Is Experience Stored in the Brain?
A Current Model of Memory and the Temporal Metaphysic of Bergson

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Abstract

In discussion on consciousness and the hard problem, there is an unquestioned background assumption, namely, our experience is stored in the brain. Yet Bergson (1896) argued that this very question, "Is experience stored in the brain?" is the critical issue in the problem of consciousness. His examination of then-current memory research led him, save for motor or procedural memory, to a "no" answer. Others, for example Sheldrake (2012), have continued this negative assessment of the research findings. So, has this assumption actually been proven since Bergson? Do we know how experience is stored? Or that it is stored? Here, a recent review and model of memory is examined to see where this assumption actually stands. Again, the assessment will be that nothing has changed.

The core of the problem, it will be argued, lies in two things: Firstly, the search for how/where experience is stored is motivated – rephrasing Bergson – in the *classic metaphysic*, a framework on space and time whose logic cannot be coherently, logically adhered to in attempting to explain how experience is stored. Secondly, the search generally assumes an inadequate theory of perception that is implicitly based in this classic metaphysic. If framed within Bergson's model of perception and his *tempora*l metaphysic, conjoined with J. J. Gibson's model, the storage-search appears misguided from the start.

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> For where is the borderline between perceiving and remembering?…Where do percepts stop and begin to be memories, or, in another way of putting it, go into storage? The facts of memory are supposed to be well understood, but these questions cannot be answered. - J. J. Gibson (1975, p. 299)

Introduction

In 1896, in *Matter and Memory*, Henri Bergson argued that whether experience is stored in the brain is the key to the problem of consciousness. In his 1910 introduction to the work, he stated this as such:

> Anyone who approaches, without preconceived ideas and on the firm ground of facts, the classical problem of the relations of soul and body, will soon see this as centering on the subject of memory…(1896/1991, p. 13).

He was equally referring, of course, to the relations of "mind and matter." The concept that *memory* could be the key to the problem of consciousness is likely very foreign to most, the very term "memory" seldom being seen in discussions of the "hard problem." The concept that our experience is stored in the brain is so central, so much a dogma, that it is an unquestioned premise in all current discussions of consciousness. Yet, as Bergson noted, this virtual dogma is in fact only an *hypothesis*. And, as he saw it then, over 120 years ago, it was an hypothesis that had never been proven. So this is the question: Has this state of affairs changed? Has current theory and research proven the storage of experience in the brain? If so, by now, theory should have at least a fairly good idea *how* experience is stored. Is this case?

We'll examine a recent model/review summary (Moscovitch, Cabeza, Winocur & Nadel, 2016) focused on the role of the hippocampus, a neural structure long seen as central, but central only in the sense that it supposedly holds "indexing" information critical to the retrieval of an experience from various other supposed storage sites in the cortical areas, the multiple cortical storage sites being equally "central" to the model. The authors comprise some of the premier theorists in the memory field, it is a wide review of the field, and the model has strong relations to the currently dominant connectionist architecture in cognitive science, with numerous connectionist models describing roughly the same architecture (McClelland, McNaughton & O'Reilly, 1995; McClelland & Cleeremans, 2009). On a whole, it can be taken as an exemplar of current thinking, and particularly so since the root problems at its base are encountered by other models in the standard literature.

There have been examinations of the lack of success in the historical effort hitherto to determine how experience is stored in the brain, for example, Sheldrake (2012). The roots of the problem begin in Lashley's (1950) frustrated attempts to find the "engram" – some precise place in the brain where an experience or a learned action is encoded/stored. Lashley's thirty year-long effort, attempting to eradicate a memory via every slicing/dicing scheme possible, ended with his principle that there is no such place, that an entire memory or learned behavior is, in his hypothesis, distributed across the brain and that any area can serve to retrieve the memory. This was extended by his student, Pribram (1971), in his holographic model of storage. Fuster (1994) noted the strange fact that every apparent "storage" site turns out to be a perceptual processing site. This history of failure is an important aspect of the problem, and it is already a curious thing that the structure of the Moscovitch et al. model gives (and can give) no incorporation of

Lashley (as no connectionist network could withstand the damage ruthlessly inflicted by Lashley). But the engram search and the storage-search failure is more a symptom than a cause. This paper will be taking a different line of analysis, one that is not touched upon, one that goes to the root problem. The analysis here will employ two aspects of Bergson, with the second being conjoined with J. J. Gibson.

The first aspect is this: The entire research effort at discovering the brain's method of storing experience is based upon an unexamined metaphysic. I term it the *classic metaphysic*. This metaphysic is the basic framework for viewing space and time which underlies current science and mathematics, to include calculus. It is actually the underpinning of *physicalism*, a framework now being increasingly blamed for our theoretical difficulty with consciousness (cf., Kastrup, 2019; Goff, in press), but physicalism as currently understood – as a framework wherein all matter and consciousness is explained by interacting particles – is but a partial expression of this underlying metaphysic. Bergson, in his analysis of this metaphysic, offered an alternative, what I term the *temporal metaphysic*. The unexamined classic metaphysic and the logical problems this engenders plagues our exemplar memory model.

The second aspect is the critical role of a model of perception, and especially – coordinate with a metaphysical problem on space and time – *time* in perception, i.e., the perception of time-extended events – stirring spoons, flies buzzing by, leaves twisting and falling. Bergson offered a model of perception which explains the origin of the image of the external world – the coffee cup with stirring spoon "out there," external to our body, with all its "qualia." Gibson's model of direct perception fits naturally within this and requires Bergson's framework (Robbins, 2000, 2006, 2013). Critical to both is that perception is of time-extended events. This perceived continuity over time, this time-extension, already implies, a) memory; in fact, that a perception is already a memory, and, b) the event is structured by invariance laws involving invariants defined only over such a continuous flow of time. Both (a) and (b) require Bergson's alternative "temporal" metaphysic, and the critical point of this analysis will be that neglecting the nature of perception in these events and thus the nature of what actually has to be stored, or put another way, assuming a deficient model of perception based in the classic metaphysic — sinks the storage-search from the start, making it incoherent from the get-go.

This is to say that the storage model can have no validity, its invalid starting point in perception making it useless as a model of "storage." The ship has already been torpedoed; the sailors just don't know it yet.

Brief Overview of the Memory Model

The Moscovitch et al. model is called the "component process model," and to set the stage, the model makes four assumptions:

1) The perception of an event: objects/scenes are comprised of "feature clusters."
2) There is *persistence* of the feature clusters during perception via neural activity.
3) Encoding the event (or a *fraction* thereof):
    - The hippocampus becomes an "index" to multiple aspects of the event stored in multiple areas of the cortex.
4) Retrieval:
    - The HPC (hippocampal complex) index is engaged, retrieving and reassembling the multiple cortically stored aspects of the event.

The last assumption already begins the two stages of their recollection process model:

> Stage 1: External or internal cueing (which engages the index) of the experience.
> Stage 2: Cortical processes may (or may not) operate on the first stage output, reinstating the *conscious* experience of the episode.

Warning: Moscovitch et al. is filled with excellent discussion and details on possible functions for various areas of the HPC and its surrounding anatomical areas, its horizontal organization, various "component processes" coming into play, etc. The authors might be a bit concerned at the strip-down to an essence this piece represents. But this article is aimed at seeing the forest for the trees.

Let us start with the assumptions. As there's nothing like a contrasting story to make the weaknesses of the current model more clear, we'll weave in the Bergson-Gibson counter-view as we go.

Assumption 1 – Perception

The first assumption of the component process model incorporates the authors' vision of the world and the events occurring within it that have to be remembered.

