contexts or histories. If I move this book, for example, its color will not change, unless there is a paint shower along the path of movement—and the walls will not move, unless the book is resting on a pressure switch

[4] Knowledge of the regularities in the world has certainly been addressed previously—for millennia, in fact—and also problems of learning such regularities—by Piaget, just for one example. What McCarthy and Hayes encountered, however, was the computational explosion encountered in trying to keep track of all of the potentially relevant such regularities and their consequences. The notion of computation, however, is relatively recent, along with its associated notion of computational intractability. Thus the argument, by some at least, that this constitutes a recent and genuine philosophical discovery. Whatever its provenance, however, it is a serious problem that has not been seriously addressed in the developmental and psychological literature.

attached to a bomb that will destroy the walls, unless the pressure switch communicates with the bomb via radio waves and I have installed a barrier to those waves, and so on and so on. Attempting to represent and to compute all such relevancies and all of their defeating conditions is an unbounded task, and, therefore, intractable. It cannot be done.

Furthermore, there are now many relatives of the original frame problem, usually all classified together as the frame problems, or just the frame problem singular, that share this characteristic of introducing computational intractabilities into tasks of representing the world and keeping those representations updated. The frame problems are considered by some to be a major philosophical problem, a problem in epistemology, that was discovered within the field of artificial intelligence (Amarel, 1981; Ford & Hayes, 1991; Ford & Pylyshyn, 1996; Pylyshyn, 1987).

What makes the frame problems so vexing is that the task of keeping up with the world as we act in it, and of keeping track of all the things that we believe and the changes in those, is rendered impossible by these computational intractabilities. Yet we all do it all the time. Furthermore, infants and children learn how to do it. So, either there is something wrong with several decades of attempts to solve the problem, and a genuine solution will emerge ‘‘tomorrow,’’ or else the problem is not really a problem of epistemology in the world at all, but is instead some sort of artifactual problem—a consequence of not understanding things correctly, a manifestation of a false underlying assumption, and, therefore, a problem that disappears when that false underlying assumption is corrected. I am arguing that the latter possibility is the case. In particular, I argue that the frame problems derive from a false and impossible model of representation, one that is nevertheless dominant. The frame problems, in other words, are a *reductio* of contemporary epistemological assumptions, not a problem to be solved *within* those assumptions (Bickhard & Terveen, 1995).

ENCODINGISM

I address first an adumbrated characterization of encodingism. It takes many forms and is at times deeply embedded in presuppositions that may not be superficially recognizable, so it is not always easy to diagnose its presence. This is not the appropriate opportunity to attempt an exhaustive characterization (for much more detail, see Bickhard, 1993; Bickhard & Terveen, 1995), but an overview of its nature and of some of encodingism’s problems (it has many problems in addition to the frame problems) will be useful.

Encodingism assumes that all representation has the nature of an encoding. A paradigm case would be the sense in which ‘‘**. . .**’’ encodes ‘‘**S**’’ in Morse code. Morse code is a conventional form of encoding, but—typically—nonconventional correspondences are also construed as encodings, such as when activities in the optic tract are taken to encode properties of the light that impinges on the retina (Carlson, 1986; Fodor & Pylyshyn, 1981).[5]

A widespread general version of encodingism today is what is generally called ''information semantics.'' The core notion is that something—perhaps optic tract activity—represents something else—patterns and properties of the light—by virtue of the first carrying information about the second. ''X carries information about Y'' in these discussions generally means ''X is correlated with Y.'' A stronger version would be to restrict the information carrying relationship to those that are instances of a natural law—a nomological relationship (Fodor, 1990; Fodor & Pylyshyn, 1981; Pylyshyn, 1984).

Some very strong restrictions must be put on the general framework, however, because informational relationships, including nomological relationships, are ubiquitous throughout the universe—every instance of every causal law is also an instance of such a nomological informational relationship—and virtually all of them are *not* representational. There is a proliferation of correspondences.

Another kind of proliferation arises when some particular causal nomological relationship is examined: if there is a causal correspondence of the critical kind between, say, retinal activities and the light, then there is also a causal relationship between those retinal activities and the surface of the object, perhaps a table, that the light was reflected from, and with the quantum level activities in that surface, and with the table being there 2 min ago, and with the table yesterday and last week, and with the trees or oil out of which it was constructed, and with the sunlight that helped those trees to grow, and so on all the way back to the Big Bang. Something very special has to restrict the generic class of correspondences.

Another problem arises when the possibility of representational error is addressed. If an instance of the favored kind of correspondence exists, then the representation exists and it is correct, while if the favored kind of correspondence does not exist, then no representation exists—there is no room in this framework for the representation to exist but to be in error. There is no ability to account for representational truth and falsehood. There are only

[5] Note that genuine encodings most certainly exist. Morse code is a prime example. However, such encodings require that the persons using them already know about the code, about what is encoded, and about the proper relationships between the two, in order for the encoding to exist. That is fine for genuine encodings, such as Morse code (Morse code is useful because it changes the *form* of representation, from characters into dots and dashes, which can be sent over telegraph wires, not because it creates *new* representations), but renders encodings impossible as sources for any *new* representations. Encodings only borrow the representational content from something else—''**. . .**'' from ''**S**''—they do not create any new such content, and, therefore, could *not* be, for example, the form in which we represent our external world. We would have to already represent the world (''**S**''s) in order to be able to construct our representations of it (''**. . .**''s) (Piaget, 1910).

two *correspondence* possibilities—the correspondence exists or it does not—but there are three *representational* possibilities that must be accounted for: (1) exists and is correct, (2) exists and is in error, and (3) does not exist. A great deal of effort has been directed toward trying to solve this problem over the past decades (Dretske, 1988; Fodor, 1990; Hanson, 1990; Loewer & Rey, 1991), but, I argue, without success (Bickhard, 1993, 1999a).

This constitutes the barest introduction to the nature and trials and tribulations of encodingism, but hopefully it will give sufficient guidance to understand the following. One of the general claims of this discussion is that the myriad problems of such encoding models, including the frame problems, cannot be overcome so long as the encoding framework remains intact. It is a false framework for trying to model representation. It is a model suited for a passive spectator of the world, who processes inputs received and attempts to infer backward down the causal flow of those inputs to what in the world it was that generated them. The interactive model, in contrast, is a forward or future looking orientation that characterizes representation as being constituted in ‘‘anticipations’’ of future potentialities for further action and interaction.

REPRESENTATION EMERGENT OUT OF INTERACTION

Consider an organism interacting in its environment. At any particular time, it must differentiate the environment that it is in; it must somehow indicate for itself what next interactions are possible in those differentiated environments; and it must select which of those possible interactions to actually engage in. My claim is that representation is emergent in this basic task of interaction indication and selection (Bickhard, 1993, 1998a,b; Bickhard & D. Campbell, 2000).

Functional control of interaction. If there is more than one action possible, the organism will need some way of functionally selecting which action to engage in. Such selections will, in general, depend on the internal outcomes of *previous* interactions—for example, if interaction **A** has just completed with internal outcome **S,** then begin interaction **B.** If a paramecium is swimming down a sugar gradient, then it will stop swimming and tumble for a bit, before resuming swimming—eventually it will hit upon a direction that moves up the sugar gradient, and then it will continue swimming (Campbell, 1974, 1990).

For more complicated organisms, the relationships among possible interaction outcomes and consequent further possible interactions will get quite complex. First, there can be multiple indications of interactive possibilities based on a single internal interaction outcome: interaction **A** with internal outcome **S** may indicate not only the possibility of interaction **B,** but also the possibilities of **C, D,** and **E** as well. Which, if any, of such multiple possibilities is selected to actually engage in will depend upon other states in the organism.

Another form of complexity is the possibility of iterated conditional relationships among possible interactions and outcomes: if **A** reaches internal outcome **S,** then **B** is possible with a possible outcome **T,** and if **B** is in fact engaged in and **T** is in fact reached, then **C** becomes possible, and so on. Combinations of multiple indications and iterated conditional indications of interactive possibility can achieve enormous complexity, including interlocking webs of indications of possible interactions with closed loops and paths of indications.

A third form of complexity is that of context dependency: outcome **S** may indicate one possibility if some *other* interaction **K** has reached internal state **X,** while **S** may indicate a different possibility if **K** has reached **Y,** or if some other interaction **L** has reached **Z,** and so on. Context dependencies of interaction complicate even more the webs of indications.[6]

To this point, I have outlined only some of the functional properties of complex interacting organisms (much more careful development is required to show that various potential problems can be avoided and questions answered, but this introduction should suffice for my current purposes—for more elaborated treatments, see Bickhard (1980, 1987, 1992a, 1993), Bickhard & Richie (1983), Bickhard & Terveen (1995), Campbell & Bickhard (1986)). In particular, as their interactive capabilities become more complex, the internal functional machinery for keeping track of what to do next, and of what *could* be done next, will get more complex accordingly. What I argue now is that this functional machinery for controlling interaction is already sufficient to capture foundational properties of representation, and in a form that avoids the frame problems.

