Anticipation and Representation

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Abstract

What is the relation between anticipations and representation? Anticipations of an external system, or of the system environment, might be generated from a model, a representation, of that system or that environment. In contrast, I will argue that there is a different sense of anticipation — internal anticipation of the flow of interaction between a system and its environment — that constitutes the basis upon which foundational representation is emergent. In simple form, anticipations of interaction appropriateness are involved in selecting what interactions to engage in, those anticipations can be false and falsified, and that constitutes the emergence of representational truth value. Other more complex forms of representation, and other psychological phenomena, are constructed out of, and within the framework of, this basic emergence.

Anticipations can certainly be based on representations, on models of the system whose activities are being anticipated. There is, however, a deeper relationship between anticipation and representation: representation is emergent in particular kinds of anticipation. An interacting system must in some manner select which interactions to engage in, or what flow of interacting to pursue. Such selections anticipate that those interactions will be appropriate in that environment at least in the sense that they proceed within anticipated bounds. They will also be selected, in general, with respect to the potential accomplishment of a goal, and that too may succeed or fail, but it is the basic appropriateness anticipation that I focus on here.

The actual flow of interaction may or may not proceed within anticipated bounds. In general, it will do so in certain environments and not in others. Selecting an interaction, then, presupposes that the environment is one of those kinds that supports that kind of interaction, that the environment has whatever the properties are that support that kind of interaction. Selecting an interaction constitutes an implicit predication of the environment: this environment is one of those, has those properties, that supports the selected interaction.

That implicit predication, in turn, that set of implicit presuppositions about the environment, can be true or false: the interaction can proceed within anticipated bounds or not. This is the point of emergence of the normativity of representational truth value out of the pragmatic normativity of success and failure (Bickhard, 1993, 2003a, in press, in preparation).

The Evolution of More Complex Representation

Representation in this primitive form emerged very early in evolution. Any interaction selection by even a one celled animal involves relevant presuppositions and truth values. Consider, for example, a bacterium that can swim or tumble, and will swim if it finds itself swimming up a sugar gradient and tumble if it finds itself swimming down a sugar gradient (Campbell, D., 1974, 1990).

The bacterium is in thermodynamic far from equilibrium conditions. It requires ongoing interactions and interchanges with its environment in order to maintain those far from equilibrium conditions. In this respect, it is like any other far from equilibrium system, including even a chemical bath in a laboratory. The bacterium, however, has some additional properties. Unlike a simple chemical bath, the bacterium makes its own contributions to the maintenance of its far from equilibrium conditions. In this, it is similar to a candle flame. The candle flame generates heat, which vaporizes wax so that it can burn, melts wax so that it can percolate up the wick, induces convection in the air so that fresh oxygen is brought in and waste products are removed. The candle flame is a canonical example of a *self-maintenant* system. It contributes to the maintenance of its own (far from equilibrium) conditions for existence.

The bacterium, however, has a crucial still further property: it can vary its activities in differing circumstances so as to maintain its property of being self-maintenant. It is *recursively self maintenant*.

The candle flame, if it is running out of wax, cannot do anything with respect to that threat to its persistence in its far from equilibrium conditions. It neither has any alternative processes it can engage in, nor any detection processes that might allow it to switch among alternative processes. The bacterium, however, has both. It can detect, or differentiate between, swimming up a sugar gradient and swimming down a sugar gradient. On the basis of such differentiation, it can switch between swimming and tumbling, and does so in such a way that it maintains its being self maintenant, its contributing to self maintenance, in the differentiated conditions. In particular, swimming contributes to self maintenance if the bacterium is pointed up a sugar gradient, but it *detracts* from self

maintenance if it is pointed down a sugar gradient. The bacterium, however, if it finds itself swimming down a gradient, switches to tumbling instead, and then tries swimming again.

Swimming contributes to self maintenance only under certain conditions: swimming up a sugar gradient, or a gradient of some other food type, swimming down a gradient of some noxious chemical, etc. For the bacterium to select swimming, then, is for it to implicitly presuppose that this current environment is one of those in which the bacterium is oriented in such a way that swimming will make a positive contribution to the maintenance of its far from equilibrium conditions. Those environments will include those in which the orientation is toward more concentrated sugar, etc., and, in that sense, that collection of "swimming positive" conditions will be presupposed of, predicated of, the environment. Implicitly so — there is no requirement that the bacterium have an explicit representation of orientations, sugar, swimming, or anything else. The bacterium simply acts in such a way that is in fact normatively positive for the bacterium only under various conditions, and those conditions are thereby presupposed in the bacterium's selection of that action.

