1. The Re-Enchantment of the Concrete

Some Biological Ingredients for a Nouvelle Cognitive Science

FRANCISCO J. VARELA
Ecole Polytechnique

1.1 Shifts in Cognitive Science

Rationalistic, Cartesian, or *objectivist*: These are some terms used to characterize the dominant tradition within which we have grown in recent times. Yet when it comes to a re-understanding of knowledge and cognition I find that the best expression to use for our tradition is *abstract:* Nothing characterizes better the units of knowledge that are deemed most natural. It is this tendency to find our way toward the rarified atmosphere of the general and the formal, the logical and the well defined, the represented and the planned-ahead, that makes our Western world so distinctly familiar.

The main thesis I pursue here is that there are strong indications that the loose federation of sciences dealing with knowledge and cognition—the cognitive sciences—are slowly growing in the conviction that this picture is upside down and that a radical paradigmatic or epistemic shift is rapidly developing. At the very center of this emerging view is that the proper units of knowledge are primarily *concrete*, embodied, lived. This uniqueness of knowledge, its historicity and context, is not a noise that occludes the brighter pattern to be captured in its true essence, an abstraction. The concrete is not a step toward anything: It is how we arrive and where we stay.

Let me unfold this emerging view, which revitalizes the role of the concrete by focusing on its proper scale: the cognitive activity as it happens in a very special space that we may call the hinges of the *immediate present*, for it is in the immediate present that the concrete actually lives. But before this unfolding we need to revise some entrenched assumptions inherited from the computationalist orthodoxy.

1.2 Minds and Disunited Subjects

If we turn to consider the living, there is considerable support for the view that brains are not logical machines, but highly cooperative, unhomogeneous, and distributed networks. The entire system resembles a *patchwork* of subnetworks assembled by a complicated history of tinkering, rather than an optimized system that results from some clean unified design. This kind of architecture also suggests that instead of looking for grand unified models for all network behaviors, one should study networks whose abilities are restricted to specific, concrete cognitive activities that interact with each other.

This view of cognitive architecture has begun to be taken seriously by cognitive scientists in various ways. For example, as is well known Minsky [15] presented a view in which minds consist of many *agents* whose abilities are quite circumscribed: Each agent taken individually operates only in small-scale or *toy* problems. The problems must be of a small scale because they become unmanageable for a single network when they are scaled up. This last point has not been obvious to cognitive scientists for long time. The task, then, is to organize the agents, who operate in these specific domains, into effective larger systems or agencies and then to turn these agencies into higher level systems. In doing so, mind emerges as a kind of *society*.

It is important to remember here that, although inspired by a fresh look at the brain, this is a model of the mind. In other words, it is not a model of neural networks or societies; it is a model of the cognitive architecture that abstracts (again!) from neurological detail and hence from the wet of the living and of lived experience. Agents and agencies are not, therefore, entities or material processes; they are abstract processes or functions. The point bears emphasizing, especially because Minsky sometimes wrote as if he was talking about cognition at the level of the brain. As I emphasize, what is missing is the detailed link between such agents and the incarnated coupling, by sensing and acting, that is essential to living cognition. But let us pause for the moment to follow some of the implications of the notions of fragmented and local cognitive subnetworks.

The model of the mind as a society of numerous agents is intended to

encompass a multiplicity of approaches to the study of cognition, ranging from distributed, self-organizing networks up to the classical, cognitivist conception of symbolic processing. This encompassing view challenges a centralized or unified model of the mind, whether in the form of distributed networks, at one extreme, or symbolic processes, at the other extreme. This move is apparent for example when Minsky argued that there are virtues not only in distribution, but in insulation, (i.e., in mechanisms that keep various processes apart[1]). The agents within an agency may be connected in the form of a distributed network, but if the agencies were themselves connected in the same way they would, in effect, constitute one large network whose functions were uniformly distributed. Such uniformity, however, would restrict the ability to combine the operations of individual agencies in a productive way. The more distributed these operations are, the harder it is to have many of them active at the same time without interfering with each other. These problems do not arise, however, if there are mechanisms to keep various agencies insulated from each other. These agencies would still interact, but through more limited connections.