> "During perception, sensory information is progressively bound into feature clusters in early sensory regions, into integrated objects and contexts in late sensory and cortical MTL regions, and into complex events binding objects with their spatiotemporal contexts together with the feeling (phenomenology) of experience in the HPC." (2016, p. 5)

So they begin with an essentially *static* view of the world – objects consist of features "progressively bound into feature clusters." The framework that objects can be described as sets of static features still is fully operative in memory theory. This is not a good start. This notion is exactly what Hummel and Biederman (1992) – somewhat epitomizing this "operative in the theoretical background" concept of "features" – noted years ago would not work in the context of perceptual recognition. The cube and cone of Figure 1, if disassembled into features and stored in a memory (whether short, very short, or long term) cannot – like humpty dumpty – be put together again unambiguously. Hummel and Biederman tried to defeat this with the notion of "geons" – elementary geometrical objects such as a "brick" or a "cone" into which the object is parsed or disassembled, serving somewhat like the picture on the cover of the puzzle box that allows us to map the pieces back into a whole. But this (again static) model also suffers multiple problems (Robbins, 2004).

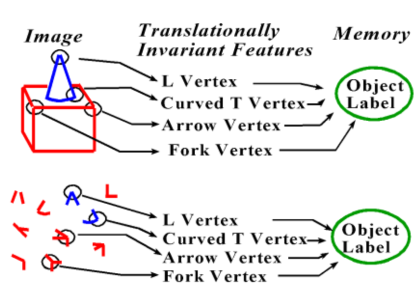

Figure 1. The disassembled "features" of the cube and cone, assembled in a variety of ways, yet labeled, "cube and cone." (After Hummel and Biederman, 1992)

The core of the difficulty rests with the fact that even form is extremely dynamic. Weiss, Simoncelli & Adelson (1998) showed that form perception relies on velocity flow fields (cf. also Watson & Ahumada, 1985; Domini & Caudek, 2003; Robbins, 2004). A rigid rotating ellipse, its perimeter in actuality a set of velocity vectors, if rotated too swiftly, becomes a non-rigid, floppy object. The rigid perimeter or sides (features) are gone. Similarly, a rotating wire-edged cube, strobed in phase with its symmetry period, retains its rigid edges and vertices (Shaw & McIntyre, 1974). Strobed out-of-phase, it becomes a wobbly, plastically changing not-a-cube – the supposedly static, intrinsic-to-the-form features (edges, vertices) are gone.

A rotating cube – call it a "Gibsonian cube" (1966, 1979) – taken in the context of velocity flow fields, is a partitioned set of these flow fields, the sides flowing towards and then away from the observer, a radial flow field on its top. From this perspective, the "edges" and "vertices" are simply sharp discontinuities at the junctures of these flows. The "features" then are creatures of the flows. And they can disappear. They do not exist in a static instant – to be bound in a static "cluster."

Per Moscovitch et al., these feature clusters are being bound "into complex events." The rotating cube is already a "complex event," but let's deepen the difficulty. Let the cube be a cubical cup in which we are stirring coffee with a spoon. As the Gibson school has described, this coffee stirring event is defined by a large number of invariance laws. To list but a few:

- A radial velocity flow field defined over the swirling liquid surface.
- An adiabatic invariant (energy of oscillation/frequency of oscillation) related to the periodic motion of the spoon, defined over the haptic flow. (Kugler & Turvey, 1987)
- An inertia tensor capturing the momenta of the spoon. (Turvey & Carello, 1995).
- An auditory clinking coordinate with the forces/invariants of the spoon's motion.
- A texture density gradient over the table, with a constant ratio of cup height to rows of the gradient relating to the size constancy of the cup if the cup (or our head) is moved forwards or backwards.
- Flow fields over the sides of the cup as the eyes saccade over it or our head moves.

These invariants – like the "edges" and "vertices" – are defined only *over time*, over the flowing transformation of the external field of which the coffee stirring is but a subset. These – for example, the adiabatic ratio, the tensor – do not exist in an instant. So if we are disassembling the event into (rather mythical) "features" in real time, and storing these in a very short term memory, and of course, reassembling these in real time – as required for the needed, usually assumed internal or mental "representation" of the stirring event – where/how is this structure of invariance being stored?

So we have an ongoing, time-extended, continuously transforming event – stirring the coffee. Yet the "perception" model (of the first assumption) envisions distinct static features that must be bound together to form a whole object, having been parsed out and stored in a memory, and there is apparently some "time-glue" holding all this together as it is unwound and reassembled over time, so to speak, for the sake of creating the internal representation of an ongoing (not static state, after static state…) stirring.

We begin to see why Bergson stated that memory is key to consciousness. We are considering a *conscious experience*, aka a dynamic perception, and already we are in the midst of a problem of memory. But there is yet a startling surprise, for per my initial quote from Moscovitch et al., all the above is *bound* "…together with the feeling (phenomenology) of experience in the HPC." We would hope that the *phenomenology* of coffee stirring, perhaps along with fairies and unicorns, is not just sitting around somewhere, waiting to "bound" to all this neural activity. But this is the authors' acknowledgement that somewhere in all this must be a solution to the hard problem, for the only thing that is going on in their model is (a description of) *neural* processes.

Perception – the Bergson-Gibson Framework

Let's place Assumption 1 with its "binding of the phenomenology" more fully against the Bergson-Gibson framework, beyond that just indicated above re invariance laws. Yes, Bergson said he started from the question of experience-storage in the brain, but in Chapter I of *Matter and Memory* (1896), it turns out, once his model is penetrated, once a concrete interpretation is available, Bergson laid out of theory of perception that in fact already dictates the answer, for *experience* – that coffee stirring – becomes such that it is nothing that even can be stored in the brain, for the image of the external world with its coffee cup – our experience – is not within the brain. This is the absolutely prior starting point of this theory. But admirers and critics alike at the time considered this chapter "obscure." In retrospect, as has been argued elsewhere (Robbins, 2000, 2006a, 2007, 2013, 2014), we can see why.

Chapter 1 of *Matter and Memory* starts with Bergson talking in an "image mode," i.e., everything in the material world is an *image*. The coffee cup is an image; we do not see the real coffee cup, its totality, the Kantian thing-in-itself. Cups, neurons, brains, atoms – all are images. Thus he spoke of the material world as the "aggregate of images." This caused philosophers like Russell (1945/1972) to simply assign Bergson to Idealism and Sartre (1962) to say that for perception, Bergson must "begin all over again." But within Chapter 1, Bergson also employs a second mode of treating the material world, and this is critical to grasping the chapter.

Bergson had anticipated the essence of Gabor's 1947 discovery of holography by fifty years. That image/experience of the coffee cup with stirring spoon – is it a "photograph" taken by, and somehow within, the brain? Obviously, said Bergson, even the neural science of the day shows there is no such photograph taken by or within the brain. But he went on:

> But is it not obvious that the photograph, if photograph there be, *is already taken, already developed in the very heart of things and at all points in space?* No metaphysics, no physics can escape this conclusion. Build up the universe with atoms: Each of them is subject to the action, variable in quantity and quality according to the distance, exerted on it by all material atoms. Bring in Faraday's centers of force: The lines of force emitted in every direction from every center bring to bear upon each the influence of the whole material world. Call up the Leibnizian monads: Each is the mirror of the universe (1896/1991, p. 31, emphasis added).

This was his declaration, well before Bohm (1980), that the universe is a *holographic* field – a field wherein at each "point" is the information for the whole. This was his "holographic mode." He equivalently described this field as a field of "real actions." Any given *object* acts upon all other objects in the field, and is in turn acted upon by all other objects. It is in fact obliged:

> ….to transmit the whole of what it receives, to oppose every action with an equal and contrary reaction, to be, in short, merely the road by which pass, in every direction the modifications, or what can be termed real actions propagated throughout the immensity of the entire universe (1896/1991, p. 38).

From the vast information in this field, our body selects only that related to its action capabilities. Highly correlated to Gibson's "affordances," what is specified and selected from the real actions is now "virtual action" —how the body can *act*.

