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Experience Recorder and Reproducer

The *experience recorder and reproducer* (ERR) is our functional basis for an information mind model. The ERR is simpler, but superior to, computational models of the mind popular in today's neuroscience and cognitive science. Mind is *immaterial* information, software in the brain hardware. ERR provides deep insight into both the problem of "meaning" and the "hard problem" of consciousness.

Man is not a machine. And the mind is not a computer.

Our specific mind model grows out of the biological question of what sort of "mind" would provide the greatest survival value for the lowest (or the earliest) organisms that evolved mind-like capabilities.

We propose that a minimal primitive mind would need only to "play back" past experiences that resemble any part of current experience. Remembering past experiences has obvious relevance (survival value) for an organism. But beyond survival value, the ERR touches on the philosophical problem of "meaning." We suggest the epistemological "meaning" of information perceived is to be found in the past experiences that are reproduced automatically by the ERR.

The ERR reproduces the entire complex of the original sensations experienced, together with the emotional response to the original experience (pleasure, pain, fear, etc.). Playback is stimulated by anything in the current experience that resembles something in the past experiences, in the five dimensions of the senses (sound, sight, touch, smell and taste), as well as unique emotional experiences.

The ERR model stands in contrast to the popular cognitive science models of a mind as a digital computer with a "central processor" or even many "parallel processors." No algorithms or stored programs are needed for the ERR model. There is nothing comparable to the addresses and data buses used to stored and retrieve information in a digital computer.

An approximation might be a non-linear random-access data recorder, where data is stored using "content-addressable" memory (the memory address - a string of bits in a digital computer - would be the data content itself).

Much simpler than a computer with stored data structures, a better technological metaphor for ERR might be a multi-channel, multi-track analog video and sound recorder, enhanced with the ability to record smells, tastes, touches, and most important, feelings. Imagine one channel for each sense, one track for each neuron. But of course machines currently do not smell or taste and have no feelings, so could not reproduce them.

Although there is really no comparison between any current technology and the ERR, the closest thing in speed and completeness of recall, with the precision that recalled items are relevant, is state-of-the-art search and retrieval engines like that of Google.

But even Google pales in comparison with your ability to instantly recall the arrangement of rooms in your house when you were a teenager. You can visualize the surroundings of your home, maybe the color of the house, the direction to the nearest bus stop, etc.

And compared to the worldwide network of computers and databases that is Google, the biological and neurological basis for ERR is very straightforward.

No modern computer can surpass the amazing information storage capability and rapidity of search and retrieval of information as that of the human neocortex.

Unlike most of the brain, the neocortex randomly grows its over 10 billion axons, each with 10,000 dendritic connections.

As can be seen in Ramón y Cajal's drawings made at the end of the nineteenth century, the neocortex consists primarily of six horizontal layers segregated principally by cell type and neuronal connections.

The neurons are arranged in vertical structures called cortical columns, with a diameter of about *1mm*. A given column may respond to a sensory stimulus coming from a certain body part or region of sound or vision. These columns are similar, and can be thought of as the basic repeating functional units of the neocortex. In humans, a column contains approximately 70,000 neurons and the neocortex consists of about 500,000 columns.

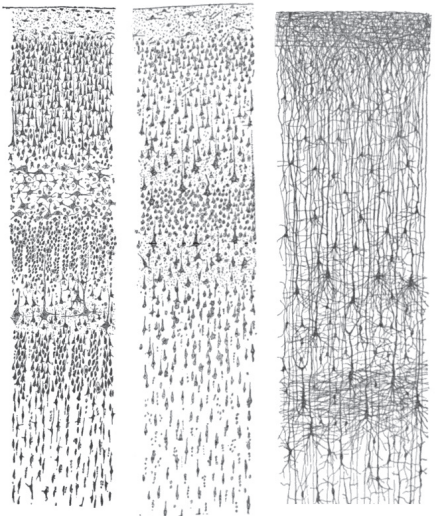

Figure 33-1. Cajal's extraordinary drawings.

The neuroscientist Donald Hebb said in 1949 that "neurons that fire together wire together." Our ERR mind model is based on the simple extension of the Hebb idea to the notion that "*neurons that have been wired together will fire together*."

- The ERR Recorder: Neurons become wired together (strengthening their synaptic connections to other neurons) during an organism's experiences, across multiple sensory and limbic systems.

- The ERR Reproducer: Later firing of even a part of the previously wired neurons stimulates firing of all or part of the original complex, thus "playing back" the original experience (including the emotional reaction to the experience).

The ERR mind model hypothesizes that related experiences are likely stored "nearby" (in the many "dimensions" of visual cortex, hearing pathways, olfactory nerves, etc., etc., plus the amygdala).

