The COST of Explicit Memory

Stephen E. Robbins
Center for Advanced Product Engineering
Metavante Corporation
10850 West Park Place
Milwaukee, WI 53224

Stephen.Robbins@Metavante.com

2/1/2008

The COST of Explicit Memory

Abstract

Within Piaget there is an implicit theory of the development of explicit memory. It rests in the dynamical trajectory underlying the development of causality, object, space and time – a complex (COST) supporting a symbolic relationship integral to the explicit. Cassirer noted the same dependency in the phenomena of aphasias, insisting that a symbolic function is being undermined in these deficits. This is particularly critical given the reassessment of Piaget's stages as the natural bifurcations of a self-organizing dynamic system. The elements of a theoretical framework required to support explicit memory are developed, to include, 1) the complex developmental trajectory supporting the emergence of the explicit in Piaget, 2) the concrete dynamical system and the concept of a non-differentiable time contained in Bergson's theory required to support a conscious, as opposed to an implicit remembrance, 3) the relation to current theories of amnesia, difficulties posed by certain retrograde amnesic phenomena, the role of the hippocampus and limitations of connectionist models, 4) the fact that nowhere in this overall framework does the loss of explicit memory imply or require the destruction of experience "stored in the brain."

Keywords: Explicit memory, symbolic function, retrograde amnesia, Piaget, stage development, Bergson, Cassirer, hippocampus, time

The COST of Explicit Memory

> They believed that they had understood and explained an intellectual act if they could break it down into its simple components – and they held it to be evident or dogmatically certain that these components could consist in nothing other than simple sense impressions…But it was precisely this fundamental vision which inevitably removed them in theory from the peculiar principle and problem of the symbolic.
>
> - Cassirer, *The Philosophy of Symbolic Forms, Volume III*, p. 215

The Phenomenon of Loss of the Explicit - H.M. and Clive Wearing

Perhaps nowhere is the problem of explicit memory better exemplified than in the cases of H.M. and Clive Wearing. The case of H.M. emerged in the 1950's and is now very well known. In 1956, William Scoville removed the medial portions of both H.M.'s temporal lobes in an attempt to control an epileptic condition (Scoville & Milner, 1957). After this operation, the nature of his conscious experience changed markedly. He displayed a severe Amnestic Syndrome, appearing unable to retain any further long-term memories. H.M. cannot remember events from one day to the next, in fact for far briefer intervals. He could retain a string of three digits, e.g., 824, by means of an elaborate mnemonic/rehearsal scheme for perhaps fifteen minutes. Yet five minutes after he had stopped and explained the scheme to experimenters, the number was gone. Remarkably, his same examiners can come into his room day after day, yet from day to day he does not remember ever having seen them. It was Milner (cf. Weiskrantz, 1997) who discovered that H.M. could learn perceptual or motor skills such as mirror-tracing. But, though steadily improving from session to session, he insisted, upon entering each practice session, seeing the mirror-tracing apparatus, etc., that he had never done this before. For H.M., by his own description, each day is "a day unto itself," without history.

Clive Wearing lives perhaps in an even shorter temporal frame. I first saw Clive discussed in Gray's (1995) paper modeling the hippocampus after a “comparator” of present vs. past event. Clive is another individual, similar to H.M., with extensive bilateral damage to the hippocampus, amygdalae, etc. Clive, as H.M., is unable to remember previous events. He feels constantly that he “has just woken up,” and keeps a diary in which this feeling is repeatedly recorded at periods of hours, even minutes. Statements are made such as, “Suddenly I can see in color,” “I’ve been blind, deaf, and dumb for so long,” “Today is the first time I’ve actually been conscious of anything at all.” To Wearing, the environment is in a constant state of flux. A candy bar, even though held in his hand, but covered and uncovered by the experimenter, appeared to be constantly new.

While Clive Wearing and H.M. are at the extreme end of the Amnestic Syndrome, it is in such cases that the problem of the explicit is shown in stark relief. Clive and H.M. are the epitome of a consciousness whose scope is limited to the present. The fundamental dynamics are operative that support the specification of the "world-out-there," the multi-modal world of present experience – conscious perception. As in H. M. and “824,” there is even extremely short-term memory. But as soon as we move to the slightly more remote past, beyond the time-scale of perception and events held by rehearsal, a whole set of higher harmonics as it were, beyond the fundamental, are no longer part of the "chord" supported by the dynamically transforming brain. It was Wolff, in 1732, who coined the termed “redintegration,” stating that "when a present perception forms a part of a past perception, the whole past perception tends to reinstate itself” (cf. Klein, 1970). We struggle yet for a theory of redintegration, the closest being the connectionist network models. But whatever the mechanics of redintegration, it must include some of these overtones, beyond the fundamental, to explain direct recall of events as explicitly *past* events, i.e., to *localize* these events as events in one's past. H.M. approaches for the *nth* time the mirror tracing apparatus. The same flow field is specified as he moves to the device, moving across the same texture gradient specifying the same floor, the same table surface, the same optico-structural transformation of the device as he moves towards it, the same action being carried out. Everything required for redintegration appears present – the same event pattern, the same perceptual information. The redintegrative dynamics should be perfectly supported. The phenomenon of priming indicates that it is. But there is no *explicit* memory of ever having done, seen or experienced this before. For a theory of consciousness, the problem is startling, with strange symmetries to the problem of perception. We have all the neural dynamics supporting perception and redintegration operating, yet there is a mysterious ingredient missing – the ingredient that makes the past event consciously remembered.