Interactive representation. Consider first the internal outcomes of interactions already engaged in. The general course of an interaction between an organism and an environment will depend on the organization of the functional system in the organism that is engaged in the interaction, *and* it will depend upon properties of the environment being interacted with—some environments will yield one outcome for that interactive functional subsystem, and other environments will yield different outcomes for that same interactive functional subsystem. Which outcome is attained after a particular interaction, then, serves to differentiate types of environments: those environments yielding outcome **S** are grouped together, and are differentiated from

[6] Interactive indications might seem to have some of the flavor of associations, but they could not be modeled as associations—for several reasons. For one, indications are strictly unidirectional, while associations tend to be symmetric. For another, indications are conditional—conditional on intermediate interactions actually being performed and succeeding—while associations tend to be transitive. Indications are closer to pointers in a computer program, but even this comparison can break down if the possibility is considered of a continuum of possible indicative states and their related indications (indications are always discrete and of small number in the text for purposes of ease of exposition). See Bickhard and Terveen (1995) and Bickhard and Campbell (1996) for more detailed discussions.

environments yielding any other outcomes. This environmental differentiation is the basic form of epistemic **contact** in the interactive model—it is how the organism maintains appropriate contact with and sensitivity to the environment.

Such differentiation is important because it is precisely such environmental differentiations that serve as the basis upon which the organism can then make further selections of which further interactions to engage in. Environments of type **S** resulting from interaction **A** will be indicated to also be environments of type **T** resulting from interaction **B** in the sense that if **A** reaches **S,** then the indication is that, if **B** is engaged in, **B** will, in *this* environment, yield **T.** It is such indications of interactive possibilities based on interactive differentiations of the environments that permit organisms to control their interactions in ways that are appropriate to those environments. This is the general form of interactive environmental sensitivity.

Truth value. This simple core of the model is already sufficient to capture a fundamental property of representation: truth value. It may or may not be the case that, when the organism engages in an indicated interaction it will arrive at one of the associated indicated internal outcomes. If it does not, then that indication is false and is falsified. If it does reach that (one of the) indicated outcome(s), then the indication is not falsified (though it is still possible that it is false in its full scope—the indication might not *always* hold). Indications of interactive possibilities with associated internal outcomes are potentially false, and potentially falsifiable—this is an emergence of the most fundamental and primitive characteristic of representation.

Thus, the interactive approach can model the emergence of truth value, and that is an emergence that has not been accounted for within the encodingist tradition. Error, in fact—as mentioned above—is seriously problematic within that tradition. If the encoding correspondence that is supposed to constitute a representation exists, then the representation presumably exists, *and is correct*, but if the correspondence does *not* exist, then the representation does not exist, and, therefore, cannot be *in*correct. The extensive efforts being expended on attempting to solve this problem (Dretske, 1988; Fodor, 1990; Hanson, 1990; Loewer & Rey, 1991) have not been successful to date. Even if they were, they would at best define error from the perspective of some external observer of the organism and its interactions (Bickhard, 1993, 1999a; Bickhard & Terveen, 1995).

Most important, there seems to be no way in the encoding framework to account for the possibility of error that might be *detectable by the organism itself*. However, this is a fundamental requirement for any model of human representation, for how can learning or error guided behavior occur if error cannot be detected?

Content. An indication of an interactive potentiality may be true, or it may be false. The dynamics of the indicated interaction will presuppose certain implicitly defined conditions being the case in the environment, in the sense that, if those conditions do obtain, then the interaction will succeed, while, if those conditions do not obtain, then the interaction will fail. That is, the interaction will succeed if its dynamic presuppositions are true and fail if they are false. It is these dynamic presuppositions that are the implicit epistemic **content** of the indication. It is the dynamic presuppositions that are true of the environment or not; it is the dynamic presuppositions that constitute such indications as representations. Dynamic presuppositions yield the emergence of representational truth value out of pragmatic success and failure.

It is worth noting that epistemic contact and epistemic content are sharply distinguished in the interactive model: *contact* is provided by ‘‘backward looking’’ differentiations, *content* is provided by ‘‘forward looking’’ indications of potentiality. Encoding models, in contrast, typically identify the two: *contact* is provided by, say, light from an object entering the eye (yielding appropriate input processing—a passive, no outputs, form of differentiation), and *content* is assumed to be the object from which the light was reflected. Contact and content are identified, and both are spectator-like, backward oriented notions.

For example, for a frog seeing a fly, an encodingist model would have it that the frog is having *contact with* a fly and is having *content about* that same fly, while the interactive model construes the contact as with the fly, as for the encoding model, but the content, in the interactive view, is that there is an opportunity for tongue flicking and eating. Interactive differentiation, e.g., of the fly (interactive contact with the fly) is *not* content with what is differentiated—contact is not content—and interactive content is future oriented. There is no interactive content about the fly at all, no fly (or light pattern) representations upon which some inference process is performed, yielding an inferred conclusion that a fly is present and could be eaten.

More sophisticated representation. Primitive interactive representation captures a basic property, that of truth value. However, such representation of interactive potentiality does not look much like the sorts of representations that we normally consider: representations of objects and abstractions, perceptions, language, and so on. I will sketch how object representations would be modeled in this approach.[7]

[7] For more detail concerning the basic model, see Bickhard (1980, 1992a, 1993; Bickhard & Terveen, 1995; Campbell & Bickhard, 1986, 1992a). For perception, see Bickhard (1992a; Bickhard & Richie, 1983). (There are strong convergences with Gibson’s theory. These are explored in Bickhard & Richie (1983).) For language, see Bickhard (1980, 1987, 1992a, 1995a, 1998b; Bickhard & Campbell, 1992; Bickhard & Terveen, 1995; Campbell & Bickhard, 1992a). (Bickhard (1987) focuses on a comparison with Wittgenstein; Bickhard and Campbell (1992) with categorial grammars; Bickhard and Terveen (1995) with AI language models; and Bickhard (1995a) with Chomsky’s universal grammar.) For explorations of the nature and emergence of sociality, see Bickhard (1980, 1992a, 1995b; Campbell & Bickhard, 1986). For further comparisons with Piaget, see Bickhard (1978, 1988a, 1988b; Bickhard & Campbell, 1989; Campbell & Bickhard, 1986, 1992b).

The basic notion of object representation is that within the webs of complex interactive indications may be some that have two basic properties: (1) All indications in such subwebs are reachable from each other. That is, the subwebs are closed in the sense that if any part of such a subweb is attainable, then all parts of it are attainable. (2) Such subweb patterns remain invariant under large classes of other interactions—they are not changed in their organization by other interactions. My claim is that these two properties capture the epistemology of objects for children and some less complex organisms (Bickhard, 1980).

Consider a toy block. It offers many possible visual scans, manipulations, tactile experiences, and so on. Furthermore, the possibility of any one of these interactions carries with it the possibility of all of the rest—if I can scan it this way, then I can turn it and scan it this other way. The interactive possibilities afforded by the block, or at least a critical subset of them, are closed in the sense outlined above. Furthermore, this entire organization of interactive possibilities remains invariantly possible under scans, manipulations, drops, throws, locomotions, head turnings, hidings, lines of approach, and so on. Of course, it does not remain invariant under burning, crushing, and so on. I offer such closedness and invariance as capturing the basic epistemological nature of object representations emergent out of interactive representations. Clearly, this is a basically Piagetian notion of object representation (Piaget, 1954).

This is a model of representation—and object representation—as being emergent in interaction, not just in the processing of inputs. In this model, representation is forward looking in time, not backward looking. Representation is most fundamentally of future potentialities for further interactions. Some patterns of such possible actions, such as with physical objects, generally remain invariant (as patterns) over time. These form a critically important kind of representation, but object representation also contributes to the mistaken assumption that representation is backward looking rather than forward looking: We think that a representation of an object is most fundamentally of the object in the past that reflected the light, rather than of the object of the immediate (or distant) future that offers multiple possibilities of further interaction.