But those presuppositions can be false. The bacterium, for example, will swim up a saccharin gradient just as readily as a sugar gradient, and saccharin is not nutritional for the bacterium. In such a case, the presuppositions are false, the conditions do not hold. And the bacterium is failing at being self maintenant.

Beyond Triggering

In the bacterium, action and interaction are directly triggered by differentiations of relevant conditions. In more complex organisms, direct triggering no longer suffices. Consider a frog, for example. The frog may have a fly in one direction, a worm in another, and the shadow of a hawk approaching. There is more than one kind of action that would potentially contribute to the self maintenance of the frog. The frog will have to select one, and the processes of such selections are of interest and importance, but what I wish to focus on here is that the selection, by whatever process, must be among some functional way of indicating the various possibilities available, the various interactions that would be appropriate to the current frog environment.

For this, triggering does not work. Indication must be functionally separated from selection, unlike for triggering, so that multiple possibilities can be indicated, can be anticipated, as potentials simultaneously. The first crucial point with respect to such anticipations of potentiality is that they involve the same kinds of presuppositions as do the directly triggered interactions: to anticipate that this kind of interaction would be appropriate in the current situation is to presuppose that the current environment has whatever those properties are that support this kind of interaction. Similarly, those anticipations can be true or false — the environment might or might not in fact support that kind of interaction (which is a prior issue to that of

whether or not that kind of interaction succeeds in being instrumental toward some goal). So, anticipations of interactive potentiality involve emergent truth values, just as do direct triggerings of interactions.

Differentiation as the Basis for Anticipatory Representation. Any such anticipation of interactive potentiality will depend on prior interactions — in general, on prior interactions that have differentiated relevant kinds of environments. Crucially, such interactive differentiations do not have to constitute representations of what they differentiate. The bacterium differentiates "swimming" environments from "tumbling" environments without representing any of what we take to be the presupposed, supporting conditions for those kinds of interactions. The frog may, on the basis of a visual scan that happens to differentiate a fly at a certain location, anticipate the possibility of a certain kind of tongue-flicking and eating. To do so, it need not represent flies at all. It needs only to differentiate environmental conditions in which that kind of tongue flicking and eating will generally be appropriate, in which "this is a tongue-flicking and eating kind of environment" will be true.

That frogs can be "fooled" into flicking their tongues by small pebbles tossed in front of them, thus, raises no more an issue of whether they represent flies or pebbles than does the bacterium's triggerings raise an issue of whether or not the bacterium represents sugar or saccharin. Neither animal represents either one: they different environments in ways that happen to not differentiate between those possibilities, and, on the basis of those differentiations, represent those environments as being appropriate for swimming or tongue-flicking, and will be correct in doing so under some differentiated conditions and not under others. The representation, that is, is interactively anticipatory, future oriented, not backward looking in time.

Conditionals and Webs. Crucially, the anticipatory representations are based on differentiations, interactive differentiations, of relevant conditions. There must be hard-wired in the infrastructure, or learned in the infrastructure, some relationship between certain kinds of interactive differentiations and consequent interactive potentialities.

That is, when there are no flies around, the conditional relationships between visual scans that happen to most often differentiate flies and the setting up of an anticipation of the possibility of tongue-flicking and eating must still be functionally present in the frog in some manner. We have not so much a condition-action relationship as a differentiated-but-not-represented-condition to anticipation-of-interactive-potentiality relationship.

Conditionalized anticipations, in turn, constitute the foundation of still more complex forms of representation. They do so by opening the possibility of being iterated: such and such a kind of interaction is a potentiality, conditional on engaging in this other kind of interaction first with such and such a flow or outcome of that first interaction. Iterated conditional interactive potentialities

can form vast and complex webs, and do so in complex animals.

Representations of Objects

With these resources, modeling the representation of small manipulable objects, for example, follows. Consider a child's toy block: it affords multiple kinds of interactions, manipulations, visual scans, dropping, chewing, and so on, all interrelated in a moderately complex web — a group, in fact — of conditional interaction potentialities. Such and such a visual scan is one potentiality among many, conditional on turning the block so that that face of it can be seen.

Furthermore, this pattern of interactive potentialities has some important invariance properties. The pattern remains invariant and invariantly accessible under a large number of other kinds of interactions and things that can happen. If the block is left in a room, it still offers those interaction possibilities should the child return. Similarly if it is put away in the toy box. These invariances, however, are not total: if the block is crushed or burned, the interactive potentialities change irreversibly.