Weiskrantz (1997) argued that in the case of the amnesic, a wide range of skills is capable of being learned and retained, not just the procedural (as in mirror tracing), in fact, nearly anything. The list includes:

- New rule learning for verbal paired associates (Winocur & Weiskrantz, 1976)
- A new artificial grammar (Knowlton et al., 1992)
- Classification of novel drawings relative to drawings previously seen (Squire and Knowlton, 1995)
- Mathematical problems (Wood et al., 1982)
- Even the answers to anomalous sentences, e.g., "The haystack was important because the cloth ripped." Answer: parachute. (Cf. Weiskrantz, 1997).
- Word processing (computer) skill and its associated vocabulary. (Van der Linden & Coyette, 1995)

There appears to be no limit, no limit, that is, as long as the task does not require the amnesic to place an event in the past. Weiskrantz expressed these amnesic-capable tasks as tasks which do *not* depend on a "joint product" relating present to past (current event x stored event). The amnesic simply cannot perform this product, this fundamental comparison – *present x past*.

The Problem of the Explicit

The memory ability that a Wearing, H.M., or amnesic in general does indeed preserve is generally subsumed under the concept of the *implicit*. Since the first coining of the now ubiquitous explicit/implicit distinction (Graf and Schacter, 1985; Schacter, 1987), I think it safe to say that there has been relatively little theory on the true nature of the difference, i.e., on the nature of the *past x present* product of Weiskrantz. In a journal for which the subject should be extremely relevant (*Consciousness and Cognition*), Light and Kennison (1996) and McKoon and Ratliff (1996) focused narrowly on identifying implicit versus explicit influences upon memory performance on a task requiring forced choice identification of words, while Bower (1996) argued that amnesics have a selective deficit in forming novel associations to contexts. In this, he neglected both the problem of retrograde amnesia (loss of memory for events which were experienced *before* any injury) and the reason why association+context is consciously experienced as an event in one's past, i.e., why association+context is still not just implicit memory? These were the first and last approaches near the subject of the explicit in this particular journal. Dienes and Perner (1999) attempted a detailed philosophical analysis of the distinction, but their primary objective was, "to create a common terminology for systematically relating the somewhat different uses of the implicit-explicit distinction in different research areas," and they stayed within this scope. In general, the explicit is associated with consciousness, the implicit is not. Little is discussed beyond this, with emphasis generally on conditions or variables inducing or affecting implicit memory performance (for example, Kihlstrom, Dorfman and Park, 2007). In general, it seems to be the view that loss of explicit memory is the result of damage to an explicit memory "system," generally considered to involve the pre-frontal, cortical areas and medial-temporal lobes, but just why its proper functioning yields a *conscious* remembrance is vague. The critical difficulty, for consciousness, is why – even in a fully functional "explicit memory system" in which all retrieval mechanisms are fully operative, be they be connectionist neural nets with their firing patterns, or the operations of cognitive symbolic programs – should these operations result in a consciously experienced remembrance as opposed to yet another "implicit" operation. This is the question: Just what is required for a past event to be consciously experienced as an event localized in one's past? What must such a system actually involve?