Implicitness. I turn now to the first step in accounting for the absence of the frame problems: implicit representation. Consider an internal indication of the possibility of interaction **B** with outcome **T.** Some environments would support that interaction yielding that outcome, and some would not. Some environments possess whatever interactive properties are required for the system to reach that internal outcome, and some do not. Note that the internal falsification of the interactive indication entails that that environment did *not* possess those properties, while the absence of falsification entails that the environment did possess (some sufficient portion of) those properties. **But in neither case is there any *explicit* representation of what those critical**

properties are. Whatever the requisite environmental properties are for reaching **T,** they are detected, or not, and represented **implicitly,** not explicitly. The dynamic presuppositions of an interaction indication are not explicitly represented by that indication—they are presupposed by that indication; they are implicitly defined by that indication. That is the key.[8]

Unboundedness. Implicit representation is unbounded. Any interactive representation of the form ''whatever yields this outcome for this interaction will also yield that outcome for that interaction'' is unbounded both for the class of **environments** that might satisfy the indication and for whatever the class of possible environmental **properties** are that would support that satisfaction. These classes may or may not be finite (this question, in fact, may not be well defined: the answer depends strongly on the formalisms chosen for explicitly representing the elements of the classes), but they *are* unbounded—there is no a priori upper bound on them. A indication for the frog, for example, that there is a tongue flicking and eating opportunity is unbounded with respect to the number of actual flies, or fly conditions (or tossed BBs), that would support it. This relationship between an interaction indication and its dynamic presuppositions is a dynamic interactive version of implicit definition in model theory, such as the sense in which the abstract axioms of geometry implicitly define the notions of geometry—point, line, etc.—and the infinite class of potential satisfiers of those axioms (Campbell & Bickhard, 1992a; Coffa, 1991; Keisler, 1977; Kneale & Kneale, 1986).

Modality. Interactive representation, and, thus, the unboundedness of interactive representation, is intrinsically modal. Interactive indicators are of *potentialities* of further interaction. They intrinsically involve the modality of possibility: it is precisely these possibilities that are intrinsically unbounded. This is in contrast to encoding approaches, in which possibilities and necessities require distinct encoded representations together with explicit markers about their modal status.

Modality and the frame problems are intimately related: the frame problems have to do with the unboundedness of possibilities of what might be the case, of what might have been the case, of what might come to be the case, and so on. There are even counterfactual frame problems: for example, if kangaroos did not have tails, they would fall over, unless they got very skilled with crutches—and so on (Stein, 1991).

The interactive model provides a natural approach to modality (Bickhard & Campbell, 1992). Actuality, possibility, and necessity are not differ-

[8] Note, however, that the indicative *relationships* among interactive processes—that interaction **A** with outcome **Q** indicates the potentiality of **B**—are *explicit.* So, therefore, are the more complex webs constructed out of such indications. However, the base remains implicit—there are *explicit* indicative relationships among *implicitly* defined environmental conditions (for a more detailed discussion of this point, see Bickhard and Richie, (1983).

entiated for a primitive interactive representation, as they are forced to be within an encoding model, but must be progressively differentiated within the fundamental interactive framework. Such a progressive differentiation is, in fact, what is found developmentally—not the explicit marking of explicit modalities invoked by encoding models (Bickhard, 1988a,b; Piaget, 1987).

The modality of interactive representation is implicit, thus unbounded. It is precisely this unboundedness of implicit modal representation that avoids the computational and memory impossibilities imposed by the frame problems. Encodings are intrinsically *ex*plicit, so any such unboundednesses easily become impossible for any reasonable resources of time, computational power, and memory (see below).

Practical implicitness. What are the practical implications of such implicitness, and, therefore, unboundedness? One example is simply that a system differentiating various categories of possible histories of its own experience can easily differentiate such categories of histories that are unbounded. Insofar as histories set up current contexts, this also implies that unbounded categories of possible contexts can be differentiated (Shanon, 1988, 1993). Insofar as future potentialities, and future interactions, are dependent upon and sensitive to such contexts, this provides an entire class of examples of unboundednesses that we all function with all of the time (Bickhard & Terveen, 1995). It is not possible to exhaustively list, for example, all circumstances—all histories and all contexts—that we would take as flattering or as insulting.

Such a list would be a list of encodings, and encodings are, and are necessarily, explicit. Encodings are correspondences to what they represent, and there must be at least one such actual correspondence with an actual encoding element for each thing or property encoded.

The only way for encodings to capture the representation of novel unbounded categories is the *definition* of a new encoding element, defined as representing ‘‘*that* (novel, unbounded) category.’’ Such definition is possible, of course, but it is parasitic, and necessarily parasitic, on an *implicit* representation of ‘‘that category’’ in order for the encoding definition to define anything at all. It is only with the resources of implicit representations that there is any possible solution to this problem (Bickhard & Terveen, 1995).

POTENTIAL ALTERNATIVES

The frame problems are standardly portrayed in the computationalist form in which they were first discussed, but symbol manipulation computationalism is not the only approach to modeling in psychology. Perhaps one of the alternative approaches currently available—connectionism, or dynamic system approaches—could solve or avoid the frame problems. I argue that, as understood in the current literature, these approaches make the same encodingist assumptions about the nature of representation as does symbol manipulation computationalism, and, therefore, are just as subject to the frame problems (along with the plethora of other problems of encodingism). Symbolic computationalism is just one version of encodingism.

Connectionism. Connectionism and Parallel Distributed Processing have created great excitement, and have excited great controversy, since the early 1980s. Connectionist networks were shown to be capable of discriminations that had been thought to be beyond their capabilities, and the vision opened up of many more problems that were proving intractable for Good Old Fashioned AI falling to the new approach. Connectionism has matured out of its early heady period, and entered a phase of serious work—and of encountering serious problems (Bickhard & Terveen, 1995; Clark, 1989; McClelland & Rumelhart, 1986; Rich & Knight, 1991; Rumelhart, 1989; Rumelhart & McClelland, 1986; Smolensky, 1988; Waltz & Feldman, 1988).

I will not explore these general problems and promises of connectionism here, except to point out one foundational limitation: connectionism is committed to the same notion of representation-as-correspondence, the same notion of encodingism, as classical AI. The correspondences in computationalism are with internal symbols, while the correspondences in connectionism are with internal patterns or vectors of activation, but both model representation in terms of correspondences. Connectionism, therefore, provides no new solutions to problems of unboundedness. It is as ineffective before the frame problems as Good Old Fashioned AI.

Connectionist systems receive patterns of inputs, and settle into patterns of outputs. Classes of input patterns can each individually settle into the same output pattern, and are, thereby, classified together. Furthermore, connectionist systems can be trained to classify training sets of input patterns in accordance with the ‘‘right’’ classification, and then will generalize (with varying ‘‘correctness’’) those classification categories to new input patterns never encountered. This possibility for training was a major source of the excitement about such systems.

It may be that the class of input patterns classified together is unbounded, so, it might be argued, here is the unboundedness that is needed to solve the frame problems. That this is not so can be seen by examining a case from classical AI: the transducer. A transducer is supposed to transduce inputs, say, light patterns, into internal encodings, which can then be processed by the symbol manipulation system of a classical AI model. The class of possible light conditions that might be ‘‘transduced’’ into a particular internal encoding might well be unbounded, if an attempt were made to list it in some notation for light patterns. In both the case of the classical ‘‘transducer’’ and the case of the connectionist ‘‘classifier,’’ unbounded input conditions may get classified together. So, the only difference between the two is that transducers have to be engineered, while connectionist differentiations can be trained.

Can the possibility of training solve the problem? No, because training is to a designed standard, set by the trainer. In both cases, whether designed or trained, supposed encoding correspondences must be set up, and instances of such correspondences must actually exist, in order for a ‘‘representation’’ to exist. All representation of all basic categories must be *explicit*—however much they may be unbounded relative to the instances of input conditions that evoke them. They must be explicit with respect to the category they represent, and, thus, cannot solve frame problems with respect to that category. As mentioned above, for explicit representations, everything turns on the notation chosen, on the basic categories in that notation. The limitations of finiteness *with respect to whatever that basic category level might be* cannot be transcended.

Connectionist ‘‘representations’’ can be ‘‘distributed’’ as patterns or vectors of activation (van Gelder, 1990, 1991). This constitutes yet another difference from symbol manipulation approaches, but does that make a difference with respect to the basic problems of encodingism? No, it does not. Connectionist ‘‘representations’’ may be trained, and they may be distributed, but they still purport to model representation as constituted in correspondences with such distributed activation vectors. There is nothing magical about either the training or the distributedness per se. What is produced is a correspondence, and connectionism provides no sense in which connectionist correspondences solve any of the encodingist problems that symbol manipulation models face. There is still no model of representational content, and no way in which to model the possibility of error or of system detectable error (Bickhard & Terveen, 1995).

Interactive implicit representation, in contrast, is not explicitly constructed out of explicit atoms of representation (whether engineered or trained—or distributed), and, therefore, is not subject to the restriction of finiteness of those constructions.