The details of such a programmatic view are, of course, debatable. But the overall picture it suggests is that of mind not as a unified, homogenous entity, or even as a collection of entities, but rather as a *disunified, heterogenous collection of processes*. Elsewhere I have discussed *in extenso* some important consequences of this idea [20]. Such a disunified assembly can obviously be considered at more than one level. What counts as an agency, (i.e., as a collection of agents) could, if we change our focus, be considered as merely one agent in a larger agency. And conversely, what counts as an agent could, if we resolve our focus in greater detail, be seen to be an agency made up of many agents. In the same way, what counts as a society will also depend on our chosen level of focus.

Having thus set the stage for this key issue in contemporary cognitive science, I want to develop its implications for the question at hand: the present-centeredness of the concrete.

1.3 Readiness-to-Action in the Present

My present concern is with one of the many consequences of this view of the disunity of the subject, understood as a cognitive agent. The question I have in mind can be formulated thus: Given that there is a myriad of contending subprocesses in every cognitive act, how are we to understand the moment of negotiation and emergence when one of them takes the lead and constitutes a definite behavior? In more evocative terms, how are we to understand the very moment of being there when something concrete and specific shows up?

[1] This idea has also been extensively explored, though in a somewhat different context, by Fodor [14].

Picture yourself walking down the street, perhaps going to meet somebody. It is the end of the day, and there is nothing very special in your mind. You are in a relaxed mood, in what we may call the readiness of the walker who is simply strolling. You put your hand into your pocket, and suddenly you don't find your wallet where it usually is. Breakdown: You stop, your mind setting is unclear, your emotional tonality shifts. Before you know it, a new world emerges: You see clearly that you left your wallet in the store where you just bought cigarettes. Your mood shifts now to one of concern for losing documents and money; your readiness-to-action is now to go back to the store quickly. There is little attention to the the surrounding trees and passersby; all attention is directed to avoiding further delays.

Situations like this are the very stuff of our lives. We always operate in some kind of immediacy of a given situation: Our lived world is so ready-at-hand that we don't have any deliberateness about what is and how we inhabit it. When we sit at the table to eat with a relative or friend, the entire complex knowhow of handling table utensils, the body postures, and pauses in the conversation, are all present without deliberation. Our having-lunch-self is transparent.[2] You finish lunch, return to the office, and enter into a new readiness with a different mode of speaking, postural tone, and assessments. We have a readiness-to-action that is proper to every specific lived situation. New modes of behaving and the transitions or punctuations between them correspond to mini- (or macro-) breakdowns we experience constantly.

I refer to any such readiness for action as *microidentities* and their corresponding *microworlds*. Thus, the way we show up *as* is the way things and others show up *to* us. We could go through some elementary phenomenology and identify some typical microworlds within which we move during a normal day. The point is not to catalogue them but rather to notice their *recurrence*: Being capable of appropriate action is, in some important sense, a way in which we embody a stream of recurrent microworld transitions. I am not saying that there aren't situations where recurrence does *not* apply. For example when we arrive for the first time in a foreign country there is an enormous lack of readiness-to-hand and recurrent microworlds. Many simple actions such as social talk or eating have to be done deliberately and learned. In other words, microworlds and identities are historically constituted. But the pervasive mode of living consists of the *already* constituted microworlds that compose our identities. Clearly there is a lot more that should be explored and said about the phenomenology of ordinary experience.[3]

My intention here is more modest, merely to point to a realm of phe-

[2] I borrow this use of the notion of transparency from an unpublished manuscript by Flores and Graves [5]. I am grateful to Flores for letting me read this ongoing work.