The ERR model might then nicely explain the philosophical notion of *association of ideas*. If it is neighboring neurons that fire, they will likely be closely related in some way (since they were stored based on the fundamental pattern of information in the experience). Similar experiences are likely stored in adjacent neurons. Note that a particular smell could cause the recall of experiences where that smell was present, and similarly for other senses.

The Binding Problem

Neuroscientists are investigating how diverse signals from multiple pathways can possibly be unified in the brain. The ERR model offers an extremely simple insight into this so-called "binding problem." There is an intrinsic binding of the multiple sensory and limbic systems present in the original wiring or "recording" of a complex experience. So the "binding" of all the original senses and emotion in each recalled thought or experience is simply the result of the Hebbian "wiring" of neurons during the original experience

We assume that whenever a particular experience plays back, it refreshes and strengthens the synaptic connections. It might also be the case that the current conditions can modify the connections somewhat, both slightly modifying the memories of the experience and the emotions associated with the experience. ERR might then become an explanatory basis for conditioning experiments, classical Pavlovian and operant conditioning, and in general a model for associative learning.

The capability of reproducing experiences is critical to learning from past experiences, so as to make them guides for action in future experiences. The ERR model is the minimal mind model that provides for such learning by living organisms. It is critical that the original emotions also play back, along with any differences from past emotions that are newly experienced during playback.

Speed and Power of the ERR

You might not normally notice the speed with which you can recall the name of a sixth-grade teacher or childhood friend that has not occurred to you for decades. Or that a few notes might bring back music and lyrics of a song not sung for many years. An odd smell might evoke memories of a foreign country. A taste might bring on feelings of nausea first experienced long ago. All the senses, not just visual stimulation, can replay complex, multi-sensory original events. How does it work so fast?

Sometimes when you consciously try to recall a particular name, it does not come immediately to mind, but you can feel it on "the tip of your tongue." Then hours, even days later the forgotten name just "pops into your head." It suggests unnoticeable "unconscious" information processing by the experience recorder and reproducer.

To make a crude estimate of the speed and power of the brain as a biological information processor, we can calculate the information creation going on in the body overall. Estimating how much power the body consumes (metabolizing of food as negative entropy), we can then use the fact that the brain uses about 20 percent of that energy.

We can take just one bodily process that is also vital to thought, the continuous replacement of red blood cells, which consumes a significant fraction of available energy. When 200 million of the 25 trillion red blood cells in the human body die each second, 300 million new hemoglobins must be assembled in each of 200 million new blood cells . With the order of a few thousand bytes of information in each hemoglobin, this is 10 thousand x 300 million x 200 million = 6 x 10^{20} bits of information per second, a million times more information processing than today's fastest computer CPU.

What is the brain doing with such immense power consumption and potential information generation. It could be the "blooming, buzzing, confusion" that William James imagined gong on just below his "stream of consciousness."

How can the mind "focus attention," as James put it? Think of how the eye can instantly be drawn to a tiny dark speck moving in our peripheral vision, or how quickly it can recall a specific fact not thought about for many years.

How the ERR works

The ERR's operation is nothing like the way a computer searches and retrieves information. ERR *does not decide what to search for* and then look systematically through all the information structures to find it.

We can compare Google's "distributed search" algorithms, which send a search phrase to hundreds of thousands of computers in centers around the world. After vast amounts of "parallel distributed processing," each computer returns its relevant pages within a fraction of a second. These are then assembled into the Google "results" pages.

By contrast, in the ERR, the current experience travels into the brain on neurons which process it in the normal way for storage, based on its analysis (breakdown) of the multi-sensory content of the image. At the same time, the neurons that are firing together are stimulating those nearby to fire, reproducing a vast number of past experiences that were (at least partially) recorded in neurons nearby the newly firing neurons.

It may sound absurd to suggest that the mind can pick anything useful out of such a cacophony. But it is precisely the past experiences found that provide the *context* for the current experience to be "meaningful." If there were nothing played back, like the infant brain, there would be no "meaning" in the experience. In the adult mind, a lifetime of experience is available, usually instantly played back unconsciously, without our ever having to consciously ask for it.

We can say that "what it's like to be" a certain animal depends entirely on what its ERR chooses to record and reproduce. A frog, for example, famously allows only the signals from certain shapes

to go beyond the frog's eye to its brain. In our ERR model, the frog has no experience recorded of concave-shaped objects moving in its visual field. Such information then is literally "meaningless."

What would the neurophysiological evidence look like that could confirm or deny the ERR model?