The discussion to this point has neglected an additional critical point. The representationality of an interactive representation is constituted in the indications of potential further interactions. Such indications may be evoked or set up *in response to* prior interactive differentiations of the environment, but ***what*** *is being represented* is not dependent on those prior differentiations. Both transductions and connectionist nets are at best differentiators of classes of environments—in general, passive, noninteractive differentiators. As such, they might be *useful* in an overall interactive system. They can, for example, be useful for setting up appropriate indications of potential interactions, for setting up appropriate interactive representations. In themselves, however, such environmental differentiations *have no representationality at all.* In an encoding perspective, they are presumed to represent that which they are in correspondence with, but the system itself cannot know what any such correspondences might or might not be with—cannot *represent* what they might be with. Furthermore, they cannot detect *errors* in any such supposed correspondence. Any such check for error will merely be a check of the transducer or connectionist net against itself: an empty circularity (Bickhard, 1987, 1992a, 1993; Bickhard & Terveen, 1995). Transducers provide *engineered* correspondences with differentiated classes of environments, and connectionist nets provide *trained* correspondences with differentiated classes, but in neither case do we have representations.

Dynamic systems approaches. The interactive model is a dynamic systems model (Bickhard & Terveen, 1995). In this view, representation and cognition emerge in the interactive dynamics of organisms, and, furthermore, have evolved in the service of those dynamics. It differs in some important ways, however, from at least some of its fellow dynamic systems approaches.

In particular, one of the controversial issues dividing the dynamic systems community has to do with the usefulness and coherence of the notion of representation in dynamic systems modeling. Some seek to eschew representation altogether, making the claim that getting the dynamics right is all that is, and all that should be, important (Brooks, 1991; Port & van Gelder, 1995; Thelen & Smith, 1996; van Gelder, 1995). Others argue, for example, that important classes of tasks—''representation hungry'' tasks—cannot be solved without representation (Clark, 1997; Clark & Toribio, 1995). What both sides of this debate hold in common, however, is their general conception of the nature of representation: they all accept some form of correspondence encodingism, and differ on whether or not such correspondences are necessary or useful in dynamic models.

Rather clearly, the interactive model rejects this common ground, and, therefore, the framework within which the dispute is posed. It may well be that some tasks—keeping track of a predator behind a rock, for example—may require maintaining a tracking correspondence (Clark & Toribio, 1995). However, such tracking does not in itself constitute, and does not require, a representation of that which is being tracked. Temperature is tracked by the bimetallic strip in a thermostat, without thereby being represented. The tracking of the predator may involve a readiness to flee, perhaps an anticipation, even a representation, of potential avenues of escape, without necessarily involving a representation of the predator per se. On the converse side, the frog does not require a representation of flies, only representations of tongue flicking and eating potentialities that happen to be appropriately evoked in the factual presence of flies.

According to the interactive model, representation emerges naturally in the dynamics of organisms, but it emerges in the future oriented anticipatory functions of action selection and action evaluation, not in the backward-oriented, passive, spectator, input processing differentiations. In this, it converges strongly with dynamic approaches, but—instead of rejecting representation, or attempting to maintain the classical but unacceptable encoding notions of representation—it offers a model of representation and cognition that emerges naturally in the dynamics of agents *and,* simultaneously, avoids the fatal flaws of encoding notions of representation, the flaws that have produced such a reaction against representation per se. In contributing a dynamic model of representation, the interactive model joins dynamic approaches that recognize *both* the bankruptcy of classical approaches *and* the necessity nevertheless to account for representation and cognition (Christensen, Collier, Hooker, in preparation; Dietrich & Markman, 2000; Hooker, 1995, 1996).

SOME DEVELOPMENTAL CONSEQUENCES OF THE INTERACTIVE MODEL

Several potentially interesting properties and processes of development follow naturally from the interactive model of representation. I will outline three of them: (1) a consequent variation and selection constructivism, (2) an avoidance of the logic that yields much contemporary strong innatism, and (3) a broad model of scaffolding that, among other things, yields the possibility of *self*-scaffolding. Following these adumbrations, I will show, in examples from the literature, how standard encoding assumptions about representation can yield serious problems—creativity and insightful argument do not in themselves protect against false premises.

Interactivism forces constructivism. If representation is thought of as being constituted by encoding correspondences, there is a temptation to think that representation could be impressed into a passive mind—transduction, induction, waxed slates, and so on. There is a temptation to think that representations are constructed out of, or inferred on the basis of, input representations. Or, if such encodings do not come in from the world, then the alternative seems to be that they were there all along, in the genes. That is, encoding notions force us, rather indifferently it seems, to either empiricism or innatism. The encodings have to come from somewhere, and there are only two possibilities: from the environment or from the genes. Encodings cannot develop, thus, encodingism leads to extreme theories that have no place for real development (cf. Elman et al., 1996).

If representation is understood as an emergent of interactive systems, however, then there is no temptation to think that functional system organizations could be impressed into the mind by the world, and no need to postulate a magical preformism. System organization can be constructed by the system itself, and, therefore, representation can be constructed by the system itself. Interactivism leads to constructivist ideas of development, with real and meaningful change across interactive experience (Bickhard, 1980, 1987, 1992a, 1993; Bickhard & Campbell, 1989; Campbell & Bickhard, 1986).

Furthermore, such constructions will not always be correct. Knowledge of which are the ‘‘right’’ constructions cannot always be presciently available to the system—if it were, then the system would already know everything. Heuristics, of course, are possible, and heuristics constitute their own form of knowledge, but the origins of that knowledge too must be accounted for. In general, the system tries out constructions to see if they work, and then uses the results as indications of erroneous constructions if they do not work. That is, the constructivism must be a variation and selection constructivism. Interactivism, then, forces a variation and selection constructivism, an evolutionary epistemology (Campbell, 1974).

Innatism. Still further, the representations that are emergent in such constructions of system organization do not *come from* anywhere. They are constructed *de novo*—they are emergent. Information in a gene pool concerning how that species can survive in a particular niche has not come into the gene pool from that niche—has not ''come from'' anywhere at all. There is no more reason for representation or knowledge to have to come from ''somewhere'' for the child. In particular, there is no reason for representation or knowledge to have to come from the genes, even if it did not or could not have come from the environment.

Contemporary developmental innatism is based primarily on the poverty of the stimulus argument, which is simply an argument that, since there is insufficient information in the environment—the stimulus—then the information must be genetic. This is an invalid argument because, among other problems, it overlooks the possibility of emergent representation (and intrinsic constraint on constructions—see Bickhard (1992b, 1995a), Bickhard & D. Campbell (manuscript, 2000), Campbell & Bickhard (1986, 1992b)). In the view of the interactive model, then, environmentalism and innatism fall together, and for the same reason: they share the false assumption that representation and knowledge must come from somewhere, and differ only on details of where it is supposed to come from.

The interactive position differs from both standard empiricist and innatist positions, *and* from Piaget as well (Bickhard, 1988a). There are partial recognitions of the importance of variation and selection constructivism in developmental psychology (e.g., Siegler, 1984; Siegler & Jenkins, 1989), but, if this argument is valid, an evolutionary epistemology is logically forced, not just an interesting possibility to study. This is one major consequence of the frame problems: explicit representation is not sufficient; implicit representation is required; implicit representation requires interactivism; interactivism forces variation and selection constructivism; variation and selection constructivism is a very underappreciated framework in today's literature.

Scaffolding and self-scaffolding. Interactivism forces a variation and selection constructivism—one of the consequences of a variation and selection constructivism is a model of developmental *scaffolding* with interesting, and arguably important, new properties. In particular, this *functional* model of scaffolding yields the possibility of, and the ubiquitous importance of, *self*-scaffolding (Bickhard, 1992a,c). The notion of self-scaffolding is an oxymoron for standard models. I turn now to an adumbration of that model.

Some constructions will be more complex than others. Successful constructions are retained, and unsuccessful constructions are eliminated—selected out. If a learning or developmental task requires a very complex construction in order for the construction to be successful, the successful constructive process is not likely to hit upon it. Most constructions are relatively simple, and the greater the complexity involved, the larger the number of alternative constructions that are possible—therefore, the less likely that any particular complex construction is one that will succeed and be retained.

Constructions, then, will progress via sequences of successful, or at least partially successful, constructions that are not too far away from previous successful constructions. That is, constructions will progress via trajectories of relatively nearby stable (successful) constructions. However, what if there are no such intermediate successful constructions—intermediate successful task or developmental partial accomplishments? If the constructions required are too complex, success at the learning or developmental task becomes extremely unlikely.