[3] I am thinking especially of Merleau-Ponty's Phenomenology of Perception as prime example and more recently of Leder [13].

nomena, that is intimately close to our ordinary experience: When we leave the realm of our lived human experience and shift our focus to animals the same kind of analysis applies as an *external* account. The extreme case is illustrative: Biologists have known for some time that invertebrates have a rather small repertoire of behavior patterns. For example, the locomotion of a cockroach has only a few fundamental modes: standing, slow walking, fast walking, and running. Nevertheless this basic behavioral repertoire makes it possible for these animals to navigate appropriately in *any* possible environment known on the planet, natural or artificial. The question for the biologist is then: How does the animal decide which motor action to take in a given circumstance? How does its behavioral selection operate so that the action is appropriate? How does the animal have the common sense to assess a given situation and interpret it as requiring running as opposed to slow walking?

In the two extreme cases, human experience during breakdowns, and animal behaviors at moments of behavioral transitions, we are confronted—in vastly different manners to be sure—with a common issue: At each such breakdown, the manner in which the cognitive agent will next be constituted is neither externally decided nor simply planned ahead. It is a matter of *commonsensical emergence*, of autonomous configurations of an appropriate stance. Once a behavioral stance is selected or a microworld is brought forth, we can more clearly analyze its mode of operation and its optimal strategy. In fact, the key to autonomy is that a living system, out of its own resources, finds its way into the next moment by acting appropriately. The breakdowns, the hinges that articulate microworlds, are the source of the autonomous and creative side of living cognition. Such common sense, then, needs to be examined at a microscale, at the moments where it actualizes *during breakdowns*, the birthplace of the concrete. This is, to be sure, also a central question for the design of autonomous robots [14], and it will be interesting to see to what extent similar solutions might not apply.

1.4 Knowledge as Enaction

Let me explain what I mean by the word *embodied*, highlighting two main points: (a) that cognition depends on the kinds of experience that come from having a body with various sensorimotor capacities; and (b) that these individual sensorimotor capacities are themselves embedded in a more encompassing biological and cultural *context*. These two points were already introduced when discussing breakdown and common sense, but here I explore further their corporeal specificity, to emphasize once again that sensory and motor processes, perception and action, are fundamentally inseparable in lived cognition, and not merely contingently linked in individuals.

In order to make my ideas more precise, let me give a preliminary formulation of what I mean by an *enactive approach to cognition* [19, 20]. In a nutshell, the enactive approach consists of two key points: (a) that perception consists in perceptually guided action; and (b) that cognitive structures emerge from the recurrent sensorimotor patterns that enable action to be perceptually guided. These two statements will become transparent as we proceed.

Let us begin with the notion of perceptually guided action. For the dominant computationalist tradition, the point of departure for understanding perception is typically abstract: the information processing problem of recovering predetermined properties of the world. In contrast, the point of departure for the enactive approach is the study of how the perceiver can guide its actions in its local situation. Because these local situations constantly change as a result of the perceiver's activity, the reference point for understanding perception is no longer a predetermined, perceiver-independent world, but rather the sensorimotor structure of the cognitive agent, the way in which the nervous system links sensory and motor surfaces. It is this structure—the manner in which the perceiver is embodied—rather than some predetermined world, that determines how the perceiver can act and be modulated by environmental events. Thus the overall concern of an enactive approach to perception is not to determine how some perceiver-independent world is to be recovered; it is, rather, to determine the common principles or lawful linkages between sensory and motor systems that explain how action can be *perceptually guided* in a *perceiver-dependent* world.[4]

In such an approach, then, perception is not simply embedded within and constrained by the surrounding world; it also contributes to the *enactment* of this surrounding world. Thus, the organism both initiates and is shaped by the environment. We must see the organism and environment as bound together in reciprocal specification and selection—a point to which we need to constantly remind ourselves, for it is contrary to views familiar to us from the Cartesian tradition.

A classical illustration of the perceptual guidance of action is the study of Held and Hein who raised kittens in the dark and exposed them to light only under controlled conditions [8]. A first group of animals was allowed to move around normally, but they were harnessed to a simple carriage and basket that contained the second group of animals. The two groups therefore shared the same visual experience, but the second group was entirely passive. When the animals were released after a few weeks of this treatment, the first group of kittens behaved normally, but those who had been carried around behaved as if they were blind: They bumped into objects and fell over edges. This beautiful study supports the enactive view that objects are not seen by the visual extraction of features, but rather by the visual guidance of action. Similar results have been obtained under other diverse circumstances and studied even at the single-cell level.