The question is extremely difficult. Perhaps this is why it has scarcely been addressed at all. It rests firstly on the unsolved hard problem, and goes beyond it. Before me, on the patio, are wind chimes waving and tinkling in the wind. As I look on them, I am reminded of a past event wherein I gave other such chimes to my wife. In this simple case reside all the problems. We do not know how the wind chimes are even perceived, that is, how they are seen in volume, in depth, externally, in space, as an image of the external world with all its inherent qualia. Because we have no theory of conscious perception, which is to say, of *experience*, our theory of memory is ungrounded – we do not truly know how experience is stored or just what is being stored. Therefore we cannot truly know how it is retrieved. Inherent in the wind chimes are their waving motions, therefore the perceived event has an ongoing time-extension. Current cognitive science does not have a theory of the memory that supports this elementary or primary time-extension in perception (cf. Robbins, 2004a, 2007), further adding to the first problem of what is actually being stored. Now we add the dimension of explicit memory. The past event of viewing the just-given wind chimes is retrieved as an *image* – a phenomenon (the image), the origin of which, as Pylyshyn (2002) argues well, there is no theory. Finally, and most difficult, the present event (the wind chimes) now functions within what I shall term an *articulated simultaneity*, for it serves both as itself and as a symbol of a past event, assuming both one meaning and another, yet within a global, temporal whole or state of consciousness. Explicit memory, then, is bound to the development of the symbolic – the ability to employ a form (the wind chimes) abstracted from our experience to represent another aspect of experience (the event of the gift) – what Cassirer would term the "symbolic function." The symbolic function, we shall see, carries this aspect of an articulated simultaneity – this "oscillation" between two elements within a temporal whole. This tells us that the symbolic itself is a problem in the relation of mind to time.

The first portion of this litany of problems underlying the explicit – the origin of the image of the external world and the primary memory underlying its time-extent, be it the image of rotating cubes, stirring spoons in coffee cups or singing violins – has been argued, in the context of our perception of dynamic forms, to be bound to our model of time (Robbins, 2004a, 2007). So too is explicit memory with the articulated simultaneity it requires. The problem is similar to the perceptual case of perceiving rotating cubes or twisting leaves, for the explicit memory state – comparing (or creating a product of) past and present – is inherently time-extended. The classical model of space-time, however, is differentiable. The essence of differentiation is to divide, whether it be the slope of a triangle or a motion from A to B, into ever smaller units, ultimately taking a "limit" of this infinite operation. Thus, classical time consists of a series of instants, where each instant can be further divided, ad infinitum. This "time," as Bergson (1896/1912) argued, is reality only an abstract space, a space which is in effect but a "principle of infinite divisibility." The just previous instant of this divisible "time" is "past," and therefore, by definition, no longer existent. It must be stored in some "memory" to preserve it. Inherent in this model is the difficulty of explaining a time-extended continuity necessary for consciousness, to include both perception and explicit memory. By infinite divisibility, the actual extent of an instant is reduced to an abstract, infinitesimally small, mathematical point. At such a point, there is no time. We cannot then invoke "time-extended neural states" for no such inherent time-extent is assignable in the classical model to the neural, material processing beyond that of this infinitely divisible, minute "instant." The state-to-state processing models of the computer paradigm, bound to the classical model of time, are bound to this time-lessness, while robotic models which now claim to support consciousness (for example, Chrisley and Parthmore, 2007; Kiverstein, 2007) are equally subject to the problem (while generally ignoring the problem of the explicit).

Three Theoretical Goals

The subject of explicit memory, then, is far from an unimportant theoretical endeavor. It is at least the start of such a theory I would like to sketch. There are three major things I would like to develop. The first develops the true complexity of this *past x present* "product." It is in general underestimated, if discussed at all. The ability does not develop overnight. The literature of childhood amnesia sees the child requiring at minimum two years to achieve explicit memory. But this literature, we shall see, rather underestimates, in fact vacillates on, what is involved.

Thus, in the last decade and more, there has been an extensive effort to show that children evidence “access consciousness” (Block, 1995) considerably earlier than this two year figure. Access consciousness, in its definition as “the ability to use previously stored representations to direct thought” is certainly subsumed in the developing ability to establish the *past x present* product. Rakison (2007), in his recent review of these attempts, has shown that in every case, this (earlier development) thesis can be rejected. The two year figure holds; the dynamic trajectory is developing a complex ability, it requires a certain time to unfold. The robotics theorist should be asking why so long a trajectory? and what is being accomplished? Here, we will view this product as the end result of the developmental trajectory Piaget described which supports a simultaneous and interrelated group of concepts – causality, object, space and time. Simultaneously and integrally with this, the ability to symbolize emerges. Therefore we will be re-examining Piaget.

