An Essay Proposing the Elemental Units of Behavior and Culture – What they do, how they do it, how they evolved, and perhaps Even What They Are – in 10 pages

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I think most anthropologists and other social scientists would agree that culture consists of more-or-less integrated patterns of socially acquired behavior, and of outcomes of such behavior such as artifacts, dwellings, customs, social structures and organizations, folktales, etc. (Kroeber and Kluckhohn 1952). The behaviors and outcomes are usually attributed to a social group such as a tribe, a village, a nation, a company, or even a police department, as that group's culture.

I have added that those behaviors and outcomes are largely mediated by cultural instructions which are stored in the brains of the group members, having been acquired by observational learning and verbal tuition (Cloak 1968a, 1975a, 1975b).

In this essay, I will present some hypotheses about the nature and workings of cultural instructions (and non-cultural instructions) and about the underlying mechanisms involved in their acquisition and storage.

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I'll begin with observational learning and work forward and backward from there. But first, a word about mental *images*:

Do you at least sometimes, when you're about to do something, imagine yourself doing it? It could be something ordinary, like taking out the trash, or it could be something novel and important, like presenting yourself for a job interview. Such imaginings are usually (perhaps always) in the form of an *image*, a mental picture, probably blurry and incomplete. It may be active, like a film clip; it may include a sound or an odor or a touch.[2] Please keep this anticipatory mental experience in

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[2] Sometimes we summon an image, or try to, to remember an incident or a face; sometimes they appear spontaneously, especially the cringeworthy ones. They are often triggered by an experience, or by a sound or smell, or by a remark, or by another image.

mind because you have just brought into your conscious awareness the fundamental process underlying all animal behavior, including human cultural behavior.

It's obvious that those mental images are products of the brain, so I postulate that each mental image is specifically produced by an underlying physical neural "image", or *nimage* for short, with its own specific locus in the brain. Nimages are more-or-less permanent structures, all animals have huge numbers of them, and they last from seconds to a lifetime.[3] In people, some nimages occasionally produce mental images, which are almost always fleeting.

All right, then, why do we have nimages? What is their evolutionary function? Why did natural selection favor them? Certainly not to produce mental images; that would be like saying the heart's evolutionary function is to produce heartbeats! No, I think nimages have been essential components of behavior ever since the earliest days of the Animal Kingdom. And that includes our human cultural behavior, the nimages of which will also be known as *memes*.

To show you what nimages do, let's now return to observational learning, to an example provided to me by Prof. Gordon Burghardt, a co-author of the experimental study Thonhauser et al. 2013, paraphrased here:

Five pairs of *stingrays*, each pair consisting of a "demonstrator" D stingray and an observer O stingray, were put through the same observational learning experiment, with five virtually identical outcomes.

Each experiment started with "RayD", a naïve demonstrator stingray, trying to extract a food reward inserted in an open-ended PVC pipe segment. After many attempts, through many trials, by trial and error she hits upon a technique that works, "Suck-and-Wave". Subsequently, she successfully uses Suck-and-Wave to get the reward in at least ten consecutive trials, the criterion set by the experimenters.

[3]Memory, as we call it, consists mainly, if not entirely, of nimages. (Perhaps each nimage is associated with a single neuron, but more about that later.)

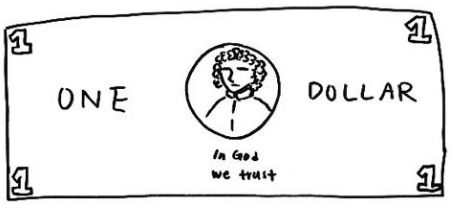
Now comes "RayO", a naïve observer stingray. Although he has never before confronted the apparatus, he watches avidly as RayD goes through her paces in several successful trials. (You can even see his eyeballs following her movements.)