[4]For more on this approach, see [10].

Lest the reader feel that this example is fine for cats, but removed from human experience, consider another example. Bach designed a video camera for blind persons that can stimulate multiple points in the skin by electrically activated vibration [1]. Using this technique, images formed with the camera were made to correspond to patterns of skin stimulation, thereby substituting for the visual loss. Patterns projected onto the skin have no visual content unless the individual is behaviorally active by directing the video camera using head, hand, or body movements. When the blind person does actively behave in this way, after a few hours of experience a remarkable emergence takes place: The person no longer interprets the skin sensations as body related, but rather as images projected into the space being explored by the bodily directed "gaze" of the video camera. Thus, in order to experience "real objects out there" the person must actively direct the camera (by head or hand).

1.5 The Fine Structure of the Present

I have now situated the emergence of the concrete within the enactive framework for cognition, where it can really make sense. We can now return to the problem we started with: How can emergent microworlds arise out of a turmoil of many cognitive agents and subnetworks? The answer I propose is that within the gap during a breakdown there is a rich *dynamics* involving the concurrent subidentities and agents. This rapid dialogue, invisible to introspection, seems to have been finally addressed directly in recent in brain studies.

The central idea was introduced by Freeman who, over many years of research, managed to insert an array of electrodes into the olfactory bulb of a rabbit so that a small portion of the global activity can be measured while the animal behaves freely [3]. He found that there is no clear pattern of global activity in the bulb unless the animal is exposed to one specific odor several times. Furthermore, he found for the first time that such emergent patterns of activity are created out of a background of incoherent or chaotic activity by fast oscillations (i.e., with periods of about 5–10 msec) until the cortex settles into pattern, which lasts until the end of the sniffing behavior and then dissolves back into the chaotic background [4]. Smell appears in this light not as a mapping of external features, but rather as a creative form of enacting significance on the basis of the animal's embodied history. What is most pertinent here is that this enaction happens at the hinge between one behavioral moment and the next, via fast oscillations between cell populations that can give rise to coherent patterns.

There is growing evidence that this kind of fast dynamics can underlie the configuration of neuronal ensembles. It has been reported in the cortex in cats and monkeys linked to visual stimulation; it has also been found in radically different neural structures such as a bird's brain, and even the ganglia of an invertebrate.[5] This universality is important, for it points to the fundamental nature of this mechanism for the enaction of sensorimotor couplings. Had it been a very species-specific process, typical, for example, of mammalian cortex, it would be far less convincing as a working hypothesis.

It is important to note here that this fast dynamics is not restricted to sensorial trigger: The oscillations appear and disappear quickly and quite spontaneously in various places of the brain. This suggests that such fast dynamics involve all of those subnetworks that give rise to the entire readiness-to-hand in the next moment. They don't only involve sensory interpretation and motor action, but also the entire gamut of cognitive expectations and emotional tonality that are central to the shaping of a microworld. Between breakdown, these oscillations are the symptoms of—very rapid—reciprocal cooperation and competition between distinct agents that are activated by the current situation, vying with each other for differing modes of interpretation for a coherent cognitive framework and readiness for action. On the basis of this fast dynamics, as in an evolutionary process, one neuronal ensemble (one cognitive subnetwork) finally becomes more prevalent and becomes the behavioral mode for the next cognitive moment. When I say "becomes prevalent", I do not mean to this is a process of optimization: It resembles more a consolidation out of a chaotic dynamics. It follows that such a cradle of autonomous action is forever lost to lived experience because by definition we can only inhabit a microidentity when it is already present, not in gestation. In other words, in the breakdown before the next microworld shows up, there is a myriad of possibilities available until, out of the constraints of the situation and the recurrence of history, a single one is selected.