Suppose, however, that some of the selection pressures that would otherwise eliminate simpler constructions are somehow blocked. Such a blocking of relevant selection pressures may allow simpler intermediate constructions to be successful in the context of those blocked selection pressures. In some circumstances, the blocking of selection pressures may create a trajectory of successful constructions that are sufficiently nearby to be traversed by the child. If such a trajectory ends on a construction that is successful in the full task environment and is stable with respect to the full set of relevant selection pressures, then the blocking of selection pressures could result in the constructive attainment of the full task capability. At that point, further blocking of the selection pressures would be unnecessary, and those blocks could be removed. Blocking selection pressures, in this sense, can serve to *scaffold* the attainment of otherwise unlikely or practically impossible developments. This is functional scaffolding.

The are a number of interesting properties of functional scaffolding, but the one that I will focus on is that the functional model of scaffolding permits *self*-scaffolding. Simply, blocking selection pressures is a function that, at least in some forms, a person can do for him- or herself. This differs from classical models of scaffolding, derived from Vygotsky's notion of the zone of proximal development (Bruner, 1975). In these notions, scaffolding consists primarily of the provision of knowledge not otherwise available—often knowledge of how to coordinate subskills into a resultant more sophisticated skill—that suffices to make a task accomplishable and thereby becomes available for internalization (Wertsch & Stone, 1985). Such provision of knowledge can be one way to block selection pressures—those that would require that knowledge for success. A child (or an adult), however, cannot provide to him- or herself knowledge that he or she does not already have. This notion of scaffolding renders the idea of self-scaffolding internally contradictory.

Blocking of selection pressures, however, can be done in myriads of ways. Problems can be broken down into subproblems; criteria for success can be temporarily set aside; ideal cases or analogies can be explored first; resources can be used that might not be needed once the overall construction is attained; and so on. These are forms of scaffolding that individuals can perform for themselves. In these forms, self-scaffolding is very possible. I argue elsewhere, in fact, that learning the skills of self-scaffolding is a major field of development, one that has been largely overlooked (Bickhard, 1992c).

The central point here, however, is that models of functional scaffolding and self-scaffolding are natural consequences of taking seriously the interactive model of representation, consequences such as variation and selection constructivism. Such models result from taking seriously the lessons of the frame problems, and moving to a model of representation that is not subject to those errors. Such a move has positive implications for understanding processes and potentialities of development.

CONSEQUENCES OF REPRESENTATIONAL MODELS

Trying to do developmental psychology, or psychological theorizing more generally, within a framework of encodingist assumptions about the nature of representation commits that work to the multitudinous and multifarious fatal errors of encodingism. These errors vitiate the work involved, at best rendering the task of separating what is valuable from what is dross a major tangle. At worst, false underlying assumptions simply destroy the edifices erected upon them: the field, and the journal, of verbal learning and verbal behavior no longer exist—the failure of their associationistic assumptions rendered them nugatory. I would like to show that encodingist assumptions are having their own deleterious effects—with a (nonexclusive) focus on the frame problems—in current work, and to point to some more promising offerings in the field.

Perner. I examine first an example of some of the difficulties that can be introduced into even the most careful arguments if those arguments are based on a false model, such as on standard encodingist models. Perspicacity and logical validity of considerations do not guarantee against the falseness of the premises—do not guarantee against unsoundness.

Perner (1991) presents a set of analyses and critiques of assumptions about representation in contemporary developmental literature, and offers a model of early representational development based on some of the most sophisticated conceptions of representation in the philosophical and cognitive science literature. His discussion draws most heavily from Dretske (e.g., Dretske, 1988) and Fodor (e.g., Fodor, 1990), and from Johnson-Laird's model of mental models (Johnson-Laird, 1983).

One of the central issues that Perner addresses is whether children are capable of reflection prior to about age 4. There is good reason to think that children *older* than 4 can reflect, but Leslie (1987) argues that pretend play, which occurs prior to age 4, requires a meta- or reflective representation—a representation that the play situation is not real.

There is little doubt that reflection is *sufficient* for pretense, but the question is whether or not it is necessary (Bickhard, 1995c), and Perner provides a compelling demonstration that it is not (a demonstration that seems to have been not understood by some: Gopnik, 1993). Perner develops his argument in terms of mental models of situations, using a military sandbox model of a battlefield as his basic analogy. He points out that if a child is capable of having multiple mental models, then those models can be indexed or marked for differences in the kinds of situations they represent. In particular, they can be marked with respect to temporal differences and modal differences: past and future; actual, possible—and pretend. A sandbox model, similarly, can represent the current battlefield, or can represent potential changes in strategy or tactics—a battlefield that is not currently ''actual.''

Perner suggests that confusion about representation is especially likely when the representation of nonexistents is considered—nonexistents such as the pretenses involved in pretend play. In particular, if we consider a representation of a unicorn, we are apt to construe not only the representation of the unicorn as representational, but also the unicorn itself as representational (there is no real unicorn, so what *is* being represented?)—a representation of a representation: metarepresentations. We have no similar intuition if the represented situation is real: the toy block that is represented is not itself a representation. Perner argues that what is represented by a representation of a unicorn is *not* itself a representation. Instead, it is a possible or pretend situation, rather than a real situation. There is only one representation involved: the representation of the unicorn. It is represented by a mental model, just like real situations, but the model carries a marker of ''play'' or ''pretense'' rather than of ''real.''

A strong reason for the pull to conclude that representations of unicorns are actually representations of representations is the correspondence model of representation itself. If representation is constituted as correspondence, then what does the unicorn representation correspond with if there are no unicorns? This is where the temptation arises to conclude that the unicorn representation corresponds to some other representation—a unicorn representation at a lower level (but what would *it* be in correspondence with?). Perner provides an alternative model. There is only one level of unicorn representation, marked as ''unreal,'' hence no metarepresentation.

Perner argues that evidence for metarepresentation is not conclusive without evidence for (meta)representation of both ends of the representational correspondence relationship—the representation *and* the represented. The strongest evidence for that capability seems to be the capacity for understanding false representation, representations involved in false belief. To represent the falseness of a representation seems to require metarepresentation of the primary level representation, and metarepresentation of what it is being taken to represent, tied together by a metarepresentation of the purported representational correspondence between them. Only in such a rich metarepresentational structure could it be represented that what is *supposed* to be being represented is not in fact the case. Such understanding of false belief seems to emerge about age 4; thus the issue outlined between Perner and Leslie.

This is an ingenious set of arguments and an alternative model for pretense. I take it as demonstrated that, within the framework of correspondence models of representation, pretense, thus pretend play, does not require genuine metarepresentation—and, therefore, that there is no convincing evidence for metarepresentation prior to about age 4.

However, what if that framework is incorrect? What of the possibility that standard encoding models have misled Perner? Then Perner's analyses are unsound. Clearly, I urge that that framework is false: it is an encodingist framework. Unsoundness does not necessarily imply that Perner's conclusions are in error, but it does imply that the arguments for those conclusions cannot be depended upon. The issues need to be reexamined.

The mental models model is just a particular example of an encoding model of representation, and, as such, all of the basic encodingist problems are manifested. I will illustrate some of them. First, I reopen the question of the representation of nonexistents. Perner rightly argues against resemblance as a foundation of representation. For one problem, A can represent B by virtue of resembling B only if the knowing agent already represents both A and B so that any such resemblance can be noticed. Resemblance presupposes the very problem it might be taken to solve.

However, the assumed alternative to resemblance as the constitutive form of representation is correspondence, and, for nonexistents, no such correspondence can exist because there is by assumption nothing to be in correspondence with. No correspondence, no representation. So how can representation of nonexistents occur?

In Perner's military sandbox models, a block of wood can represent a nonexistent tank because the officers using the model *understand and interpret* the blocks of wood as representing tanks. Similarly for sticks representing soldiers, and so on. However, who or what is the equivalent of the interpreting officer for *mental* models? Who is the homunculus that understands and interprets them?

Perner models pretense without metarepresentation by introducing markers for various statuses of situations that the mental models represent. Some may be of past situations, some of possible future situations, some of pretend situations. Particular elements of such mental models may be representing nonexistents by virtue of the overall situation being past or future or pretend. This does avoid metarepresentation, but it does not solve the homunculus problem. Who is the homunculus that understands and interprets those markers?

Still the question remains of what constitutes understanding and interpreting an element of a mental model as representing something if that something does not in fact exist. No correspondence is possible, so how does the homunculus understand what the supposed correspondence is supposed to be with?

That would seem to be the problem of representational content all over again: how can representations of nonexistents have representational contents for the agent him- or herself? (For that matter, how does the *existence* of a correspondence create or generate or constitute any such content: how does the agent know that there *is* any such correspondence, or know what any such correspondence is a correspondence with, even if such a correspondence does in fact exist (see Bickhard (1993, 1999a), Bickhard & Terveen (1995.))

