chapter 15

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<u>NICOD CHAPTER FIFTEEN</u>

<u>SPACE AND TIME</u>

Before turning to the problem of how pure representations of goal states develop from pushmi-pullyu representations, there are two more common kinds of factual or semi-factual representations --pushmi representations each of which has a variety of pullyu uses-- that should be mentioned. A great variety of animals seem to be capable of collecting over time and storing representations of both the spatial layouts of the territories in which they live and also of the temporal layouts, the patterns of conditional probabilities of ordered occurrences that characterize their environments.

Perception normally requires the integration of information that flows in to the sensory surfaces over a period of time. This is true even of organisms having the most humble of nervous systems if we take into account habituation and sensitization. Gibsonian psychologists have been especially helpful in highlighting the importance of the animal's own movements in gathering information during perception. In humans, eye saccades are especially important, along with movements of the head and body, movements of the hands when exploring by touch, approaching and moving around objects, and so forth. These exploratory motions have been called "epistemic actions." A great many perceptual illusions that can be induced when freedom of movement is denied dissolve as soon as the subject is allowed to move freely again. Epistemic activity is important for the perception of objects and objective situations. It is equally important, of course, for the perception of enabling relations (Chapter Fourteen).

Epistemic activity helps the animal to separate aspects of the surrounding energy array that vary with its own movements from those that are invariant, thus helping to detach perception of objects from perception of enabling relations. It helps the animal to take into account the particular media through which perception is occurring, for example, to separate lighting conditions from properties of seen objects, and to separate the different sources of various sounds reaching the ears. It also helps in the construction, over a short period of time, of perceptions that represent, for example, the whole shape of an object, not merely the part that is seen at a given instant. It is this last benefit of epistemic activity on which I wish now to focus.

In Chapter Fourteen, I mentioned that one of the abilities that it is important for an object-recognizing animal to have is the capacity to identify the same object or kind by a variety of alternative diagnostic properties or sets of properties. This is because the animal's encounters with an object or kind will reveal certain of its properties under some perceptual conditions and from some perspectives, but other properties only under other conditions or from other perspectives. Like most people, Helen Keller was able to identify a very large number of different objects and kinds under the right conditions. Her handicap was in the scarcity, for her, of the right conditions.

Now one way to recognize a shape is to recognize a given object and to remember what shape that object has. For example, suppose that by prior epistemic activity I have discovered and now recall what shape my flashlight has, the relative position of its various parts, and so forth. If I now recognize my flashlight in the dark by feeling one end of it, I may be able to represent the enabling spatial relations of its various other parts to my groping hand, thus allowing me to adjust my hand so as to find the switch with my thumb, at the same time pointing it to shine in the right direction. Similarly, if by prior epistemic activity I have discovered what lies inside apples, that is, in what spatial configuration their various inner parts lie, then I may only need to see or feel the outside of an apple to be enabled to begin neatly to quarter and core it. Knowledge of the inner configuration of oranges, on the other hand, directs quite different initial motions in the process of procuring the meat. Think too of performing these tasks in the dark. Consider another example. Free-living young grey squirrels soon acquire a lot of experience with trees. Standing trees generally have a similar sort of abstract shape, with a trunk leaving the ground roughly vertically, then branching into limbs that in turn branch into branches and then twigs. I don't imagine that a squirrel encountering a tree trunk as it races from a dog chasing after needs to look up in order to recognize it has come to a tree. And it seems likely that its starting up the trunk is guided in part by a representation of an enabling relation to higher parts of the trunk and to the branches assumed to be above. Its movements are guided by a representation of the trunk stretching upward, and of branches overhead in a certain enabling relation to it, and the safety these are envisioned to afford.