This fast dynamics is a very good candidate for the neural correlate of the autonomous constitution of a cognitive agent. Future work will determine whether this is actually the case or whether we need an alternative mechanism. For our purposes, what is important is that it gives the moment of behavioral selection its rightful place.

1.6 From Temporal Fine Structure to Cognitive Action

It is important to sketch in this context how I envisage cognitive structures to emerge from the kinds of recurrent sensorimotor patterns that enable action to be perceptually guided. As stated, the fast dynamics of agent reciprocity provide the playground for the emergence of a microworld. What

[5]For a recent review, see [18]. The work of Gray and Singer [7] has been largely responsible for the wider acceptance of this hypothesis; for Hermissenda, see [6].

we need to examine now is some evidence as to how to link this sensorimotor coupling with other kinds of higher cognitive performance. Otherwise, we might be tempted to attribute no significance to the foregoing except for the low level event of sensing and acting, but not for the true higher cognitive levels. In fact, this basic idea is at the very core of the Piagetian program and has been argued for in various recent works, such as Johnson and Lakoff [9, 12]. I present the idea of embodied cognitive structures with special reference to their work. Once again we must move out of the abstract and emphasize an experientialist approach to cognition. As Lakoff said, the central claim of their approach is that meaningful conceptual structures arise from two sources: (a) from the structured nature of bodily and social experience; and (b) from our capacity to project imaginatively from certain well-structured aspects of bodily and interactional experience to conceptual structures.

Rational and abstract thought is the application of very general cognitive processes—focusing, scanning, superimposition, figure-ground reversal, etc.—to such structures. Eco [11] provided a concise overview of Lakoff and Johnson's experientialist approach. The basic ideas that embodied sensorimotor structures are the substance for experience, and that experiential structures motivate conceptual understanding and rational thought. Because I have emphasized that perception and action are embodied in sensorimotor processes that are self-organizing, it is natural to see how cognitive structures *emerge* from recurrent patterns of sensorimotor activity. In either case, the point is not, as Lakoff noted, that experience strictly determines conceptual structures and modes of thought; it is, rather, that experience both makes possible and constrains conceptual understanding across the multitude of cognitive domains.[6]

Lakoff and Johnson provided numerous examples of cognitive structures that are generated from experiential processes. To review all of these examples here would take us too far afield. Let me discuss briefly only one of the most significant kinds: basic-level categories. Consider most of the middle-sized things with which we continually interact: tables, chairs, dogs, cats, forks, knives, cups, and so on. These things belong to a level of categorization that is intermediate between lower (subordinate) and higher (superordinate) levels. If we take a chair, for example, at the lower level it might belong to the category *rocking chair*, whereas at the higher level it belongs to the category *furniture*. Rosch and others have showed that this intermediate level of categorization (table, chair, etc.) is psychologically the most fundamental or *basic* [17]. Among the reasons why these basic-level categories are considered to be psychologically the most fundamental are: (a) the basic level is the most general level where category members have similar overall *perceived shapes*; (b) it is the most general level where a person uses similar *motor actions* for interacting with category mem-

[6]Ibid., p. 120.

bers; and (c) it is the level where clusters of correlated attributes are most *apparent*. It would seem, therefore, that what determines whether a category belongs to the basic-level depends not on how things are arranged in some predetermined world, but rather on the sensorimotor structure of our bodies and the kinds of perceptually guided interactions this structure makes possible. Basic-level categories are both experiential and embodied. A similar argument can be made for image schemas emerging from certain basic forms of sensorimotor activities and interactions.

1.7 In Conclusion

Let me conclude by considering where the ideas sketched here have taken us. I have argued that perception does not consist in the recovery of a predetermined world, but rather in the perceptual guidance of action in a world that is inseparable from our sensorimotor capacities. I have also argued that cognitive structures emerge from recurrent patterns of perceptually guided action. We can summarize by saying that cognition consists not in representation, but in *embodied action*. Correlatively, the world we know is not pre-established; it is, rather, enacted through our history of structural coupling. Furthermore we have also seen that the hinge that articulates *enaction* consists of fast noncognitive dynamics wherein a number of alternative microworlds are activated. These hinges are the source of both common sense and creativity in cognition, the key ingredients for a tasty nouvelle cognitive science.