In essence, Bergson was envisioning the brain (with all its bodily connections), as *a modulated reconstructive wave* passing through the holographic field and specific to, or specifying, a subset (or source) *right where it says it is, external, within the field*, related to possible action, and now by this process manifest as an *image* of a part of the external field—the coffee cup with stirring spoon (Figure 2).

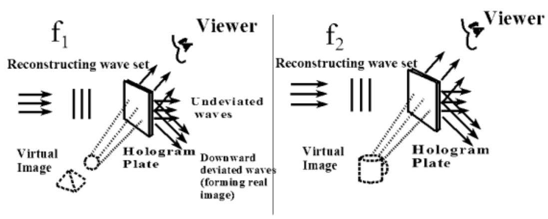

Figure 2. Reconstructive wave modulation in holographic reconstruction. Modulating the reconstructive wave passing through the hologram plate to frequency 1 specifies the original object wave source from the cube. Modulated to Frequency 2, the cup is specified.

The structure of the dynamic changing event ongoing within the external field – all those invariance laws defining stirring the coffee – is driving the modulation pattern of this very complex, brain-supported or brain-created reconstructive wave. This is where Gibson merges with Bergson. Gibson argued that the mathematical information in the environment is "specific to" the environment. The texture density gradient defined over the surface of the table on which the coffee cup sits is "specific to" an *extending* surface. The constant ratio of texture rows occluded as the cup's height increases or decreases as it is moved back and forth on the table is "specifying" the size constancy of the cup. The brain merely "resonates" to this information and by this, *specifying* the external surface and event. For Gibson, as Bergson, there is no image within the brain. Perception is direct; the image is right where it (the object) says it is, *within the external field*. But for Gibson to be coherent, to actually explain how an image is obtained from "specification" and resonance, the origin of the image of the table surface and the cup must be placed within Bergson's holographic framework, now with Gibson's "resonance" as supporting a reconstructive wave. In addition, we'll see, it requires Bergson's framework on time.

Now some immediate, contrasting takeaways from this:

- The invariance laws (or invariance structure) defining the events of experience are absolutely intrinsic to experience. Ignoring them in a theory of how experience is stored is akin to treating the fact that bodies are described by skeletal structure as well as protoplasmic structure as irrelevant.
- Experience is not occurring solely within the brain. The coffee cup experience – at least its optical and sonic aspects – is out there, in the external field. How can the experience be solely stored there?
- The specification of the external event – the coffee stirring with its browns, swirls, clinks – is equally a specification of *phenomenal* experience. There is no need of an additional "binding of the phenomenology" (Robbins, 2007; 2010). But this implies a quite different model of memory.

In this, there is yet the obvious fact, already noted, that the coffee stirring is occurring over an *extended* period of time. It is defined by invariants that do not exist in a static "instant" or state. Thus we are seeing the *past;* the perception is already memory. This will bring us to the metaphysic assumed by Moscovitch et al. in contrast to Bergson-Gibson.

Assumption 2 and the *Classic Metaphysic*

The authors recognize that indeed there is a bit of a problem – a memory problem – explaining the continuity of a time-extended *event* like stirring coffee, or even for just a static coffee cup on the table, for we have the second assumption:

> "The same regions remain active for a while due to top-down modulation from the PFC [prefrontal cortex], which allows the persistence of object and context representations, as well as unified event representations, within Working Memory." (2016, p.5)

This is a common move: Explain the continuity of the ongoing perceived event via the "continuity of neural oscillations" or (same thing) of neural activity (e.g., Taylor, 2002). So, let us ask this: *Why, in the first place, is there the theoretical pursuit of the brain's method of storing experience?*

Per Bergson (1889), the origin of this pursuit lies in the classic metaphysic. He was reacting to the foremost expositor of the underlying framework of science at the time, Herbert Spencer, whose ten volume work (*A System of Synthetic Philosophy*, 1896) codified and crystallized this metaphysic. To Spencer, time was to be treated as if it were little different from space. Like space, time is measurable and contains juxtaposed parts. Like space it is a homogeneous medium whose parts and properties are everywhere alike. Like space then, it is capable of being measured by mathematical concepts, and one can say that one time is equal to another, or twice as long as another, etc. Thus, it is meaningful to say that time is composed of instants and that the movement of time can be viewed as a series of instants, as a body moves from point to point in space. Ultimately, within this space, since given these fixed, static instants, determinate values are deemed possible, all change is reducible to the completely predictable motions of material particles.

This "space," as Bergson termed it, is essentially "*a principle of infinite divisibility*." As *space*, this is expressed as the infinitely divisible (3-D) continuum of points or positions. The motion of an object across/through this continuum/space from point A to point B is treated as a line or trajectory, of course also consisting of points. Each point successively coordinate with the object's motion is also an "instant" of time. As *time*, then, the principle is expressed as simply the 4th dimension (also infinitely divisible) of the infinitely divisible space. The classic metaphysic is a *spatial* metaphysic. It is the metaphysic within which classic science functions – physics, calculus, the treatment of motion, though with counter rumblings, e.g., Lynds (2003).

Moscovitch et al. work within the classic metaphysic but fail to be consistently aware of or admit to its implications: Each "instant" of the time-extended motion of the circling, coffee-stirring spoon, taken as described by the growing (as the trailing past) 4th spatial dimension of "instants" of this motion, is itself infinitely divisible. The limit of this infinite operation (if one can ignore "infinity" and allow this limit) is a mathematical point, i.e., a point that is indivisible because it has no beginning and no end. This now time-less, changeless point is the "present" – the present instant. By definition: 1) each preceding instant has fallen into the *past*, the past being the symbol of *non-existence*, 2) *matter* is considered to extend in time only for this "present" instant, 3) the *brain*, being matter, must be tasked with preserving (instantly) the successively moving-into-non-existence instants of our circling spoon.

This metaphysic is the very reason why our theorists are seeing the need for "storing" the past in the (always present) brain, else it is lost to non-existence. But the brain too, with its neural oscillations, being *matter*, only has the existence – the time-extent – of the "present," of a mathematical point. Neural oscillations therefore can have no time-extent either. They *cannot* be employed to explain the perceived continuity. This is the standard blindness or failure to be consciously aware of its own metaphysic – the *incoherence* – that plagues memory theory: The classic metaphysic is the cause for, the motivation for, the need for, storing experience in the brain. *Ignoring* this classic metaphysic, say, via the handy "time-extended neural oscillations" – this is used to explain time-extended perception.

Having your cake and eating it too may make for comfortable theorizing. It does nothing for clarity on the problem. The theorists are implicitly assuming, as we'll see now, Bergson's temporal metaphysic, but not recognizing the implications.

The Temporal Metaphysic

Bergson, in assessing Spencer, was struck by the fact that experienced time is nothing like the abstract "time" – the series of instants – of the classic metaphysic.

> Below homogeneous [abstract] time, which is the [spatial] symbol of true duration, a close psychological analysis distinguishes a *duration* whose heterogeneous moments *permeate one another*; below the numerical multiplicity of conscious states, a self in which succeeding each other means melting into one another and forming an organic whole. (1889, p. 128)

He would also compare this flow to a *melody*, where each "note" (read "instant") permeates the next, where the state of each reflects the entire preceding series, and where these comprise an organic continuity.

Motion, he argued, must be treated as *indivisible*. When, per Zeno, Achilles successively halves the distance to the tortoise, it is his track in space, the infinitely divisible line, of which we think. Rather, Achilles' *motion* (the *process*) is indivisible; he moves with indivisible steps, he most certainly catches the tortoise. Per Zeno, the arrow, always being coincident with a static point on this infinitely divisible line, "never moves." But the arrow in fact moves in an indivisible motion.