It is an empirical matter, of course, whether this is really what happens in squirrels, or whether the squirrel is merely following out a chain of affordances as described for the pure pushmi-pullyu animals of Chapter Thirteen. But the point is general. The pure pushmi-pullyu animal is certainly capable of learning, but this learning is what psychologist's call "procedural learning." It learns what to do after what, completion of each link in the chain producing perception of a new affordance which guides production of the next link. But here I have in mind the capacity for quite a different kind of learning. This kind of learning is sometimes called "declarative" because it is tested for in humans by asking them to state or declare what they have learned. There is no reason to suppose that memories of this sort are representations that could be translated or portrayed by sentences, however (Chapter Seven). On the other hand, this kind of memory does seem to be a memory for facts. Such a memory is a descriptive representation of an affair in the world that can be recombined in perceptions of alternative affordances. A representation of the abstract way trees are laid out may be a detached fact representation for squirrels, useful in connection with chasing, fleeing, finding food, finding shelter and so forth. The animal stores a representation of the spatial configuration constituting a certain kind of whole object, then later recognizes its current relation to some part of the object. Joining these two yields a representation of current affordances of unobserved parts and of their currently enabling relations.

Perceiving and remembering the spatial configuration of something you are outside of is continuous with perceiving and remembering the spatial configuration of something you are inside of, such as a sheltering structure or a spatial locale. The squirrel climbing and scurrying about in the tree is a good example of this. Is the squirrel inside or outside of the tree? Learning to manipulate objects and learning to navigate paths are in many ways similar. Recalling that the perception of objects often requires the integration of information gathered by epistemic activity over a shorter or longer period of time, consider an animal engaged in exploring its territory. Very many animals do this quite systematically. The animal seems to be constructing a representation of the territory it is exploring, possibly a sort of spatial map, or possibly a representation in some other form. Rats that have been allowed to explore a maze for some time before having to run through it for a reward show clearly that they have already learned much about how to navigate the maze without the reward. Many animals and birds are able to remember very large numbers of places in which they have cashed food, the nutcrackers being the most celebrated. Clark's nutcracker, in particular, is able to remember hundreds of cashing places in some cases for tens of weeks (Balda and Kamil 1992). Chimpanzees that are carried around while a human experimenter hides food in a variety of places will later go directly to each those places to retrieve the food. This sort of learning cannot be explained by classical principles of conditioning. That many animals can head straight for home after being transported blind to any portion of their known territories has often been considered evidence that they have something like maps in their heads, and not merely topological maps, but representations of a metered geometrical space (for example, Olton and Samuelson 1976). In any event, it seems they can construct some kind of general-purpose representation of the spatial layout of a territory.

Presumably, such a representation usually includes a representation of navigable paths or corridors within the territory. It will represent these as generalized or detached affordances, that is, as paths or corridors for traveling from here to there, for whatever further reason. Such a representation might serve any of numerous purposes when attached on one side to the animal's perception of its current location within the territory and on the other to representations of where various affording objects and places are within the territory. Joining an ego-implicit representation of its own momentary position and orientation within the mapped terrain to its egoless representation of the terrain as a whole, it is now ready to see any affordances within the terrain, old or newly learned, from within any part of the terrain. Recognizing the same place or part of the terrain again from another orientation, in different lighting conditions, in different weather and so forth is, of course, like recognizing any other object again from another angle, under different mediating conditions and so forth. The animal's perceptual representation of its current environment can now be extended or filled out by memory to produce a representation of more distant affordances and of the animal's current enabling relations to these more distant affordances. The representation of the enabling relation that extends beyond what is currently directly perceived may be a very abstract representation, but still definite enough to set the animal on the right path or heading in the right direction. Enabling relations will be represented more exactly as the animal proceeds on its way and as more concrete places along the path come to be perceived directly and recognized.