In part, it will be the discovery by neuroscientists of the physical locations where memories are stored. Eric Kandel has spent decades in search of our memory systems.[1] Theories range from the relatively large synaptic structures that connect the neurons, to absurdly small sub-cellular components like the microtubules that form the cytoskeletal structures holding up the cell walls.

Better evidence will come from advances in the speed and resolution of tools that image brain activity. They are currently very slow, reacting to gross blood flows in the active areas. These will be combined with traditional studies of mental associations, presenting a subject with elemental experiences like images, sounds, and smells and watching where the brain is active as it elicits playback of important experiences.

The ERR and Consciousness

Humans are conscious of our experiences because they are recorded in (and reproduced on demand from) the information structures in our brains. Mental information houses the content of an individual character - the fabric of values, desires, and reasons used to evaluate alternatives for action and thus to make choices. The information in a human brain vastly exceeds our genetic information. Because humans store and retrieve information outside their minds, it has allowed human beings to dominate the planet. Animals may exceed us in strength and speed, but we have experience, memory, wisdom, and skills that have accumulated over thousands of generations.

The relatively small amount transmitted genetically is tiny compared to that stored in the experience recorder and reproducer of a single human mind. But even that enormous amount is being rivalled by the total knowledge stored externally (we call it the Sum)

1 Kandel, et al. 2012

now becoming available to all humans because it is being stored on the world-wide web and Internet.

Consciousness can be defined in information terms as a property of an entity (usually a living thing but we can also include artificially conscious machines or computers) that reacts appropriately to the information (and particularly to changes in the information) in its environment.

In the context of information philosophy, the experience recorder and reproducer can provide us with what we can define as information consciousness.

An animal in a deep sleep is not conscious because it ignores changes in its environment. By contrast, an inanimate robot may be conscious in our sense. Even the lowliest control system using negative feedback (a thermostat, for example) is in a minimal sense conscious of (aware of, exchanging information about) changes in its environment.

This definition of consciousness fits with our model of the mind as an experience recorder and reproducer (ERR). Can we say that an organism is "unconscious" If no past experiences are playing back during its current experiences? Can we say that a frog is "not conscious" of the concave objects flying by?

A conscious being is constantly recording information about its perceptions of the external world, and most importantly for ERR, it is simultaneously recording its feelings. Sensory data such as sights, sounds, smells, tastes, and tactile sensations are recorded in a sequence along with pleasure and pain states, fear and comfort levels, etc. We sometimes speak of a "heightened" consciousness that excels at this recording.

All these experiential and emotional data are recorded in association with one another. This means that when the experiences are reproduced (played back in a temporal sequence), the accompanying emotions are once again felt, in synchronization. Although past experiences played back internally are not the same as the current external, they can make us currently "conscious" of past pleasure and pain states, fear and comfort levels, and so forth.

Bernard Baars's Global Workspace Theory uses the metaphor of a "Theater of Consciousness," in which there is an audience of purposeful agents calling for the attention of the executive on stage.

In the ERR parallel, vast numbers of past experiences are clamoring for the attention of the conscious mind at all times, whenever anything in current experience has some resemblance to past experiences. If we define "current experience" as all afferent perceptions plus the current contents of consciousness itself, we get a dynamic self-referential system with plenty of opportunities for negative and positive feedback.

The "Blackboard model" of Allan Newell and Herbert Simon imagines pictures or words (concepts, say) being written on a mental blackboard by our current perceptions. Deep memory structures are watching what is written on the blackboard. They call up similar concepts by association and write them to the blackboard, which is visible to our conscious mind selecting the next things to think about. The ERR model clearly supports this view and explains the neural mechanism by which concepts (past experiences) are retrieved and come to the blackboard.

In Daniel Dennett's consciousness model, the mind is made up of innumerable functional homunculi, each with its own goals and purposes. Some of these homunculi are information structures in the genes, which transmit "learning" or "knowledge" from generation to generation by heredity alone. Others are environmentally and socially conditioned, or consciously learned through cultural transmission of information.

Four "Levels" of the ERR

We identify four evolutionary stages in the development of the experience recorder and reproducer.

• *Instinct*. These are animals with little or no learning capability. Reactions to environmental conditions have been transmitted genetically. Information about past experiences (by prior generations of the organism) is "built in" as inherited reactions.

• *Learning*. Here past experiences of animals guide their current choices. Conscious, but mostly habitual, reactions are developed through recorded experiences, including instruction by parents and peers.

• *Prediction*. - A Sequencer in the ERR system can play back beyond the current situation, allowing the organism to use imagination and foresight to evaluate the future consequences of its choices.