The abstract space of the classic metaphysic with its mathematical treatment erases *real*, *concrete* motion. The point can move across the continuum (or coordinate system), or the continuum move beneath the point. Motion now becomes *immobility* dependent purely on perspective. All *real*, concrete motion of the matter-field is now lost. But, Bergson argued, there must be *real* motion. The universe, the entire matter-field, must dynamically change and evolve over time. Trees grow. Flowers bloom. People get older. Mountain ranges appear. Stars shrivel and die. He would insist then, already acknowledging the only partial validity of a relativistic point of view:

> Though we are free to attribute rest or motion to any material point taken by itself, it is nonetheless true that the aspect of the material universe changes, that the internal configuration of every real system varies, and that here we have no longer the choice between mobility and rest. Movement, whatever its inner nature, becomes an indisputable reality. We may not be able to say what parts of the whole are in motion, motion there is in the whole nonetheless. (1896/1991, p. 191)

We must, he argued, view the entire matter-field as a *global* motion over time. We must see the *whole* changing, he argued, "as though it were a kaleidoscope." We want to ask if individual object X is at rest, while individual object Y is in motion. But both "objects" are simply arbitrary partitions, phases in this globally transforming field. As such, the "motions" of "objects" are seen as *changes or transferences of state* – rippling waves – within the dynamic, indivisible motion of the whole.

From this perspective, there is a "primary memory." It is a property of the matter-field itself and of its melodic motion. This primary memory underlies the motion of the rotating cube, even the motion or flow in the neurons of the brain. The motion of the field, of which the rotating cube is just a phase, does not consist of discrete instants that fall away into the past, or into non-existence. For this reason, the brain, as a reconstructive wave, is able to specify a *past* transformation or motion of the matter-field. The brain can specify "rotating" cubes or the "singing" notes of violins. We are always viewing the past. Perception is always, already a memory. To answer Gibson's question, there is no "dividing line."

So, again, some immediate takeaways:

- The brain cannot be interested in static features, for static values cannot be determined in a continuous flow, as there is no interval of duration, no matter how infinitesimal, in which there is not constant change (cf. Lynds, 2003).
- The brain can only be responding to invariance over continuous flow or change.
- The entire, continuous event is being specified – as a memory; there are no "snapshots" (instants) that can be selectively stored, or not stored.

The last point, or better, its failure to be understood, is the root cause of another theme we are about to encounter in Moscovitch et al., namely, a fundamental ambiguity over the storage of the "details" of experience.

Assumption 3

The third assumption too is common in the literature:

> "During encoding, a *fraction* of transient representations in WM [Working Memory] are transformed to a long-lasting format [LTM] in the cortex and HPC." (2016, p. 5, emphasis and brackets mine)

This is also a feature of the indexing model (Teyler & Rudy, 2007) we'll see below, where "…most of what is initially stored is of little importance and will be forgotten (p. 1167)," i.e., not stored unless "consolidated," a process itself in great question as we'll see. So there is little in the way of a principled mechanism for the selection of this "fraction." The concept that an HPC component (CA1) might act as a *comparator* is noted (2016, p. 10). For example, the comparator normally detects some new aspect when I walk into my kitchen, but if this comparator is damaged, the new experience is not stored. This almost implies that only *differences* are "stored," but this is so contradicted by other aspects of the model, as we shall see, that the seriousness of this is questionable. As in any comparator concept to my knowledge (for example, Gray, 1995), the coherence thereof relies on a static state framework: the position of the stirring spoon at (static) instant 1 is compared to its position at instant 2. In the reality of dynamic events – stirring coffee with its adiabatic invariance, tensors, flow fields – defining the form of mechanism that could actually be detecting differences between one ongoing event during this dynamic flow versus multiple previously experienced others (e.g., how would you sync them up for comparison?), particularly given the cognitive AI/symbolic or neural net frameworks normally assumed – is just not attempted.

This "fraction" also flies in the face of a phenomenon becoming ever more widely accepted, nowadays termed *Highly Superior Autobiographical Memory*, and a problematic difficulty we will meet again. Sacks (1987) had noted these cases, for example the retardate twins who, given any date in their past, could describe the day in detail – what they had for breakfast (in detail), the news, conversations, what was on TV, etc., or the retardate man who could cite *verbatim* any of the 6,000 pages of Grove's *Dictionary of Music and Musicians*, a book his father had read to him daily in his youth. This means, for these HSAM folks, this fraction-selection mechanism must be entirely turned off. And, rather, *everything* must be – and, more importantly, *can be* – stored to the most minute detail, in the brain (or somewhere). This "fractions" concept and its problems will re-embody below under the subject of the "details" of events, stored or not stored.

The rest of assumption 3 is:

> "The HPC representation points to the location of cortical memory traces…"

This is invoking the already noted Teyler & DiScenna (1986; Teyler & Rudy, 2007) model of the HPC as an "index" pointing to storage nodes (for features of an event) at multiple cortical sites. This subject of the HPC index itself could be a paper; it should be examined a bit here.

The HPC Indexing Theory

Consider the indexing theory relative to the coffee stirring event, but placed very explicitly within the operative (classic) metaphysic, where it belongs. The event is broken down into a series of static instants, like a set of cartoon frames. In each frame are the questionable static features which supposedly will be stored in various cortical sites. Per Teyler & Rudy (2007), "The theory assumes that the individual features that make up a particular episode establish a memory trace by activating patterns of neocortical activity (p. 1158)." Abstractly, the cortex is pictured as a 2-D plane with points (say, A thru Z) representing neurons. These project downwards to the smaller 2-D plane of the HPC with its own points/neurons (a to k). The HPC plane also has projections back into cortex. At t_1 of the coffee stirring, linked cortical activity in

ABCDEF projects to, for example, (a, b) in the HPC. At some later date, a portion of the activity, a partial cue, say (ADE) is activated again in the cortex, in turn activating (a, b), which, acting as an index to the original cortical pattern via their back projections, activate the whole original cortical activity, ABCDEF.

As the event is coffee stirring, the original pattern ABCDEF is a snapshot, at an "instant," a single frame. In just 20 seconds of stirring, there is a whole lot of such frames, each with its index. It is the static "bundle of features" of the coffee stirring that is registering on the cortex, frame after frame. Presumably, then, at retrieval/recall, the next cortical pattern from the external event arrives, say, BGY (a partial cuing of the stirring), projects down to the HPC, is fully reconstructed or completed in the cortical plane as BDGMNY, and so on. This would seem a strange oscillation of event frames in the "cortical plane" and thus in our *experience* as well (read in the following, "=>" as "is completed by"): ADE => ABCDEF which then disappears, replaced by partial cue BGY => BDGMNY, which then disappears, replaced by the next instant of the cue event, XYZ => XTYUZR, and so on. Or are all the successive frames simply *chained* (linked) from the initial pattern cortical pattern? In this problematic structure, as noted already, there is no worry about, or attempt to engage where the invariance structure went – the adiabatic ratio, the inertial tensor, the flow fields. Is a "feature" the periodicity captured in the adiabatic invariance? Or in an inertial tensor? Or in a constant ratio of cup height to occluded rows of a texture gradient? Yet frame (or state) after instantly disappearing frame (state) does not a constant ratio make; *continuity* over time, some temporal glue, is required, but this is surreptitiously being assumed, contrary to the *operative*, classic metaphysic. In any case, these cortical patterns are somehow taken to be the swirling coffee flow field, the adiabatic periodicity over the kinesthetic flow, the form of the cup, etc. But how? Implicit here is the "binding to the (mysteriously existing somewhere) phenomenology."