Perner has been careful about distinctions between representation and represented, and perspicacious in diagnosing equivocations between those in other literature, but the encoding models of representation that he relied on do not provide any understanding of what representation is—of what constitutes representational content for an epistemic agent.

A second question to be raised about mental models addresses the fact that they presuppose objects. People, soldiers, tanks, furniture, and so on are the sorts of things that the elements of a mental model are supposed to represent. What about properties, events, actions, processes, scripts (Nelson, 1985, 1986), and so on?

Furthermore, even within the object focus, is a 2-month-old infant's representation of an object the same as that of a 10-year-old's representation of that same object? Presumably not, but if correspondence is all the resource available to model representation, then the 2-month-old will have correspondences to precisely the same object as the 10-year-old—and how are the differences between the infant and the child to be accounted for? How can Perner's mental models model account for any such developmental changes? As mentioned above, encodingism makes genuine development difficult to account for.[9]

A third question addresses how mental models are individuated. Are the representation of the child's bedroom and the representation of the child's living room parts of the same mental model, or are they different mental models? How far does a mental model extend spatially—how about temporally? What about the child's representation of the day care center play room that he or she has not been to for a week? This issue is crucial to how many mental models and how much mental-model-computation is required. For a closely related issue, is the child's representation of a play room specific about where all the toys and furniture and people are located? Not likely. How do mental models handle indefiniteness of that sort?

A fourth asks how mental models are set up or created. If mental models constitute our basic epistemic and representational contact with the world—our copies of the world—then how do we know what the world is in order to construct our mental model copies of it (Piaget, 1970)?

Still another question to be addressed to mental models is simply the error

[9] Encodingism motivates methodological errors in addition to its conceptual and theoretical errors; see Bickhard (1997), Bogartz, Shinskey, and Speaker (1997), and Haith (1998).

question. How can someone check whether or not their mental model is correct? Presumably by checking it against the world that it is supposed to represent. However, how can they know how the world actually is in order to be able to compare it to how their mental model represents it to be? If their representation of the world *is* their mental model, then checking their mental model is just checking it against itself. Any such check is circular, and, therefore, no check at all. How can mental models account for representational error that the agent can detect for him- or herself?

The final critique that I will bring to bear against mental models is the frame problems. There is a particular aptness in this, because Perner's reply to Leslie's claim that pretense requires metarepresentation consists of mental models carrying markers of their temporal and modal status. One mental model might represent an actual situation, while another could be marked as possible or as pretend.

It is such considerations of what might be, of what might occur, that generate the frame problems. There are unbounded spaces of such considerations. How do we take them into account? In the mental models framework, this becomes the question of how mental models could handle unbounded organizations of possible situations. How many mental models are required to keep track of all that we seem to take into account?

Mental models, whatever their status regarding present or past or future or actual or potential, and so on, are of *particular* situations. Mental models are explicit representations, and, therefore, must be of explicit particular situations. There must be a model for each potentiality. This property they share with all encoding models. However, it immediately follows that they cannot handle the frame problems: unbounded numbers of mental models would be required, and unbounded amounts of computation would be required to take all of them into account. There is no machinery in the mental models model for addressing the frame problems.

I conclude that the mental models framework within which Perner analyzes childrens' representational development suffers from its own fatal problems. This conclusion suggests that those developmental issues need to be reexamined. I will address, though only briefly, two of the primary issues that Perner discusses: pretense and metarepresentation.

Pretense. I would argue that Perner's basic intuition regarding pretense is correct and offer an interactive account of pretense that supports it. Pretense, along with other indexing such as for temporal differences and modal differences, requires appropriate contextualization of the representations involved, and that contextualization does not necessarily require metarepresentation. The difficulty in Perner's model is that the only means available for such contextualization is some sort of context-marking markers, and these simply recreate all of the problems of encodingism at the level of the markers, as well as at the level of the mental models being marked: rampant homunculi, no model of representational content, and so on.

In the interactive model, all representation is intrinsically contextualized. All system interactive organization is contextualized in the sorts of activities that make some suborganization appropriate. All interactive organization, in order to be functional for the system, must be interactively reachable by the system—there must be some sets of interactions that, if followed, would arrive at the suborganization of interactive potentialities in question. That suborganization will be *functionally* contextualized in whatever might lead to it, and *representationally* contextualized in whatever that functional context represents. So, if the context is a play situation, then the subrepresentations will be specific to that contextualizing play situation. The play representations are pretense precisely in the sense that they are accessible and functional only within the play situation. They are ''play''-context representations. Instead of Perner's markers, then, I suggest a functional embedding into a contextual interactive representation. This captures a similar idea, but does not commit to homunculi to interpret the markers—not to mention the representations per se.

This addresses only the most basic of the issues involved. Another issue is concerned with the fact that pretense generally involves making use of *some* aspects of external objects in order to carry out the ''symbolicness'' of the pretense, but ignoring other aspects. Wooden blocks can serve as sandbox models of tanks because they share some properties, such as rough shape, with tanks, but they clearly differ in others, such as size, weight, self-locomotion, and so on. Similarly, a child can use an eraser as a pretend snail (Piaget, 1962). Pretense, in other words, involves making use of some properties of real objects, and ignoring others. Pretense involves representation and functioning at certain levels of generality, but disregards more particular levels. How is such representational generality possible? (Note that Perner's mental models do not address this issue, even though the analogy is dependent on it.)

Interactive representation, unlike encoding representation, is intrinsically general. It is intrinsically contextual *and* general. It is general to whatever differentiations are involved, but not necessarily at any more particular level. If a control system can control a robot in a room without bumping into anything, then it could also in principle control a pen to draw the layout of the room. Similarly, a control system that could control a visual scan of a house could in principle control a hand holding a pen to draw the house (Bickhard, 1978). Any control system that can control any particular interaction can in principle control a different interaction that manifests the same general interactive properties. The interactive model, in other words, offers a rich set of resources for modeling pretense, including generality, without adverting to metarepresentation (Bickhard, 1980).

Metarepresentation. This point brings us to phenomena of metarepresentation. I will be quite brief here, because there is considerable other discussion available. The interactive model yields a natural model of levels of reflective knowing—reflective or metarepresentation—similar to Piaget's levels of reflective abstraction (Bickhard, 1973, 1980; Campbell & Bickhard, 1986). This model addresses such apparently reflective phenomena as imagery that occurs prior to age 4, shows that it does *not* require reflection, and identifies the age at which genuine reflection *does* occur at about age 4 (Bickhard, 1973, 1978). That model of roughly age 4 reflection, in turn, can address metarepresentation, including Perner's metarepresentation, as well as multiple other developmental shifts that seem to occur at about the same age (Bickhard, 1992d).

In a partial convergence, then, the interactive model agrees with Perner that pretense does not require metarepresentation, but can be modeled with proper contextualization, and it supports and generalizes Perner's claims about metarepresentation, including even the age of emergence of genuine metarepresentation (Bickhard, 1973, 1978, 1992d). The interactive model, however, is not subject to the encoding aporias, including, especially, the frame problems.

JOHNSON-LAIRD

Perner makes central use of Johnson-Laird's mental models model (Johnson-Laird, 1983). How does that model fare on its own?

It should be clear that the general mental models model is subject to the questions concerning origins, the object focus, how to individuate one model from another, the creation of models, the determination of error, and the potential proliferation problems that constitute the frame problems. These questions have somewhat less force against Johnson-Laird than against Perner, however, because Johnson-Laird, in general, is proposing the mental models model to account for various kinds of thought or problem solving, not necessarily as a model of the nature of representation per se. Because of this narrower focus, the discharge of the encodingist homunculus is diverted to whatever broader model of representation and thought the mental models model might be integrated into. The *person* is Johnson-Laird's homunculus: the *person* is who purportedly constructs and uses mental models.

Nevertheless, encoding problems still bedevil the model, with the frame problems prominent among them. When addressing human reasoning from simple and limited sets of premises—e.g., syllogistic deduction—the construction and manipulation of associated mental models does not appear as problematic (Johnson-Laird, 1983; Johnson-Laird & Byrne, 1991). However, when addressing simplistic toy worlds, simple and limited worlds, the computations involved in a robot keeping track of that world and the consequences of its actions similarly do not appear as problematic. Even computationally intractable problems may be solvable if we address only sufficiently small versions of them.