30 minutes later, it's RayO's turn to try to get the treat. Just like RayD, he uses trial-and-error and ends up using Suck-and-Wave for success in at least ten consecutive trials. But it takes him fewer than half as many trials as it took her to reach that criterion! How in the world does he manage that? Here's how:

Watching RayD, RayO has recorded his perceptions of her actions, including Suck-and-Wave, as nimages in his brain. Then, on test, he too engages in trial-and-error learning, playing back certain nimages in his repertoire, now including the Suck-and-Wave nimage, and trying to match his perceptions of his own actions to each nimage.[4] With each trial, the likelihood of his trying to match the Suck-and-Wave nimage increases because matching it is followed by obtaining the reward. Because he had already acquired the Suck-and-Wave nimage by observing RayD's action, he didn't have to go through the tedious trial-and-error process she went through to acquire it. Therefore, it takes RayO fewer than half as many trials as it took RayD to reach criterion. That held true for five different complete runs of the experiment, each run using a different pair of naïve animals.[5]

It's clear that RayO used this play-back process again and again, for his ten consecutive successes. But, one may ask, how did RayD reach her ten consecutive

[4] The "match" need not be exact (Pearson and Kosslyn 2015). Epstein (2016) may inadvertently illustrate the difference between nimage and matching perception when he reports an ad hoc experiment he has used in his classes to attack representationism. He had an intern draw a U.S. dollar bill first from memory and then while perceiving a dollar bill. Here is the result:



From memory – image, reflecting nimage

From life, reflecting perception

[5] Needless to say, the experimental results met all the standard requirements re statistical significance, etc.

successes? Did she have a Suck-and-Wave nimage for that? Yes, she did; she constructed it herself, except that first she had to stumble upon the Suck-and-Wave action through trial-and-error, thereby creating her own Suck-and-Wave nimage by recording her perception of her own accidental Suck-and-Wave action.

Now, it appears, we have at least the beginnings of an elemental-unit hypothesis for observational learning and, serendipitously, one for trial-and-error learning as well. The underlying process, in fact, applies to behavior in general.[6]

The process is called *perceptual control*. It was developed theoretically by electronics engineer and cybernetician William T. Powers, who applied it to experimental psychology in 1973 in a seminal work, *Behavior: The Control of Perception*. In our example, the stingrays ended up utilizing the neural mechanism[7] which, by generating action, controls its (the mechanism's) perception to match its Suck-and-Wave nimage. In other words, the nimage is a goal for its mechanism's perception; the mechanism takes action to perceive that goal. (To do so, of course, the mechanism has access to the animal's sensory apparatus and ultimately to its motor apparatus.)

Has anyone proposed a better physical mechanism underlying observational learning? Apparently not,[8] so I think the existence of observational learning provisionally provides strong evidence for Powers's Perceptual Control Theory. Given all the experimental evidence for perceptual control,[9] I happily extrapolate it to all animal behavior, back at least to our most recent common ancestor with stingrays and even with octopi, the successful subjects of another observational

[6] Behavior and its evolution characterize the Animal Kingdom from its very beginning ca. 580 million years ago (Early Life n.d.).
[7] "control system", in the language of Perceptual Control Theory (Powers 1973: Fig. 15.2, p. 218.).
[8] Some workers, e.g. Lago-Rodríguez et al. 2014, assert that mirror neurons are implicated in observational learning. I suggest that mirroring, imitation, etc. are simply other outcomes of the observational learning process outlined here, except that the observer already possesses the nimage involved.
[9] See the references in Powers et al. 2011 and in Wikipedia: **Perceptual control theory.**

learning experiment (Fiorito & Scotto 1992).[10] Nimages are our (hypothetical) elemental units of behavior.

But wait. What initiated the stingrays' behavior? What turned it on? It would be another nimage-mechanism, something like "Eating that Treat". That mechanism would activate (technically, *address*) different subordinate nimages for ways of trying to get a treat, eventually addressing the nimage "Suck-and-Wave" (and sticking with it). And what is addressing the "Eating that Treat" nimage? A higher-level nimage-mechanism, perhaps simply "Eating"; and so forth, all the way up to, say, a genetically inherited "Stayin' Alive" nimage-mechanism. So you see that nimage-mechanisms are connected in hierarchies, all active at once, each mechanism trying to match its perception to its nimage by addressing the nimage below it.

And the hierarchies extend downward, too: "Suck-and-Wave" addresses nimages of different limb motions and positions, down to nimages of muscle feedbacks, and then down to feedbacks from the finest nerve-endings.[11]

Finally, any nimage may be addressed by multiple nimage-mechanisms above it, and any nimage mechanism may address multiple subordinate nimages. The resulting network of hierarchies shows how the very simple idea of the nimage-mechanism can ramify into a seriously complicated structure. Moreover, most of those hierarchies are always "on" (the nimages in them are constantly addressed), certainly while the animal is awake. Their function is to monitor the animal's internal and external environments, and try to maintain equilibrium despite the disturbances presented by those environments.[12]

It's truly remarkable how culture has, so to speak, tapped into that very complex system: RayO's nimage replicate of RayD's nimage is what I called a "cultural

[10] Our most recent common ancestor with stingrays (*Potamotrygon falkneri*) was a jawless "fish", about 290 million years ago. Our most recent common ancestor with *Octopus vulgaris* was a sea-bottom flatworm, about 541 MYA (Early Life n.d.).