There is another difficulty. Make the event the strobed, rotating wire-edged cube. Each frame would now be considered to hold a set of features of the cube – the edges, the vertices – which are going to be stored in the cortex. But after the first frame, given the rotation, there is the next frame, and the same features have rotated/moved a bit, and must be tracked – for *correspondence*. We need to *track* the same vertex, say, from frame to frame, i.e., we must track *all* the features from frame to frame, else we cannot store or retrieve or compute the form of the rotating cube event properly for that supposed internal representation. But this is termed the *correspondence problem* (cf. Adelson & Bergen, 1985). It is the very reason why Weiss et al. and others before them abandoned features and moved to "energy models" and velocity flow fields – *because the correspondence problem is deemed intractable.*

These difficulties are obscured by the language and vagueness of the indexing model. Again, the term from which fog and mists arise, giving the illusion of continuity over time, is "cortical activity." But the vagueness of the "features" of coffee stirring, with no principled method of stating what they are, but hypothesized for "bundling," at least gives way to something seemingly less vague, more obvious – the "features" of the rotating cube – those edges and vertices. Yet, each out-of-phase (with the symmetry period) strobe of the rotating wire-edged cube *is* a *sample* at an instant, a frame of the event. But the rigid edges and vertices are not "there" in this instant, nor there to be stored as a bundle of features in a cortical pattern, ABCDEF, at an instant. The brain is specifying rather a plastically changing (far from a rigid "cube") object. This seems to mean that we must consider seriously what Gibson (1966, p. 276) noted, namely that the brain is not interested in, not operating with, "these abstractions borrowed from physics," or in Bergson's terms, the brain is not operating in the world pictured by the classic metaphysic.

This brings us to Assumption 4, and the two stage recall model.

Assumption 4/Two Stage Recollection Model

The fourth assumption involves the HPC index as a retrieval mechanism from the cortical sites and is incorporated into the two stage model of recollection.

> Stage 1: There is either external or internal cueing of the experience. The HPC index is "engaged," re-assembling the experience from the multiple cortical sites.
>
> Stage 2: This second stage may or may not occur. If it does, cortical processes operate on the first stage output, reinstating the *conscious* experience of the episode (i.e., creating an *explicit* memory of the event).

One can ask here, is the, say, external cue, static? This is implicitly envisioned. But a static snapshot of a hand hovering over a coffee cup is ambiguous. The coffee cup could be flipped off the table, or rung as a dinner bell, or the hand throws the spoon away. A less ambiguous, more powerfully redintegrative cue-event would contain the dynamics, the invariance structure of the event – the actual periodicity, the resistance encountered, the clinking sound. This is an implicit finding of memory research (Robbins, 2006b). But then, what does this index look like in the HPC? It could not be just a static, single state index; it too must capture the dynamics. How can it be less than at least something close to, a subset of, the structure of the event itself? But yet, per this model, this event sub-structure is somehow contained *entirely* in the HPC – while all the many aspects of (and for each of the many frames of) the event are stored in cortical areas. The more this index concept is placed within the context of the actual dynamics of events in continuous time, the less coherent it becomes.

Now there are several critical aspects in the model that bear on whether there is any clarity on either how or just what of experience is stored. As we shall see, the problems already noted – the unclarity on the implications of the metaphysic, the artificiality of the static event framework, the underestimate re the significance of the dynamic nature of the events to be remembered, the stance that one can pretty much ignore the problem of where the phenomenology of remembered events comes from, the ignoring of the invariance structure of events – these are chickens that will come home to roost. One chicken is the complete ambiguity on whether the "details" of experience are stored, or can be stored, for, deep down, the details demand dynamics – swirling coffee surfaces, adiabatic ratios over energy and frequency – and coming to grips with how this can be stored.

Schematization – Not Consolidation

Consolidation is the concept that the HPC chemically drives storage of an event into various cortical sites. This HPC-driving occurs for some mysterious, unspecifiable length of time. For example, the famous Ribot curves (Figure 3) show that greater percentages of events are recalled the further in the past one goes from the trauma that caused the amnesia, i.e., more events are remembered that occurred 50 years ago than at 40 years ago, etc. But this would imply that chemically-driven consolidation is virtually unending, and must be happening simultaneously for all events experienced. This is one major problem with the entire notion. The authors still cling to this notion, but barely, the discussion of consolidation being miniscule, near zero.

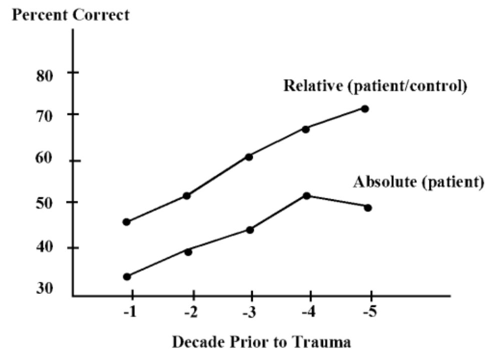

Figure 3. The Ribot curves. Memories increasingly resist destruction with age.

In a 2018 talk on the history of HPC research (Nadel, 2018), Nadel noted that there are two possible views re consolidation:

1) Physiological (neural reverberation, chemical modulation)
2) Psychological (rehearsal, reactivation, reintegration).

The latter view (the psychological), he notes, was lost or buried for years. But it is to this psychological interpretation that the authors entirely turned. This psychological view, they term *schematization*.

An example of schematization: I take a two week canoe trip in Canada. I relive, or remember it many times over the years. I tend to remember catching the big walleye, capsizing in a rapids, a monster Northern Pike, huge waves on Basswood Lake. The point is, these are actually new events – remembering events – but each a new, unique re-creation of the experience. Each successive time in the remembering I could be viewed as reinforcing:

- A certain pattern of retrieval.
- A certain set of events within the canoe trip.
- A schematization of the trip.

This schema is considered *cortically* stored (not in the HPC).

Schematization's Implications

Schematization explains the Ribot curves where the older the event is, the more resistant it is to amnesia. It is the cortically-stored schema that is surviving. It is analogous to a semantic-memory, e.g., St. Paul is the capital of Minnesota, or the US has 50 states. These semantic-memories too are resistant to amnesia. Thus we don't need consolidation to explain the curves, where the greater resistance with age was attributed to the longer consolidation processes, driving the (memory) nails deeper so to speak, unfortunately, say, for 50 *years* of chemical consolidation.

Of course schematization implies some notion of a schema, and we have already seen one (the first, below). However, the authors actually imply two different notions, subtly moving from one to the other.

- Schema 1: A pattern of retrieval of the *same* event.

    - I recall my (one) canoe trip again and again.
    - In a certain way, certain selected events.
    - It is a pattern of retrieval.
  - Schema 2: An invariance or set of such over *multiple* events.
    - Invariants over multiple canoe trips.
    - Or over multiple coffee stirrings.

In the authors' definition of schemas, they have moved to Schema 2:

> "…adaptable associative networks of knowledge extracted over multiple similar experiences…" (2016, p. 15)

The function of these is:

- To make predictions about what to expect in a given context.
- To aid in interpreting events that occur there.
- To enable one to notice new details *that do not fit the schema*.

And they note an example:

> "For example, one may have schemas of what kitchens are like and what one does in them. Walking into a strange kitchen may produce a novel episodic memory for the kitchen and for the local events that transpire there; schemas ensure that the experience of being in the kitchen is not in itself strange but relatively predictable." (2016, p. 15)

Now, as this stands, this "not fitting the schema" is a restatement of the *frame problem* (McCarthy & Hayes, 1969), long standing in AI, faded gradually into non-discussion, but yet entirely unresolved (cf. Wheeler, 2008). Put in AI/robotic terms, this problem is: How does a robot, viewing an event, know when things are happening that should not be expected? For example, while the robot is stirring coffee, the coffee begins to spout geysers, or the liquid rises in mass repeatedly and uniformly in a block an inch above the cup and then down, or goes "snap, crackle, pop," or the coffee liquid suddenly gives the resistance of thick cement. Are these (anomalies) expected as part of the event? Well, all are violations of the invariance structure of the event, of the invariance laws defining it. In the Gibsonian framework, one can note, such anomalies could be viewed as being instantly detected as a *felt dissonance* (i.e., an *intrinsic* intentionality) vis a vis a set of redintegrated coffee stirring events with their invariance structure.