Mental models, in fact, are ''just'' a particular kind of symbolic data structure that persons purportedly use to reason. The usual research contrast for the mental models model is a formal syntactic-based rules model of reasoning, not any alternative symbolic data structure model (Johnson-Laird, 1983; Johnson-Laird & Byrne, 1991). Mental models are supposed to capture semantic based reasoning, not just syntactic reasoning. Research to date has focused on reasoning from very limited premises, and thus has not encountered the explosions of computation and data that constitute the frame problems. Attempting to use mental models in the ''reasoning'' processes that are involved in moving around in a real room, however, will proliferate just as explosively as any other attempted encoding of the relevant situations, regularities, and their consequences. I would certainly agree with the necessity for taking representation—''semantics''—into account in any model of thought, but not with the mental models presumption of the encoding nature of that ''semantics.''

The mental models model suffers from some additional encoding problems, however, even if the frame problems are set aside. One of the fundamental problems for any encoding model is whether or not the basic encodings should carry truth value. A supposed encoding of an object does not carry truth value; a supposed encoding of a proposition does. If the basic model has only non-truth-value encodings, then it proves to be rather difficult to account for truth values. If the basic encodings all carry truth value, then it is difficult to account for object representations (among others). If the model contains both, then it proves to be difficult to account for their relationships.

There are many manifestations of these issues, both in psychology and in philosophy. The one I wish to focus on here, however, is that a non-truth-value encoding of a kind of object—perhaps ''ball'' or ''unicorn''—does not in itself carry any assertion that an object of that kind exists (or does not exist). If it did, then it would be true or false. Nevertheless, having an encoding of an object, such as in a mental model, invites the presupposition that such an object exists—at least in the minds of the researchers who think about the mental models model, even if not in the minds of their subjects, who may not make use of encoded mental models in their reasoning at all.

Syllogistic reasoning. Johnson-Laird (1983) is concerned with, among other things, syllogistic reasoning, which certainly involves representations with truth values, but he proposes a model of thinking and reasoning that fails to address the truth value emergence issue, and thereby introduces confusion even at the level of truth valued logic. The general form of this model involves representations of categories by means of representations of generic members of those categories. Neither category representations per se nor generic member representations carry truth values. In particular, a representation of a category is indifferent to whether or not any members of that category actually exist and, similarly, a representation of a generic category member does not explicitly specify whether any such members exist—though, in this case, a member representation, even if generic, *motivates* a presupposition that some such member exists. On the other hand, an assertion that a category *does* have members does carry a truth value. Johnson-Laird presupposes that category representations carry with them an assertion of the existence of one or more members, and this is the point at which confusion is introduced. The confusion is in fact highly motivated by the particulars of the mental models proposal—categories are taken to be represented by generic members, and, since the generic members are presumed to exist, the category members are presumed to exist. The particular example is a syllogism:

All of the bankers are athletes.
None of the councillors are bankers.

Johnson-Laird concludes that the only valid inference from these premises is that

Some of the athletes are not councillors.

In particular, those athletes who are bankers are not councillors. This is correct, so long as there *are* in fact one or more bankers, but false otherwise. For Johnson-Laird, however, since the class of bankers is represented by one or more representations of generic bankers, the presupposition of the existence of bankers is automatic, and, therefore, so also is the validity of the above conclusion. If the assumption of the existence of bankers is *not* made, however, there is *no* valid conclusion.

The consequences of this error are not limited just to this example. The example is one of a class of syllogisms that are classified by the mental models model as being very difficult, and that classification—and therefore the model itself—is taken to be confirmed by the number of persons giving the incorrect answer. ''Where premises, such as: None of the A is a B; All of the B are C; support only a valid conclusion of the form: Some of the C are not A, . . . , the task is exceptionally difficult. We have only ever encountered one subject who performed at a better than chance level with such problems'' (Johnson-Laird & Byrne, 1991, p. 113). However, in this case, the *correct* answer, or, at least *a* correct answer—There is no valid conclusion—is being classified by the experimenters as *incorrect,* which classification of the answer thereby seems to confirm the classification of the syllogism as difficult. If the subjects were *not* presupposing the existence of bankers, however, then those who answered ''No valid conclusion'' were in fact correct.

The mental models model presumes existence presuppositions. It thereby invalidates at least some of the data claimed to support it since the ''correct'' answer in some cases depends on a logically arbitrary choice concerning whether or not such an existence assumption is to be made. (Contemporary formal logic, however, does *not* make an existence assumption in sentences with universal quantifiers.) It also renders the model overall as at best incomplete since—however many people there may be who *do* make the existence presupposition, and therefore for whom this aspect of the model is correct—it is certainly clear that there are *some* people who do not make this presupposition, and, since the mental models model cannot accommodate those people, it fails to hold for them.

It would be possible to introduce an existence-assertion encoding—an existential quantifier—to both bridge the gulf between non-truth-valued member encodings and truth-valued syllogism premises, and to make explicit whether category-membership existence is being postulated or not. This would violate the basic form and motivation for the mental models model, however, and would solve the logical problems in only an ad hoc way via the introduction of a new sort of encoding that by ad hoc definition carries existence and assertoric content.

What Johnson-Laird does instead, however, is to attempt a methodological fix: ''In all cases, we shall assume that there is no doubt about the existence of members of the relevant sets—an assumption that is generally warranted in daily life and that we made explicit in our experiments'' (Johnson-Laird & Byrne, 1991, pp. 120–121). However, if mental models, together with their existence assumptions, are the way that people solve these problems, then why is the methodological directive needed? On the other hand, if mental models and their existence assumptions are not correct models of human reasoning, then what does such a directive do to their reasoning processes when people have to incorporate that directive as an additional (and unacknowledged by the experimenters) premise to the problem?

Modal reasoning. As used by Johnson-Laird, a mental model is a representation in terms of encoded generic objects of a possibility that is consistent with the premises of an argument. If all such consistent possibilities are represented, then the homuncular person can examine them in an attempt to determine what, if anything, follows from those premises. The predictions derived from the model generally have the form of some kinds of reasoning problems being more difficult than others based on the difficulty of making such an inference from inspection of the mental models—some mental model properties are much more perspicuous than others, and some tags and mental footnotes are easy to forget. The alternative models to which these mental models are compared are most frequently those of reasoning as formal rule following.

If some characteristic is the case in every model that is consistent with a set of premises, then that ''something'' follows from those premises—and it follows *necessarily* in the sense that there is no model consistent with the premises for which that characteristic does not hold. The mental models model, therefore, is involved in characterizing modal reasoning even in its most basic deductive reasoning framework.

Bell and Johnson-Laird (1998) have developed this aspect of the model as an application of mental models to modal reasoning per se. The general point is that anything that holds in *one or more* of the mental model possibilities is therefore *possible* given the premises; anything holding in *every* mental model possibility is therefore *necessary* given the premises. Negative conclusions emerge from the point that if no mental model possibility exemplifies a candidate possibility, then that candidate is not possible, and that if even one mental model possibility violates some candidate characteristic, then that candidate is not necessary. These forms of reasoning proceed by inspection of encoded generic examples and counterexamples, and this yields familiar kinds of hypotheses about some kinds of problems being more difficult than others, along with the hypotheses based on forgetting mental footnotes, and so on.

This is a straightforward application of mental models to modal reasoning. It involves asking a slightly different set of questions about—a different inspection of—the mental models possibilities that are set up from the premises than does deductive reasoning, but the basic mental model framework is the same. As such, it inherits the strengths and weaknesses of the basic model of nonmodal reasoning. The strengths include being ‘‘semantics’’ based instead of relying solely on encoded formal rules. The weaknesses include the undischarged homunculus that sets up the mental models, interprets them, examines them, and so on—the standard labyrinth of encodingism problems.

There is also an additional problem associated with inferences of necessity. Something is necessary if it is the case in all possible models. This point is exploited in Johnson-Laird’s discussions regarding necessity, but he does so in the framework of his mental models model of reasoning and, in this framework, an additional assumption or premise is required: the mental models being considered must in fact exhaust all possible such models in order for such inferences of necessity to hold. The mental models model, in a familiar point by now, strongly motivates such a presumption—after all, these are all of the mental models that ‘‘I’’ have been able to think of—but this presumption is not always the case and is not always made by human subjects. That it is not always the case is obvious: sometimes we miss such possibilities (even if we were to think of such possibilities always in the form of a mental model—a point that is itself questionable, of course). That this presumption is not always made is also obvious, although perhaps with slightly more reflection: for some problems, we expend considerable effort attempting to ensure that we have thought of all relevant possibilities, and no such presumption is automatic at all. The mental models model fails particularly strongly here: how do we ever make confident conclusions of necessity in the face of questions about whether all possibilities have been, or are being, considered? Such issues are left unexamined in the homunculus that purportedly creates and uses the mental models.