Such an invariant organization of interactive potentialities, of anticipations of such potentialities, constitutes a child's representation of that toy block. This model is essentially Piaget's model of small object representation recast in interactive terms (Piaget, 1954). Piaget's model can be shamelessly stolen in this manner because both models are action and interaction based: both models have representation emergent in interaction systems. I would argue that Piaget's model requires significant change, but this aspect of it transfers quite well (Bickhard, 1988; Bickhard & Campbell, 1989; Campbell & Bickhard, 1986).

Another potential challenge to the interactive model of representation — How could it possibly model the representation of abstractions, such as number? What is the "environment" with which the system could interact to represent such abstractions? — can also be met in a roughly Piagetian manner, though here more significant change from Piaget is required (Campbell & Bickhard, 1986; Bickhard & Campbell, 1989).

Perception?

One domain that seems to strongly resist an interactive approach to representation is that of perception. Surely it is "obvious" that perception involves inputs that carry information about the environment that are then processed so as to extract and infer the surfaces and objects in that environment. Perhaps it is "obvious", but it is false.

Perception too is strictly anticipatory. We have already seen that seeing a small object *as* a small object is constituted in the anticipations of the invariant patterns of interactions that it affords. This is so even if the cognition, the representation, of the object is based on a quick glance and does not involve any of the further interactive

potentialities anticipated. It is the "setting up" of such an organization of interactive anticipations that constitutes representing the object, not the actual interacting.

Consider next seeing a straight line. A line will project onto the retina, intersecting rod an cone receptors. Some it may cut in middle, some just at the edge, and some it will just miss. The pattern of receptors involved in that straight line projection, then, is itself *not* straight, but will wander back and forth across the receptive field. A scan of a straight line along the line will, however, leave that pattern, whatever it is, invariant. It will project on the same pattern of receptors, so long as the line is in fact straight. Conversely, if that pattern were to change under a scan along the line, that constitutes the detection that the line is *not* fully straight. The crucial point is that seeing the line *as* straight is to see it with the anticipation that a scan along the line would yield invariance, similar to the small object, even if such a scan is not in fact undertaken. Seeing it as straight is to anticipate a potential interactive invariance.

What about colors? This domain is one in which the classical "input-processing" intuitions are strongest and seem most unassailable. Consider, however, seeing red. Red sensitive receptors are densest in the middle of the macula. They decrease by about 50% toward the edge of the macula, and even further outside of it. The central point for the current discussion is that there is a definite pattern of dominantly red sensitive receptors organized in the retina. A visual scan of a red spot, say, will then move that red light across the pattern of receptors, stimulating a moving pattern of them in a manner determined by the shape of the red spot, the pattern of receptors, and the pattern of the scan. Most importantly, the organization of the potentialities of the changes in reception patterns in such a scan *will remain invariant* with respect to such parameters of shape, receptor pattern, and scan pattern. Any such scan will produce an anticipatable pattern of receptor changes. The invariance here is more complex than for a straight line: it is a parameterized group, with the scan pattern and the receptor pattern being part of the parameters. The shape of the spot also is determinative, and is an aspect of what is "seen" in engaging in such a scan. Seeing red, then, is anticipating invariances of the receptor pattern changes (O'Regan & Noë, 2001; Bickhard, in press). Seeing red is anticipative, not just a matter of input processing.

More generally, visual perception is not just a processing of visual inputs. Visual perception, and all perception, is a matter of patterns of interaction with the environment. Inputs are certainly one aspect of such interactions, but they help *constitute* the interactions, they are not preparatory to some further stage at which the "perception" is finally observed by the perceptual homunculus (Gibson, 1966, 1977, 1979; Bickhard & Richie, 1983).

Further Cognitive Phenomena

A claim that interactive representation is the foundational form of representation writes multiple and multifarious

promissory notes to be able to account for many further kinds of cognitive phenomena. Perception is a major challenge, but it is not the only one. I will briefly indicate how the model can address a few additional phenomena.

Memory

Another classic domain for input models of representation is that of memory. Again, it seems obvious that memory is some sort of storage of perceptions that are input from the environment. The discussion of perception above ought to give some pause to this challenge, but more can be done.

The crucial point is that memory is the storage of changes in processing modes, and there are many kinds of such processing modes, each corresponding to a different kind of memory. Memory, then, comes in many guises — it is the "past dependency" aspect of learning.