This introduces a major problem that we are about to see with the model – a problem centered on the "details" of experienced events that are stored. In this case, re coffee stirring and the multitude of possible dissonances that could be experienced, we ask: just which details of these experiences are you storing? ALL can be relevant!!! By what principle would one decide what "details" are *not* to be stored?

So consider the kitchen schema noted above. Some things one does in a kitchen:

- Stirring coffee
- Cooking eggs in a frying pan
- Eating eggs with a fork
- Cutting a stack of pancakes
- Spooning cornflakes

Each of these is a dynamic invariance structure with invariants only defined over time, which cannot exist in static instants, which cannot be stored statically. This dynamic event structure should be the starting point for memory theory. Ignore it – your theory is sadly lacking. *How* are you actually storing these dynamic events, constantly changing even within the most infinitely minute interval of time such that there can be no determinate values, with invariants defined only over these flows?

Coffee stirring as a concept can be considered an invariance structure defined over multiple such events. Anomalous events fail to resonate – they create a felt dissonance – with this structure. And it has been noted (Robbins, 2017), to support analogy (or, for that matter, a dissonance), you need *all* the details, the *entirety* of these events, for any aspect – any invariant – can emerge by the very operation of analogy. This is to say that it can be argued that the operation of analogy itself is defining the "features" on which it appears to based (cf. also Dietrich, 2000), not the inverse where pre-defined features are employed to (algorithmically) make an analogy, this being the AI approach (e.g., Gentner, 1983). This "details" difficulty was the centerpiece of the Hofstadter & Sander (2013) work on analogy. In their book, Hofstadter was struck by this experience: Standing in front of the majestic temple of Karnak in Egypt, his companion-friend bends down to pick up a bottle cap (an interest of his). At that moment a previous experience of years ago comes rushing back when, before the majesty of the Grand Canyon rim, Hofstadter's son Danny bends down to examine a small insect. The analogy, "attending to a trivial item on the ground before a majestic scene," illustrated the difficulty: How would one ever delineate which details from an experience are stored and which not? An analogy can derive from any detail of experience.

Those Details

To continue on the interesting role of "details" in the model, the authors state that memories are *transformed* from detailed to schematic (on this, they reference Bartlett, 1932). Well, some memories. Some remain detailed, and the HPC is critical to detailed remembering:

> "Insofar as memories remain detailed and retain their contextual specificity, they will continue to depend on representations encoded in the HPC, regardless of their age." (2016, p. 13)

And:

> "Both types of representations can coexist and dynamically interact, so that a memory that has previously been manifested in a schematic rather than detailed form can regain its specificity with appropriate reminders and once again engage the HPC." (2016, p.13)

But if the schematic form (of my canoe trip) can interact with the "detailed" form, and bring it back, isn't this admitting, *as the term "detailed" is vague enough to construe to be the entirety of the original experience*, that the detailed form – the original experience – *was never lost*?

This is the implication of the earlier noted, ever more accepted Highly Superior Autobiographical Memory, e.g., the retardate twins who could state what they had for breakfast (in detail) on, just picking an example date, 7-19-1975. There is clearly an individual condition where all experience is retrievable; it is never lost, where the proposed normal, ongoing "schematization" of experience is a *non-factor*. (This of course is badly opposed to the "only fractions" are stored.) Again, if we can restore the experience with specific cues – it has never been lost.

But if we have pulled the rug out from under chemical consolidation, and with no known instantaneous molecular transcription mechanism, it is interesting to wonder just how this cortical pattern for a detailed experience is permanently embedded in just one pass? We certainly do not have the standard neural net framework with the many iterations and the weight adjustments required to establish a response pattern.

Then the quote above states that a memory can "regain its specificity" (details) and "engage the HPC." Presumably, while using my standard *schematic* recall for the canoe trip, a chunk/schema (cortically stored, say MNEFGE) can act as a cue, initiating ADE => ABCDEF (completing the "detailed"), where ADE is now engaging the HPC and the cuing cycle described earlier begins, frame after frame after frame. With an amnestic syndrome, in this model, it is damage to this HPC index that would prevent this retrieval, but the implication, again, is that everything, in detail, is there in the cortex, it just cannot be accessed.

But it is not clear that the cueing scenario described in the previous paragraph, which at least attempts to stay in the HPC-as-index framework, is what is actually meant. In his 2018 talk, Nadel states: Remote memories, to the extent they are *vivid*, activate the HPC to the same extent as recent memories. He also says: It is the "vividness" of the event that excites the HPC! And he notes that the details (certainly correlated with the "vividness"), are not stored in the HPC. But where does this "vividness" come from? What is vividness in the Teyler & DiScenna model? How is vivid different cortically from a less-vivid? A more voluminous cortical pattern? From whence does this difference arise? Why/when does the HPC retrieve the vivid versus the less-vivid? Yet Nadel ends the talk by invoking Teyler & DiScenna (and thus all the problems already explored, to include the contradiction here that, per Teyler & Rudy, an *intrinsic* feature of their model is *throwing unreinforced or "insignificant" experience away*!). So we have:

a) The "vividness" – the details – "engage the HPC."
b) The HPC has the index that retrieves the details!

I have to say, it seems there is an implicit view operating here verging back to Mr. Bergson.

Bergson's Virtual Objects/Events

The holographic model described earlier is the perceptual foundation for Bergson's model of recall – a *perceptual* foundation that not only does not exist in memory theory today, but, worse, is not understood as required to exist. After developing this foundation in Chapter 1 of *Matter and Memory*, he proceeded in Chapters 2 and 3, in perhaps the earliest exposition/chronicle of the storage hypothesis failure, to: 1) analyze the assumed strongest existing body of evidence invoked at the time which seemed to justify experience as stored in the brain, namely, the apparent *destruction* of stored memories/experience due to amnesias or aphasias. In all cases he showed the non-necessity, in fact, the incoherence of this hypothesis. 2) Given his model of perception, he began developing a multi-faceted model of recognition and recall in which one type of recall – call it "free recall" or "episodic memory" in our modern terminology – involves the progressive actualization – within multiple neural structures of the brain – of a virtual object/event within our 4-D being, e.g., a chunk of canoeing down Basswood Lake from that canoe trip.

As a student of Bergson, I readily admit that this aspect of Bergson (and this aspect includes an image-driven model of voluntary action, e.g., reaching for the coffee cup) is the most difficult, sitting as it does on the interface of mind and body, and despite the resolution he offered in this mind/matter relation, even he recognized that more theoretical insight was needed. But, if you have no theory of perception in the first place, heavy rock throwing is done from a very precarious platform.

Bergson did not have the wealth of information that is available today on the HPC, but at the time the critical role of the temporal lobe in the memory of language was understood, and this became his primary focus in his construction of what may be happening as a virtual event actualizes, bringing about, as he argued, the same neural responses involved in the original perception. In this, the more fully the virtual event gradually impresses itself on the neural structures, i.e., the greater the "engagement," the more *vivid* it becomes.

So, in the Moscovitch et al. model, we have: an experience, detailed, *vivid*, from *somewhere* (for we know not how this dynamic experience is even stored in the brain), "engaging" the HPC. From Bergson, we have: A virtual object or event in time gradually impressing itself on ("engaging") the HPC (and other neural structures), becoming more vivid as it does so. And in both cases, the HPC must provide the *spatial scaffolding* for the event, for the event's "scenes," for its dynamics.

Where Maguire Fits

This latter point, where the HPC provides the spatial scaffolding, is the critical insight of Eleanor Maguire as to the role of the hippocampus (Maguire, 2014; Maguire, Intraub & Mullally, 2016). Moscovitch et al. note that episodic experience is always in spatial context, thus the HPC's importance, and the scene construction thesis of Maguire is brought in here. Maguire was to trying to reconcile two things: 1) the well-known critical role of the hippocampus in spatial navigation (or in "cognitive maps"), and, 2) its apparent critical role in just plain recalling experience. She had patients with hippocampal damage try to visualize scenes (say, a man paddling a canoe on a lake). She found they could not. Per one patient, "There is no scene in front of me here…there's no visual scene opening out in front of me." Per another, "It's as if I have a lot of clothes to hang up in a wardrobe, but there is nothing to hang them on, so they all fall on the floor in a complete mess." In other words, they had no *spatial scaffolding* upon which to construct (or "hang") elements of a scene.