Many animals are capable of representing temporal layouts as well as spatial layouts. As emphasized in Chapter Thirteen, there is nothing more mysterious about a capacity to perceive future events than about a capacity to perceive spatially distant events. And future events, like current events, are often perceived by integrating information over time. You perceive where a ball is going to land by tracking its projectory for a time with your eyes.[1] Among natural signs of the future are obvious goal-directed actions of others, for example, you perceive that a person is about to pick up the salt by seeing the direction of their reaching movement or by seeing where they are looking as they reach. And just as many animals construct representations of the spatial layouts in which they live, many construct representations of regularities in the temporal layouts in which they live. This does not mean that they represent historical time, a time line that has various past and future events on it. In order to represent historical time they would have to have some use for representations of dated past events, and it is unclear what use this would be.[2] But an animal need not understand time as linear in order represent it. Rather, time seems to be represented by animals as a set of conditional probabilities or temporal contingencies, probabilities that concern what is likely to accompany what in time, what is likely to occur after what but less likely to occur otherwise, and at what temporal intervals various events are likely to occur.

It used to be thought that classical or "Pavlovian" conditioning caused an animal to treat the conditioned stimulus as a substitute for the unconditioned stimulus. For example, if a bell is rung every time just before a puff of air is blown into your eye, your eye will soon close automatically at the sound of the bell. But closer analysis suggests that what is learned is better described as a contingency relationship. The conditioned response is merely one that attempts to take account of that learned relationship. For example, Pavlov's dogs, for which the ringing of a bell was paired with the arrival of food, did not attempt to eat the bell when there was no food, but rather salivated in appropriate response to the expectation of food. The rat conditioned by a buzzer that accompanies electric shock jumps and its heart beats faster when it is shocked but cowers and its heart beats slower when it hears the buzzer alone (Gleitman 1991, p. 110). Simultaneous pairing of the unconditioned and conditioned stimuli is much less effective in training than when the conditioned stimulus is presented just before the unconditioned one. And pairing of a conditioning stimulus with an unconditioned one is completely ineffective if the unconditioned stimulus is presented without the conditioning one as frequently as with it (Gleitman p. 127, Rescorla 1988).

Perhaps the most dramatic evidence that a representation of temporal order is what lies behind classical conditioning is the work of Matzel et al (1988). They showed that if rats are conditioned to associate a tone with a light flash that followed at an interval *i*, then conditioned to shock occurring without a tone but just before the light at an interval less than *i*, the effect is a fear reaction on hearing the tone again.[3] That is, although the rats have never experienced shock after the tone, they have experienced light after the tone, and they have experienced shock just before the light. The result is that they represent shock as sandwiched between tone and light. Apparently, just as an exploring animal may construct, over time and over separate episodes of exploration, something like a map of the spatial locale in which it lives, it may also put together something like a map of the temporal contingency locale in which it lives.

Similarly, although it used to be thought that instrumental conditioning acts directly on responses, increasing the probability of whatever the animal did just prior to reinforcement, there is now evidence that what instrumental conditioning directly affects is the animal's representation of temporal conditional probabilities or of cause-effect relations. A nice illustration is given by the experiments of Colwill and Rescorla (1985). They showed that rats who have learned to pull a chain for sweetened water and to push a bar for food, abruptly stop pulling the chain but do not stop pushing the bar if (in another situation) drinking sweetened water is followed by nausea. Much more simply, pigeons if conditioned to peck a key for food, peck with slightly open beaks ready to eat; if conditioned to peck for water, they peck with beaks almost closed ready for sipping water; if conditioned to gain access to a mate, they coo as they peck the key. It is clear that they do not just respond to a stimulus but anticipate the results of their pecking.[4]

These then are two common kinds of factual knowledge that many animals seem to pick up and store away, ready for uses that may be discovered only later.

FOOTNOTES

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1. There is evidence that perception of the location of moving objects precedes the actual location of these objects (Nijhawan 1994)

2. Chapter Nineteen will address the question how humans are able to construct and use representations of the historical past.

3. Standard controls were used, of course.

4. For an excellent discussion of the evidence that all conditioning is basically learning about conditional probabilities in the animal's environment rather than just learning to react or behave in certain ways, see (Gallistel 1990).