• *Reflection*. Here conscious deliberation about values influences the choice of behaviors. The ERR plays back a range of similar experiences including the reactions and feelings expressed by others to those experiences.

All four levels are *emergent*, in the sense that they did not exist in the lower, earlier levels of biological evolution.

Even the most primitive of biological systems are cognitive, in the sense that they use their internal information structure to guide their actions. Some of the simplest organisms can learn from experience. The most primitive minds are the earliest experience recorders. They reproduce past experiences as alternative possibilities for current actions.

In humans, the information-processing structures create new actionable information (knowledge) by consciously and unconsciously reworking the experiences stored in the mind.

Emergent higher mental levels exert downward causation on the contents of the lower bodily levels, ultimately supporting mental causation and free will.

What It's Like To Be A...

There are characteristic differences between the mental and the physical that modern science, even neuroscience, may never fully explain. The most important is the internal and private first-person point of view, the essential subjectivity, the "I" and the "eye" of the mind, its capability of introspection and reflection, its intentionality, its purposiveness, its consciousness. The mind records an individual's experiences as internal information structures and then can

play back these recordings to compare them to new perceptions, new external events. The recordings include an individual's emotional reactions to past experiences, our feelings. The reproduction of recorded personal experiences, stimulated by similarities in current experience, provide the core of "what it's like to be" a specific individual.

The external and public physical world, by contrast, is studied from the third-person point of view. Although putatively "objective," science in fact is the composite "intersubjective" view of the "community of inquirers," as Charles Sanders Peirce put it. Although this shared subjectivity can never directly experience what goes on in the mind of an individual member of the community, science is in some sense the *collective mind* of the physical world. It is a pale record of the world's experiences, because it lacks the emotional aspect of personal experience.

The world of chemistry and physics has no sense of its history. It does not introspect or reflect. It lacks an ERR and so lacks consciousness, that problem in philosophy of mind second only to the basic mind-body problem itself.

Mental States?

The ERR avoids the vague idea of a "mental state," whatever that may be. The ERR stores specific information in the brain's neural networks about all the perceptual elements (sight, sound, touch, taste, smell) of an experience, along with emotions felt during the experience. They automatically are stored in whichever neurons fire together.

Later, any new perceptual element that fires the some part of those neurons can activate the neural network to replay the original experience, complete with its emotional content. The unconscious mind is a "blooming, buzzing confusion" playing back many similar experiences, to some of which we focus our attention, as William James pointed out.

This rich spectrum of past experiences provides the "*alternative possibilities*" for action that James said was the first stage in his two-stage model of free will.

Instead of a general idea of a "mental state," ERR describes a mind full of many possible specific mental states simultaneously, any one of which may be focused on as the free thought that leads to the next action "self-determined" by the mind, brain, and body.

ERR finds support in the idea of *empathy* and the recent discoveries of "mirror neurons" in higher primates. Observing another being having an experience fires similar patterns of neurons that play back the observer's similar experiences, along with emotional reactions to those earlier experiences.

Different emotional reactions can explain how different individuals can be attracted to or repulsed by otherwise similar experiences.

Summary

The biological model for the experience recorder and reproducer is neurons that wire together during an animal's experiences, in multiple sensory and limbic systems, such that later firing of even a part of the wired neurons can stimulate firing of all or part of the original complex. Where Donald Hebb famously argued that "neurons that fire together wire together," our experience recorder and reproducer ERR model assumes that "neurons that have been wired together will fire together."

Neuroscientists are investigating how diverse signals from multiple pathways can be unified in the brain. We offer a simple insight into this "binding" problem. There is an intrinsic binding of the multiple sensory and limbic systems present in the original wiring or "recording" of a complex experience. So the "binding" of all the original senses and emotion in each new experience is partly the result of the *Hebbian* "wiring" of neurons during a similar original experience

Beyond the obvious relevance (survival value) for an organism of remembering past experiences, we suggest the "meaning" of information is found in the experiences reproduced by the ERR, when presented with that information.

A conscious being is constantly recording information about its perceptions of the external world, and most importantly for ERR, it is simultaneously recording its feelings. Sensory data such as sights, sounds, smells, tastes, and tactile sensations are recorded in a sequence along with pleasure and pain states, fear and comfort levels, etc.

All these experiential and emotional data are recorded in association with one another. This means that when the experiences are reproduced (played back in a temporal sequence), the accompanying emotions are once again felt, in synchronization.

The capability of reproducing experiences is critical to *learning* from past experiences, so as to make them guides for action in future experiences. The ERR is the minimal mind model that provides for such learning by living organisms.

Something like an ERR is obviously present in all the higher primates and it is unclear how primitive an animal must be before it cannot learn something from its experiences.