Moscovitch et al. give little more attention to this. Yet it is obviously critical, for its negative point (for their model) is this: The critical role of the hippocampus may have little to do with the indexing/retrieval of experience per se. Rather, it is, 1) likely critical in the spatial organization/orientation of the *original event*, and, 2) equally crucial then to the re-instantiation of previously experienced events as spatial scenes. This does not at all imply that this experience is coming from some storage areas within the brain.

Cassirer (1929/1957) had already deepened this "spatial scaffolding" thesis (Robbins, 2009). He had noted similar problems, for example, an aphasic patient who could not draw the objects in a room with their locations unless someone marked an "X" on the paper showing the patient's current position in the room, or a patient who could hammer a nail into a wall in actuality, but could not step back two feet and do this in imagination. He argued that in these cases what is now lacking is essentially the capability of "providing a fluid center," ultimately relating to supporting a mathematical group of spatial motions. Though he was not arguing specifically re the HPC, it is likely highly related to the mechanism of spatial scaffolding provided by the HPC, and far from a storage function for the HPC.

Explicit Memory

In the model, what is explicit memory of the past? That is, what is underlying the *conscious* localization of a past event in time, in one's history? The authors offer little on this question, the vague "binding of the phenomenology" to cortical processes being an index as to how vague on this they are. They envision the HPC working together with the prefrontal cortex to achieve explicit episodic memory:

- The PFC: The larger context, the schema – either invariance over many events (of coffee stirring in kitchen) or a schematized retrieval of an event.
- The HPC: The local event coherence spatially with its other aspects – the coffee stirring.

As noted earlier, the authors state, per the two stage model, 2nd stage processes may (or may not) "operate" on the output of the first (the redintegrated experience) to create an *explicit* memory of the experience. But why this conjoint mechanical "operation" should yield *conscious* remembrance, i.e., why it should yield anything more than just a yet more complex mechanical process – there is silence. That is, why would we have anything more than a robot? Why can't a robot (its computational processes) "operate" on the output" of its retrieval stage? And why can't we "bind phenomenology" to a robot's computations?

I would say here that the "COST" argument (Robbins, 2009) still holds; it just makes actuality more complex. COST is the interrelated complex of concepts: Causality, Object, Space, Time. There is, as described by Piaget (1954), a dynamic developmental trajectory over two years that the brain requires to achieve this complex and the correlated ability dependent upon it, as he termed it, the "conscious localization of events in the past," e.g., little Jacqueline at roughly age two, seeing a piece of green grass, is *explicitly* reminded of playing with a grasshopper the day before with her little brother. Complex as this trajectory is, there must be points for breakage via neural damage. As was argued, this complex dynamical state must be supporting an *articulated simultaneity* to account for explicit remembering, for one must hold a present event in a simultaneity with a past event in a whole – a waving piece of green grass + jumping green grasshopper I was playing with yesterday. This was the implication of Cassirer (1929/1957) and also of Weiskrantz (1997) and the "past by present product" the latter saw as required for explicit memory.

This requires Bergson's *temporal metaphysic* – mind integrally embedded in the *indivisible* transformation of the holographic field. In a little example of explicit memory: I notice wind chimes tinkling on the porch. This redintegrates an experience: Holding the (tinkling) wind chimes in the store, buying them as a present. The present-buying is a virtual event, within the 4-D extent of my being. All the dynamics underlying the articulated simultaneity supporting this explicit memory – holding the present event together with the past event as a simultaneous whole – is needed. Without such a thesis, we just have a robot/machine loading a "schema" into place (or something); we have no explanation for conscious, explicit memory.

Now, per Moscovitch et al., the HPC is "*engaging*" with a (vivid, detailed) experience, an experience for which they have no coherent model of its storage or of its retrieval. Again, one can certainly ask, how far is this from saying that the brain is being engaged by a virtual event in time, an event in 4-D being? This interaction – with the virtual – could be viewed as what Moscovitch et al. are, in effect, well, actually invoking without being explicit.

Summary of the Problem

Is experience stored in the brain? Is this position – an hypothesis exalted to a dogma – still SO obvious? I would say, not. Rather, it is now very strained. Its creaks and groans are hidden in models that are superficially coherent, and by vague, increasingly difficult to defend statements:

- "'Binding' to the phenomenology."
- "'Detailed experience' engaging the HPC."
- "Only a fraction of experience is stored."

What we are seeing is the verification of Bergson in at least this much: Whether experience is "stored" in the brain is critical to the problem of consciousness. Are you storing every instant of an ongoing perceived event – the rotating cube, the stirring coffee? You *must* do so in the storage model! Given its metaphysic – where each "instant" moves into non-existence – you must.

But are you dis-assembling these events into static "features," storing each "feature" in an extremely short-term memory, then reassembling all these "features" in real time (as an internal "representation") as the event is ongoing? Then what happened to the invariance structure? And still, by your metaphysic, this does not help you. You cannot explain continuity – the perception of a time-extended event – *stirring* coffee, *rotating* cubes. So, we need to see how perception can actually work in your theory of memory, for your theory of memory must *begin* with perception.

So this must be recognized: Perception = Experience = Consciousness. A theory of memory must be a theory of perception, i.e., of *experience* – and equally then – a theory of consciousness, of phenomenology. A theory of memory must account for rotating cubes and stirring spoons. But what have we seen? We have Moscovitch et al. theorizing as though memory is virtually a separate subject from consciousness and perception, particularly perception of dynamic events. Yes, this seems to work to a degree, for a period, but when all three are treated as such – as independent – *all* become misguided.

What we have seen re current theory is: a) There is yet little idea how experience is "stored" in the brain, b) There has yet to be any engagement with the dynamic nature of the events of experience, c) Actual engagement will clearly make "how experience is stored" very more problematic. Add in, re current theory:

- It totally ignores Gibson's invariance laws (theorizing, as it were, inside a "safe space").
- Its "consolidation" construct is barely breathing.
- Its "fragments" stored – scarcely defensible, lacking a principled mechanism.
- Highly Superior Autobiographic Memory – unintegrated theoretically, an anomaly.
- Its "features" of objects/events – vague, an intractable problem at its core.
- It is, on the frame problem (a problem of *memory*) as lost as AI.
- Its theory of explicit memory as a problem of *consciousness* – missing.
- It is a theory of the static – a static world that does not actually exist.

The reality, in my estimation: theory is being driven to a far different model.

An Alternative

The purpose here has been to expose the problem, particularly from a core-origin seldom if ever described. For many, this is not enough; this demands at least some vision of a road to a solution, though I would note: without some realization that there is a problem, no such vision-demand even emerges, and as noted, the consciousness literature on the hard problem certainly evidences zero such realization or demand. But in terms of an alternative, with what elements from Bergson and Gibson would we be starting?

The first element is this: Perception, thus the external event – our perceived coffee stirring – is not occurring solely within the brain, therefore it cannot be stored there. Gibson's "specification," it was noted, has to be taken in Bergson's context wherein the brain, with all its processes or "computations" (as we presume today) is a concrete dynamical device fulfilling the role of a very concrete reconstructive wave passing through a holographic field and "specific to" an event right where the event commonsensically "says" it is – eternal to us, within that external field – the cup and coffee being stirred. This model of perception precludes any simple notion that this ongoing experience is being stored within the brain, and an alternative model of memory must start with this premise, i.e., some other method of retrieval is going on, something other than re-assembling stored "elements" of the event from within the brain. Note too, this equally implies that the *memory experience* of the once external past event – *recall* of the coffee stirring – cannot be and will not be occurring simply "within the brain" either.