The interactive model shares with the mental models model that it is a model of representation, not just of formal rules. Interactive representation is also inherently modal representation—it emerges in functional indications of interactive *possibilities*. This it shares with most action-based models of representation, including Piaget’s (Bickhard & Campbell, 1989). Unlike mental models, however, the interactive model accounts for *emergent* representation and does not rely on encodingist homunculi to do all of the representational work. Also unlike mental models—and like Piaget—the modalities of possibility and necessity are undifferentiated in simple interactive representations, and the child must learn to differentiate them from each other out of a more primitive modal framework (Bickhard, 1988b). Modal reasoning, therefore, does not follow directly on modal representation.

For still another difference from mental models, realms of possibilities are most fundamentally represented in the interactive model *implicitly*, not by explicit models. This changes an issue of necessity from one of whether or not all explicit models have been constructed to one of whether or not the potentially necessary property or conclusion is internally, or intrinsically—*necessarily*—related to the implicitly defining characteristics of the representations involved. Constructing explicit models is only one way of approaching such issues.[10]

Encodingism regnant. Encodingism dominates contemporary psychology, including developmental psychology—not to mention philosophy, cognitive science, linguistics, and others—just as it has for millennia. Each version of encodingism, however, will have its own particularities, its own details, that might seem to require detailed analyses in each case. As an unfortunate matter of the sociology of the science, that requirement of one-by-one-by-one examination does seem to hold (for a number of such critiques, see Bickhard, 1993, 1999a; Bickhard & Terveen, 1995). However, if encodingism is fundamentally flawed, then no amount of the critiquing of individual exemplars will suffice to move us away from the overall framework—there will always be another, there will always be yet another, encodingist model to consider and to appreciate in its own uniqueness and to critique. Foundational errors cannot be eliminated by piecemeal elimination of the individual models constructed upon those errors. Foundational errors can only be eliminated by in-principle critique.

To appreciate how dominant encodingism is in the field, consider that information processing approaches are straightforwardly encodingist. Connectionist models, insofar as they claim to treat representational phenomena, are also encodingist (e.g., Elman et al, 1996). Dynamic systems approaches, whether they reject representation or embrace it, do so with an encodingist notion of what representation is. I have argued that Demetriou's model is damaged by its basic encodingism (Bickhard, 1999b). Mandler proposes a straightforwardly encodingist model (Mandler, 1998; Müller & Overton, 1998). Similarly, Karmiloff-Smith's model is a clear encodingist effort

[10] More detailed discussions of modalities and interactive representation can be found in Bickhard (1988a,b, in preparation), Bickhard and Campbell (1992), and Bickhard and Terveen (1995).

(Bickhard, 1995c; Karmiloff-Smith, 1992).[11] Perner adopts an encodingist framework. And so on. Along with all of the standard fatal encodingist problems, these face the proliferations and intractabilities of the frame problems—or would face them if the presuppositions were examined.

The massive work claiming to demonstrate ever earlier manifestations of various kinds of cognition—after all, it is only the motor abilities that are not adequate to the task; the cognitions are just fine—are directly based on encodingist errors (e.g., Carey & Gelman, 1991). If an object is encoded, then an object is represented, whether by an infant or an adult. Infants, in this view, do not—and cannot—perceive a fundamentally different world from adults: perception is just encoding. This results in multifarious errors, including the absence of any controls for perceptual alternative hypotheses (Bickhard, 1997; Bogartz, Shinskey, & Speaker, 1997; Haith, 1998; Haith & Benson, 1998; Müller & Overton, 1998). Encodingism makes development impossible, so control conditions that involve the possibility that the apparent ‘‘understanding’’ of some phenomena by infants and toddlers might be a developmentally different cognitive condition from adults, or that it might be a manifestation of perceptual processes per se, and not of cognitive understanding at all, do not tend to occur. As is always the case for foundationally flawed research, extracting what might remain as correct from such flawed work is deeply difficult.

Action-based models. Psychology is dominated by encodingist approaches, but alternatives do exist. Action based models constitute the primary alternative, and Peirce was the first to introduce action as the locus for the study of mental phenomena (Joas, 1993). In psychology, this pragmatic influence has been primarily via Piaget, with the descent being the previously mentioned line from Peirce and James to Baldwin to Piaget. It is precisely Piaget’s action framework, his movement away from classical encoding models, however, that is most often and most deeply misunderstood within the empiricist encoding framework of developmental psychology (Chapman, 1988; Lourenço & Machado, 1996).

The shift into an action framework is the most fundamental and the most important, irrespective of the details developed within that framework. Theorizing within such a fundamentally different view is an unfamiliar process for most, and cannot be captured just by substituting a few action assumptions in one’s deductive reasoning. This makes the instances in which Piaget’s

[11] Karmiloff-Smith’s notion of redescription is a reencoding of representational content that must already be present in the lowest level representations. It is ‘‘simply’’ making more perspicuously available representational information that already exists—encodings cannot yield new representation, but can only borrow content from other representation. In that sense, redescription is a matter of functional access to representational information, not the generation of new representational information. Karmiloff-Smith, in fact, pays little attention to the basic nature of the representations that are supposed to be involved (Bickhard, 1995c).

insights—or some alternative genuine process framework—are being carried forward and developed further of particular importance, because relatively few are engaged in such projects (though both the fading of anti-Piagetianism and the surge of dynamic approaches is changing that), and because neither Peirce nor Piaget—understandably—got things fully correct within this action framework. Much more work needs to be done.

In Piaget's case, these residual errors include his encodingist model of perception, his notion of figurative knowledge generally, and even the sense in which concepts represent via a (modal) kind of correspondence (Bickhard, 1988a; Bickhard & Campbell, 1989). A more specific example from Piaget is his wont to model representation only in terms of one thing standing-in for another, an object focus that skips over the more fundamental issue of emergent representational truth value and attempts to construct, in effect, an encoding model within the framework of action and interaction. In my judgement, the error in this approach is not avoided even in sophisticated contemporary attempts (e.g., Müller, Sokol, & Overton, 1998). It is possible to account for derivative encodings—real encodings—on an interactive representational foundation (Bickhard, 1998b; Bickhard & Richie, 1983), but the more primitive interactive emergence of truth value cannot be skipped. Again, much more needs to be done, and many issues remain to be explored *within* the action and interaction framework.

In this regard, I would commend the work of, for example, Brown (1990), Campbell (e.g., Campbell 1991, 1992; Campbell & Bickhard, 1986, 1992b), Christensen (e.g., Christensen, 1996; Christensen, Collier, Hooker, in preparation), Hooker (e.g., 1995, 1996), Lourenço (e.g., Lourenço & Machado, 1996), Moreno (e.g., Moreno & Ruiz-Mirazo, 1999; Moreno, Umerez, & Ibanez, 1997), Müller (e.g., Müller, Sokol, & Overton, 1998), Smith (e.g., 1993, forthcoming), and, hopefully, my own, to anyone wishing to pursue dynamic, action-based approaches further. Researchers who understand the impossibility of encodingism, and the promise of action frameworks for escaping those impossibilities, will not always agree in all details, but—if the critique of encodingism is at all valid—the collective ferment of ideas and models and research within this framework is—*necessarily*—the future of the field.

CONCLUSIONS

The frame problems are problems of computational intractability. They are inherent for any system that has only explicit representations. However, unboundednesses of representation is commonplace in living and in child development. Consequently, it is not possible for all human representation to be explicit representation, as they are in standard conceptions. Human representations must be implicit, but standard conceptions of representation compel that it is all explicit. Standard conceptions of representation cannot be correct.

My proposal for a form of pragmatically based ''interactive representation'' offers implicitness of representation, and, thus, offers unboundedness of representation. It offers to solve the frame problems, but only by abandoning the dominant conceptions of representation fundamental to many fields today: information processing, symbol manipulation, computer modeling, sensory encoding, and connectionist approaches to understanding the cognitions of children and adults.

Standard approaches to cognition in terms of explicit encoded representations, then, cannot solve the frame problems because such approaches are the *sources* of the frame problems. The frame problems are not a fundamental problematic of epistemology; but rather a refutation of representational models that require representation to be explicit. Psychology cannot ultimately progress within an approach that is subject to such deep and unavoidable refutations. In contrast, the interactive approach to representation, by virtue of its fundamental implicitness, dissolves the frame problems.

Of particular importance to developmental psychology is that encoding models of representation drive us to the absurd anti-developmental extremes of innatism and environmentalism. The interactive model avoids both by providing a model of the *emergence* of representation, representation that does not have to come from anywhere.

The frame problems, then, are a *reductio ad absurdum* of standard encoding approaches to representation. Real children do *not* have to solve the frame problems, because they never arise. They never arise because real children do not epistemically relate to the world via foundational encodings. Taking that *reductio* seriously and making the consequent shift to an interactive model of representation offers many advantages.

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