[11] At the lowest levels, the mechanisms may not even have nimages. The addressing mechanism directly provides all the "reference signal" that is needed.

[12] Perceptual Control Theory considers such activities to be behavior. Nimage-mechanisms may also be responsible for emotions, especially emotions linked to behavior: anger, empathy, etc.

instruction" (1968a, 1975a) and Richard Dawkins famously dubbed a *meme* (1976, 1982; Blackmore 1999). A meme is simply a nimage that has been acquired by means of observational learning (or verbal tuition, as we shall see). But it takes more than one meme to build a culture. Occasional examples of observational learning pop up as early in evolutionary history as other forms of nimage acquisition, at least in the laboratory,[13] but no non-human species has adopted it as a principal mode of learning.[14]

On the other hand, observational learning enables humans to acquire behavior of almost every sort.[15] The clearest examples occur when D is unaware that O is watching or listening, as when children acquire memes for facial expressions, gestures, gait variations, social norms, and linguistic elements characteristic of their group; in other words, acquire bits of their group's culture. The ease and speed with which children do that would indicate the existence of a genetically evolved high-level self-starting nimage-mechanism, "Learning by Observation". In humans, observational learning has become a goal in itself. The nimages known as memes are our (hypothetical) elemental units of culture.

Memes for tool making and use are also obvious examples. It appears that the adaptive trend(s) leading to sophisticated observational learning took place during some 700,000 years beginning about 2.5 million years ago, as our ancestor *Homo erectus* spread throughout Africa and into most of the eastern hemisphere. Morgan et al. 2015 postulate an evolutionary sequence of (1)imitation/emulation, (2)basic teaching, (3)gestural teaching, and eventually at least the beginnings of (4)verbal teaching, based on their reverse engineering of *H.erectus's* Lower Paleolithic Oldowan stone tool technology as it evolved into the much more sophisticated Acheulean industry. Observational learning evolved through genetic mutation and Darwinian natural selection, enabling the tool tradition to

[13] Cf. the examples referred to in Thonhauser et al. 2013:927. See also Wikipedia: Observational Learning.
[14] The spread of yam-washing and grain-filtering found in some troops of Japanese macaques comes to mind here, as do certain tool-making behaviors of chimpanzees. One argument for calling those infra-human examples "cultural" is that, at least at first, memes tend to spread rapidly within a local group but stop at group boundaries.
[15] "Most human behavior is learned observationally through modeling: from observing others, one forms an idea of how new behaviors are performed, and on later occasions this coded information serves as a guide for action." (Bandura 1977:22)

evolve culturally, through "memetic mutation" (e.g., the process illustrated by stingray RayD) and Darwinian natural selection (Cloak 1968c, 2002; Dawkins 1976; Cziko 1995; Boyd and Richerson 1985; Wikipedia:Cultural Evolution).

Just as natural selection of genes can result in complex functionally integrated wholes such as horses and ant colonies (Carroll 2005), so natural selection of memes can result in complex functionally integrated wholes such as pre-industrial village cultures and band cultures. On the other hand, memes are much more likely to "go rogue" than genes, as we all can attest -- think fads, slogans, etc.

Without language, the highest level nimage-mechanisms are those genetically provided to meet basic physiological and social needs for survival and reproduction; e.g., "Stayin' Alive" and "Taking Care of Mate & Offspring". Memes acquired by observational learning are selected if they serve those nimage-mechanisms; i.e., if they become incorporated into hierarchies under those genetically provided nimage-mechanisms.

Nimages, including memes of course, are goals for perceptions of actions and their outcomes. Language lets us humans share and store goals that are more like the everyday usage of the term, even including nimages that can override the basic needs nimages, such as "Getting Rich", "Serving God", or "Fighting for My Country".