,

A second element: The time-extended coffee-stirring event – itself simply a part of the ever transforming holographic field – is an indivisible flow or motion. The invariants structuring the event are defined only over this flow; invariants do not exist in a static instant or series of such (unless some source of continuity or memory is surreptitiously assumed). The event is necessarily a 4-d structure, with this property being provided by the indivisibility of the field's motion or transformation.

This second element, we should note, is a restatement of Bergson's temporal metaphysic. Yes, the fact is, this metaphysic implies a modification in physics, a different view of the field of matter, but it can scarcely be said that the two sciences – physics and psychology – are not now understood to be entwined, nor can it be said that quantum mechanics has not exposed deep, unresolved issues in its mother science, nor can it be unnoticed that physics' treatment of time is emerging as a very salient issue (Lynds, 2003; Nottale (1996); Smolin (2013); Unger & Smolin, 2014). The temporal metaphysic is saying that if we abandon the classic framework on motion/time with its infinite regress and its other logical difficulties, if we take the transformation of the material world or field as indivisible, the past of the field must exist in some form. In Bergson's terms, we would at least say that the past is *virtual*.

Let us take this last statement – on the virtuality of the past – as sufficient for now. Now what would a memory retrieval theory look like if we were not asking how experience is stored in and retrieved from the brain, but rather how the brain accesses this virtual field? A natural answer is to envision some form of *resonance*, i.e., the brain sets up a resonance with events of the virtual past, this forming a basis for remembering. Sheldrake (2012, Chapter 7), for example, applied his concept of "morphic resonance" to memory retrieval, invoking "resonance across time." The "across time" is an implicit appeal to what was, and is, the far more explicitly stated temporal metaphysic with its indivisibly, melodically transforming holographic field implying a four-dimensional structure. This is to say that the brain is resonating within a 4-D temporal structure that comprises our being.

"Resonance," note, entails a very concrete physical, dynamical state, as concrete as a resonating violin string or even a bridge resonating in the wind; abstract symbol manipulation has nothing to do with this, can achieve nothing like this. This brain-supported resonance is with the flow of the event, itself structured by those invariance laws, and it is this structure that allows us to get more precise than Sheldrake's morphic resonance.

The most fundamental operation of event retrieval is "redintegration," a termed coined already in 1732 by Wolff, a disciple of Leibniz, in his *Psychologia Empirica*. It is defined roughly as "a part of a current event retrieves the whole of a past event," or as Klein (1971) puts it, a *pattern* in a current event retrieves a past event with a similar pattern: a bolt of lightning strikes and I am instantly reminded of my childhood house being struck; a rustling motion in the grass reminds me of snake that once slithered by me. One could recount here the history of theories on redintegration for the last 288 years, from verbal learning to connectionism; their obvious neglect, as we have already seen, has been any attention to actually describing, addressing, or employing these *patterns* of events, i.e., a sad ignoring of Gibson and the invariance laws defining events.

So the law of redintegration in Gibsonian terms would be:

> *A current event, E', redintegrates a previous event, E, when E' and E share the same invariance structure*.

Stirring the coffee at the kitchen table is defined by the afore-described invariance structure. Per Gibson, the brain is resonating to and specific to this structure; in Bergson's framework, this dynamically changing structure is modulating the reconstructive wave specifying the event within the external field. And in the redintegrative framework, there is resonance to a set of virtual coffee stirring events with a similar structure.

An invariance structure is a *parametrically variable* structure. Coffee stirring with its invariants is defined by a set of parametric values – the normal amplitude value of the stirring, the resistance of the coffee medium, the value of the inertial tensor, the form of the radial velocity flow. Cake batter stirring has yet another set values on the parameter range of stirring; cement stirring another range, and "stirring" in general has a parameter range embracing all these variants. In recognition experiments, recognition performance (familiarity values) on previously presented events can be affected it has been argued (Robbins, 2006b), by manipulating these parameters, e.g., a coffee stirring event will be increasingly less recognized or rated as increasingly "less familiar" as the test stimulus parameter values verge towards, say, cake batter stirring.

To illustrate with one other simple example, the experiments of Pittenger and Shaw (1975) showed that the invariance law describing the aging of the facial profile is a strain transformation upon a cardioid (Figure 4). Originally the subjects looked at many pairs of generated profiles, judging each time (quite correctly) which of the pair was the older. Changing this to a memory task, a profile/face of a certain age can be included in a set of various items successively presented to a subject. On the recognition task, a face is now presented transformed by a certain parametric aging value, i.e., a new value of the strain transformation. Familiarity rating values can be expected to be a function of the strain value of the transformation – the farther away from the original value, the less the rating for familiarity.

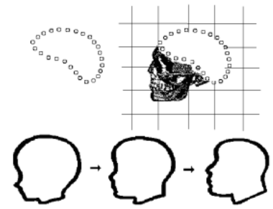

Figure 4. Aging of the facial profile. A cardioid is fitted to the skull and a strain transformation is applied. (Strain is equivalent to the rubber sheet-like stretching of the meshes of a coordinate system in all directions.) Shown are a few of the possible profiles generated. (Adapted from Pittenger & Shaw, 1975)

This optical modality in the profile case is but one dimension of invariance, where the stirring coffee event exemplifies the actual multi-modal nature of this. But this has been discussed in more detail elsewhere (Robbins, 2002, 2006b, 2014), to include research findings in the memory field that already indicate this parametric case. This implies by the way, that any memory theory has the *requirement* to handle this dynamic variation – based, as it is, on invariance! Moscovitch et al., based in their static feature bundles, cannot; connectionism, similarly based, cannot. But for current memory theorists, a massive hurdle in accepting such a sensible and testable theory is that it envisions simply a global resonance pattern assumed by the brain but this is not involving the retrieving and reassembling of static elements of an event from various cortical storage sites (or from anywhere) within the brain. And of course one can ask, but how is a *specific* event in one's past remembered – my stirring of the coffee *yesterday*, or the windchimes suddenly tinkling on the porch bringing back the specific event of buying them as a birthday present a year ago? As noted above, this is the problem of achieving an explicit (conscious) memory of an event localized in one's past versus an implicit memory which involves nothing such, a question clearly involving the theory of consciousness.

Conclusion

Of course there are numerous other questions, but the redintegrative aspect I have just sketched, and which requires Bergson's temporal metaphysic and perception framework, are but part of Bergson's overall memory model. For example, there is his distinction between motor memory (or what would now be called *procedural* memory) which in *Matter and Memory* he held to be stored in the brain as a neural modification, versus experience itself, which cannot be so stored, the latter corresponding to "episodic" memory. This would be the difference, for example, between the resultant *motor* structure eventually laid down over the course of multiple piano practice sessions of a Chopin waltz and the many *experiences* of each practice session (when the teacher was mad, when it was storming outside…). This distinction, as Sherry and Schacter (1987) noted, has been reflected by several other theorists, to include their own "System I" and "System II." But, I fear, when one studies closely Bergson's concept of the *dynamic scheme* (1912/1920), only initially foreshadowed in *Matter and Memory*, even *this* motor storage becomes questionable, though a questioning consonant with Lashley's discovery that no matter how radically he sliced, diced, scrambled or threw away parts of the poor rat's brain, he could not eradicate a learned behavior, say, running a certain path through a maze (cf. also, Gunther, 2012).

There is also Bergson's distinction between automatic and attentive recognition, still needed today, and his model of the role of the memory image in voluntary action, also the role of memory in speech perception and understanding – all of which would become extremely important if moving to a new framework. But this last section has been but the beginning of a sketch of the alternative; the goal has been getting us to see that a "storage" problem exists, that it begins already in perception – and the metaphysical origin thereof.

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