The most primitive kind of memory, then, is that for alterations in how the organism interacts, sometimes called enactive memory (Nelson, 1992; Squire, 2004; Tulving, 1985). Note that even at this level, the representation of invariances of interactive potentials that constitutes representation of a small object also constitutes a kind of memory about the environment: to indicate that the toy block can be interacted with by returning to the toy box and retrieving it is to remember where it is. It is to begin to represent, *and thereby remember*, an environment beyond the immediately perceivable environment.

There are many kinds of memory (Nelson, 1992; Squire, 2004; Tulving, 1985). Perhaps the canonical memory challenge to an interactive model of representation, however, is that of event or episodic memory. This is commonly construed as some kind of storage of sequences of snapshots, or perhaps a mental video tape, of what went on during some time period. It is not canonical for an interactive approach.

But not being canonical for interactive modeling does not mean that it cannot be accounted for within an interactive framework. Here is the basic idea: a complex organism will have a complex organization of conditionalized webs of potential interactions indicated *as* potential for that organism in the current situation. But this organization of potentialities will not remain constant. In fact, it will change from moment to moment, as the organism interacts and as perceptual interactions ground alterations in what is now possible conditional on what intermediaries. This process of maintenance and updating of the situational knowledge of interactive potentialities is called *apperception* (Bickhard, 1998, 2003, in preparation; Bickhard & Campbell, 1996).

Apperception, then, traces a possibly complex trajectory of changes through time in what the organism takes to be possibilities that the environment affords. Such an organization of indicated interactive potentialities, however, can never be complete. There will always be further potentialities that are not explicitly indicated in the flow of apperception. In fact, it will on occasion be useful to be able to return to some experiences to re-engage in the apperceptive flow that accompanied (or constituted) those experiences in order to pursue some direction of apperception further than was the case at that time. Perhaps there are implications that might now be useful but were not apperceived as being useful earlier.

If an organism — a species — has the capability to re-engage apperception in this manner, it constitutes a capability for re-calling that flow of experience. It constitutes a memory for that flow of experience, for that flow of "events". It is, in other words, precisely the kind of memory that might otherwise be taken as a fatal challenge to an interactive anticipatory approach to representation.

Motivation

Interaction based models of representation integrate multiple further psychological phenomena, phenomena that remain relatively cut off in standard models. Motivation is one. The problem of motivation can be viewed, and all too often is viewed, as the problem of what makes the organism do something rather than nothing, what energizes it or pushes it into action? Organisms, however, are, as mentioned above, in far from thermodynamic equilibrium conditions. They cannot "do nothing" without ceasing to exist. Motivation, accordingly, cannot be the phenomena of energizing the organism into doing something rather than nothing.

Instead, the problem of motivation is what and how does the organism select what to do — it has to do something. The function of interaction selection, however, is precisely the function that interactive anticipation has evolved to serve. It is precisely the problem out of which representation has emerged: selections occur from within the framework of anticipations concerning what further interactive flows are possible. Motivation has to do with the selection aspect, representation with the anticipatory aspect, but they are both aspects of the same interactive system organization. Representation and motivation are not separated in this model (Bickhard, 2003b). Similarly, there are close relationships with phenomena of emotion (Bickhard, 2000), consciousness (Bickhard, 2000, in press), and language (Bickhard, 1980, 1995; Bickhard & Campbell, 1992; Bickhard & Terveen, 1995).

Learning

On the basis of apperceived anticipations of interactive possibilities, the organism — the central nervous system — will prepare for one course of possible interactions rather than some other. This process of preparation, or "setting up", is called *microgenesis* (Bickhard, 2000, in preparation; Bickhard & Campbell, 1996). There is much of interest to model about microgenesis, but the crucial point for the current discussion is that such a preparation for some course of potential interaction constitutes an anticipation that the actual flow of interaction will stay within the bounds prepared for, within the bounds anticipated, by that microgenetic "setting up". If the actual

flow of interaction violates those anticipations, it falsifies the presuppositions of those anticipations.

If microgenesis has the property that it is destabilized by violations of its anticipations, we have a foundational form of learning. Error in interactive anticipation generates destabilization of microgenesis, which means that microgenesis will engage in some different process the next time those conditions are encountered. Destabilization of microgenesis, then, introduces variation in the system. Error in interaction, then, generates variation, while success in interaction yields stabilization. This is a basic variation and selection constructivism, an evolutionary epistemology. It is a foundational form of learning. There are more complex forms of learning, and they require more complex modeling (Bickhard & Campbell, 1996), but the foundational issue of learning is accounted for in a natural manner within the overall model.