At some point during the evolution of language capability,[16] it became possible to describe perceptions; i.e., express them with utterances, like "(I see) a bird" or "(I smell) a rat", thus evoking a nimage of a bird or a rat in the hearer. After that, it was an easy evolutionary step to describing nimages, which of course requires the hearer to re-create the nimage.[17] If the hearer *adopts* the nimage, i.e., incorporates it into a nimage-mechanism, it becomes a goal for his/her perception, a meme.

[16] I won't try to explain how speech and language evolved. See Wikipedia: Origin of Language.
[17] This could be where people began to experience mental images.

As language-culture evolves, a novel nimage can be generated by a shift of words in a sentence or simply by "anything a person can imagine wanting to perceive".[18] If he/she then describes the novel nimage to another person and the other person also adopts it, it thereby becomes a meme, subject to natural selection and therefore, possibly, propagation.

With language-propagated memes, planning becomes possible: gratification can be deferred more widely and much longer in time. Opportunities for cooperation and competition increase greatly. Social groups can become much larger, although culturally less cohesive -- from band gatherings to empires.

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More about the nature of nimages: The nimage framework, along with the apparatus of the accompanying mechanism, evolved genetically and is, of course, genetically programmed. Individual nimages may also be genetically programmed, or they may be captured from a perception (Powers 1973: 217). Besides being visual, the nimage may, like a perception, be based on any sensory mode or even be multimodal. It may be three dimensional. It may even be four dimensional, like a 3-D film clip. With language, it may be constructed from a perception of an utterance or a paragraph on a page.

I would add that we animals build our nimages, adding to them and paring them down. For instance:

- With repeated perceptions of the same person, place, or thing, our nimages grow and become more comprehensive. Our images seem more representative of the "entire" person, place, or thing. A hologram might be a good metaphor here.

[18] I think combining two or more nimages, letting them run together, and adopting (or rejecting) the outcome nimage fits well into D. T. Campbell's (1960) theory of creative thought. Example: "What if I was sitting on the horse, instead of hitching it to a cart?"

- We animals build “maps” of our territories, sequential nimages of landmarks we want to see on our way to various locations and on our way home.
- Humans, at least, can combine disparate nimages, and can even subject the resulting nimage to selection before adopting it (Campbell 1960).
- It’s well known that our nimages change every time we access them. Even genetically programmed nimages are subject to modification by experience.

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Powers: “We are assuming that memory is recorded in the form of a physical change in a molecule.” (1973: 207). Marx and Gilon (2012, 2019) have shown that a memory (*engram*) can be stored biochemically in the *extracellular matrix* surrounding a neuron. I propose that a nimage-mechanism may be stored in and around a single neuron – the nimage in the extracellular matrix, and the perceptual control mechanism in the cytoplasm or perhaps in a special organelle.[19]

If that seems unlikely, remember that almost every cell in an organism contains all the information necessary for directing the construction of that organism; the cell’s machinery for reproducing itself, feeding itself, repairing itself, etc.; and the incredible mechanisms by which the cell’s DNA directs the assembly of just those proteins, including enzymes, necessary for it to fulfill its specific function in the organism (Carroll 2005; Fester Kratz 2020:291-310). There should be plenty of room for a nimage-mechanism.

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To sum up and conclude: my main hypothesis is that animal behavior is not just an extensive tweaking of the reflex arc, it is entirely produced by seeking to match

[19] A decisive advantage of this hypothesis, over any which propose that several neurons are required for a nimage-mechanism, is that intracellular chemical signals are several orders of magnitude faster than action-potentials (signals involving axons and dendrites). On the other hand, abutting cells do communicate chemically (Fester Kratz 2020:123-138), so perhaps a tight cluster of neurons would work.

perceptions to nimages. Nimages are physical structures in the brain, and every animal has thousands of them. Most of them are accompanied by a mechanism of perceptual control which generates action to match its perception to the nimage. Nimages, accordingly, are the elemental units of behavior. They are stacked in hierarchies and acquired by genetics, individual learning, observational learning, and, in humans, verbal teaching. Nimages acquired by the latter two modes are memes, the elemental units of culture.

A second hypothesis is that each nimage-mechanism may be stored in and around a single neuron.

It goes without saying that much research is required to test either hypothesis. That would entail an interdisciplinary grouping of behavioral scientists of all types, neuroscientists, and molecular and cell biologists (cf. Berg 2023).

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