If there is something that is nouvelle in the enactive direction of cognitive science evoked in this gathering, it is that it points in a direction we can consider post-Cartesian in two important respects. First, knowledge appears more and more as being built from small domains, microworlds, and microidentities. Such basic modes of readiness-to-hand are variable throughout the animal kingdom. But what all living cognitive beings seem to have in common is that knowledge is always a knowhow constituted on the basis of the concrete; what we call the general and the abstract are aggregates of readiness-for-action.

The second post-Cartesian aspect is that such microworlds are not coherent or integrated into some enormous totality that regulates the veracity of the smaller pieces. It is more like an unruly conversational interaction. It is the very presence of this unruliness that allows for the constitution of a cognitive moment according to the system's constitution and history. The very heart of this autonomy, the fast time of the agent's behavior selection, is forever lost to the cognitive system itself. Thus, what we call traditionally the irrational and the nonconscious is not contradictory to what appears as rational and purposeful, but its very underpinning.

References

[1] Bach, R. (1962). *Brain mechanisms in sensory substitution*. New York: Academic Press.

[2] Fodor, J. (1983). *The modularity of mind*. Cambridge, MA: MIT Press, Bradford Books.

[3] Freeman, W. (1975). *Mass action in the nervous system*. New York: Academic Press.

[4] Freeman, W., & Skarda, C. (1985). Spatial EEG patterns, Nonlinear dynamics, and perception: The neo-Sherringtonian view. *Brain Research Reviews, 10*, 145–175.

[5] Flores, F., & Graves, M. (1990). Unpublished manuscript. Berkeley, CA: Logonet.

[6] Gelperin, A., & Tank, A. (1990). Odour-modulated collective network oscillations of olfactory interneurons in a terrestrial mollusc. *Nature, 345*, 437–439.

[7] Gray, C., & Singer, W. (1986). Stimulus-specific neuronal oscillations in orientation columns in cat visual cortex. *Proceedings National Academy of Sciences (USA), 86*, 1698–1702.

[8] Held, R., & Hein, A. (1958). Adaptation of disarranged hand–eye coordination contingent upon re-afferent Stimulation. *Perceptual Motor Skills, 8*, 87–90.

[9] Johnson, M. (1989). *The body in the mind*. Chicago: University of Chicago Press.

[10] Kelso, J., & Kay, B. (1987). Information and control: A macroscopic analysis of perception-action coupling. In H. Heuer & F. Andries Sanders (Eds.), *Perspectives on perception and action*. (pp. 3–32). Hillsdale, NJ: Lawrence Erlbaum Associates.

[11] Lakoff, G. (1988). Cognitive semantics. In U. Eco *Meaning and mental representations* (p. 121). Bloomington: Indiana University Press.

[12] Lakoff, G., & Johnson, M. (1989). *Women, fire and dangerous things*. Chicago: University of Chicago Press.

[13] Leder, M. (1990). *The absent body*. Chicago: Chicago University Press.

[14] Maes, P. (1989). How to do the right thing. *Connection Science, 1*, 291–323.

[15] Minsky, M. (1986). *The society of mind.* New York: Simon & Schuster.

[16] Neuenschwander, S., & Varela, F. (in press). Sensori-triggered and spontaneous oscillations in the avian brain. *European Journal of Neuroscience.*

[17] Rosch, E., Mervis, C. B., Gray, W. D., Johnson, D. M., & Boyes-Braem P. (1976). Basic objects in natural categories. *Cognitive Psychology, 8*, 382–439.

[18] Singer, W. (in press). Synchronization of cortical activity and its putative role in information processing and learning. *Annual Review of Physiology.*

[19] Varela, F. (1989). Connaitre: les sciences cognitives [The cognitive sciences]. Paris: Seuil.

[20] Varela, F., Thompson, E., & Rosch, E., (1991). *The embodied mind: cognitive science and human experience.* Cambridge, MA: MIT Press.

Part I

Research Programmes