"Symbols"

There is nothing akin to standard symbols in this model. There is no encoding of inputs to be processed into further encodings and symbols. There is a natural manner, however, in which the combinatoric power of symbols can be captured, but without all of the properties of symbols as classically conceived (and problematically conceived: Bickhard, 1996, 2003a, in preparation; Bickhard & Richie, 1983).

The central point is that there are circumstances in which it is useful for the overall system to be able to engage in off-line processing. processing that is not directly engaged in interaction with the current environment. One reason for this is that such processing may be, for example, exploring possibilities in some heuristic manner, and there should be no consequences for current interaction until the heuristic process has come to a completion — with a heuristically positive outcome.

Such off-line processing introduces a number of interesting modeling possibilities, but the core of how such processing can be accounted for is to recognize that the system can set up internal stand-ins for various organizations of interactive anticipation — for various representations. If the possibility of interacting with some object is apperceived, a stand-in for that organization of possibilities might be set up. Such a stand-in thereby is made available for off-line processing, along with possible other such stand-ins — including, in particular, the possibilities generated by potential combinatorics of such stand-ins. If selected at some further point, the resultant such stand-ins can then be "translated" back into apperceptive organizations that can guide further interaction selection.

Such internal "stand-ins" capture much of might otherwise be rendered in terms of "symbols". They offer manipulation possibilities, including potential combinatoric powers, but they are not empty symbols, and have a definite grounding that provides them with representational content. They are not faced with a "syntax must provide semantics" problem: they are generated out of a framework in which representational content is already emergent. Any combinatoric "syntax" is built on top of that, rather than having to somehow magically generate content or "semantics".

These internal stand-ins, however, are not classical symbols. Their content is interactive, not encoding. It is future interactively oriented, rather than past input processing oriented. It is based on differentiations of the environment, not on correspondences to particulars — object representations, for example, are not primitive, but are rather sophisticated constructive capabilities that many species will not be fully capable of. And so on (Bickhard, 1998, 2003a, in preparation).

Artificial Agents

This discussion has proceeded primarily in terms of biological agents. What relevance might it have for artificial agents? The central point is that any autonomous system will face the problem of action selection, and, therefore, the problem of determining and indicating what future interactions might be appropriate in the current environment.

It is within this framework that representation and motivation emerge. It is specializations of various aspects of these processes that yield perception and memory. It is further processes within this framework, such as microgenetic destabilization, that generate learning, emotions, and reflective consciousness. And so on.

The interactive model entails that such phenomena are natural developments of and within the basic problems posed to an interactive system. Natural evolution has explored these problems and their solutions, and artificial agents have begun that exploration as well.

One of the clearest examples is the modeling of interactive anticipation in rhythm. Buisson (2004) constructed a system that learned to capture rhythms that are taped onto a keyboard, and that can learn to learn in the sense that experience with simpler rhythms makes possible the later learning of more complex rhythms. Stojanov and collaborators have explored some of the potentialities of the interactive model for *developmental* robotics (Stojanov, Bozinovski, & Trajkovski, 1997; Stojanov, 2001; Stojanov & Kulakov, 2003). Earlier, Cherian and Troxell (1995a, 1995b) advocated and illustrated advantages of the interactive model for designing robots, especially concerning robot representations.

These projects have been directly guided by the interactive model. But, if the model is correct, all explorations of autonomous agency — all cognitive robotics — will have to address these problems, and will find solutions that fit within the overall model. Consider, for example, the independent development of notions of learning about a space of possible motions and using that knowledge to plan motions that occurs in Bickhard (1978), on one hand, and Mataric (1990) and Stein (1994), on the other, or the (partial) convergences between Brooks' work

more generally and the interactive model (Bickhard & Terveen, 1995).

With a caveat about the emergence of genuine normativity, which is inherently difficult within an artificial framework (Bickhard, 2003a, in preparation), the problems of agency *are* the problems of interactive anticipation, selection, learning, etc.

Conclusion

Anticipation is at the core of representation, perception, memory, learning — of all psychological phenomena. Psychological agents are anticipatory agents, anticipatory of their own possible interactive futures. More basically, psychological phenomena are phenomena of agents, not of input processors, and agents are future oriented; they are anticipative at their core.

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