The second subject (though treated last) sketches the framework in which this symbolic function must be embedded to support explicit memory. As alluded to above, it must be a framework which carries a solution to the hard problem. The one framework that accomplishes this, I have argued in detail (Robbins, 2000, 2002, 2004a, 2004b, 2006a, 2006b, 2007), rests in Bergson’s theory (*Matter and Memory*, 1896/1912). In this, there are three major components. Firstly, Bergson’s concept of time views the time-evolution of the matter-field as indivisible or non-differentiable (Nottale, 1996, following Feynmann and Hibbs, 1965), as opposed to the classical model of time (or space-time). This conception of time yields the “primary memory” supporting the time-extended perceptions of “rotating” cubes, “twisting” leaves or “buzzing” flies. It is this conception also that yields the time-extension necessary for explicit memory with its articulated simultaneity. Secondly, a significant aspect of Bergson’s model is that the external image of an ongoing event, e.g., the wind chimes, and therefore experience itself, is not occurring solely within the brain. As such, experience cannot be exclusively stored within the brain. This does not preclude a form of memory which is clearly brain based such as the procedural, or that consonant with neural net modifications, i.e., the implicit, but experience itself cannot be solely brain based. Indeed, Bergson's model, extended with J. J. Gibson's, provides a redintegrative mechanism for the retrieval of experience that does not rely on storage of experience in the brain. Yet the very phenomenon of explicit memory – the apparent loss of past experiences due to brain trauma – has historically been associated with proof of just this – that indeed experience is stored in the brain. To Bergson, this was *the* pivotal question for the theory of consciousness: If experience must be stored in the brain, then theories of consciousness are absolutely constrained by this fact – the perceptual image of the external world would necessarily be *generated* from short-term stored "elements" within the brain, while for memory images of previous experience, generated via long-term stored elements. Searle's (2000) principle of "neurobiological sufficiency" would be a fact. But if experience is not stored in the brain, indeed cannot be, our theory of consciousness is opened to new considerations. This crucial question, though scarcely discussed or emphasized today, has not gone away. The constraint applied to the theory of consciousness by the first and currently standard answer (storage-in-the-brain) thoroughly exists today. The subject of explicit memory, then, is pivotal. I will be taking the opportunity to show here that nowhere in the dynamic mechanism underlying explicit memory is there a need to interpret the loss of explicit memory as due to the destruction of experience stored in the brain.

Wherever I speak of a "dynamic mechanism" underlying explicit memory, I am intending a very concrete meaning of "dynamic." This concrete dynamics is the third, implicit component of Bergson's framework, required for the explicit. What Bergson envisioned in 1896, stated in modern terms, is a model wherein the brain assumes the role of a reconstructive wave passing through the external field of matter, where this field is taken as a holographic field. The brain is not simply a "hologram," rather it forms, globally, a reconstructive wave passing through the hologram, specifying, in perception, a virtual image of a *past* time-extent of the non-differentiable motion of the field (e.g., the motion of the wind chimes) at a specific scale of time. The image is precisely where it says it is – within the external field. This is why experience is not solely occurring in the brain, nor solely stored there, for experience is not something that can simply be re-generated by replaying some neural pattern. Both terms – brain (reconstructive wave) and external field – are equally required. But the same reconstructive wave, passing through the holographic field, can serve simultaneously as a redintegrative mechanism for past experience. Loss of the ability to retrieve experience is due, not to damage to memories stored in the brain, but rather damage to the brain's ability to assume the complex modulated waveforms (dynamics) required either for redintegration itself or for supporting the global state of explicit remembering.

Though it is certainly not unprecedented to view the brain as supporting a wave (e.g., Yasue, Jibu & Pribram, 1991), at present, this is a conjecture, but this short sketch should not be confused with the matrix of reasons developed elsewhere supporting this, perhaps the best being Robbins (2006a, 2006b), with Robbins (2007) being the most directly aimed at the hard problem and the problem of qualia. In essence, this conception sees the neural flows, the oscillations and the resonant feedback that hitherto have been construed to be supporting only abstract computations, as comprising, rather, a device as concretely dynamical as an AC motor. The AC motor's purpose is to create an electric field of force. The purpose of the brain is to establish a very concretely embodied, modulated waveform, while simultaneously supporting a form of computing fully consonant with a broader definition of computation found also in Turing (c.f. Copeland, 2000; Robbins, 2002). Abstract computationalism, in and of itself, is not a sufficient framework to support a theory of consciousness.

Such a dynamic system can also be described by the phase-state language of dynamic systems theory, but the mathematics, be it differential equations or group theory, can only be a description of the physical device – it is the actual physics that must be modeled. Mathematics is not the AC motor. Such a system's development, growth or complexification over time – even unto the complex, concrete, time-extended wave patterns developmentally achieved by the child which support the capability of explicit memory – can also be described by dynamic systems theory as the bifurcations of a dynamic "trajectory," but again, this description does not absolve us of the physics. Neither does it relieve us of the fact that non-differentiable means just that – non-differentiable. The “continuity” of the differential equations describing other, more dynamic neural networks (for example, Grossberg, 1995), while our best formal description, is the continuity of classical space-time, it is not the concrete flow of indivisible time, while all the discrete brain states one desires cannot represent a non-dfferentiable flow or motion. As I have developed in detail (Robbins, 2007), it is the failure to grasp the import of Bergson’s indivisible or non-differentiable motion of time that is at the core of the hard problem.

All this necessitates the third major point, namely, how this interpretation of the basis for explicit memory relates to current theories of amnesia, particularly connectionist, and the possible role of the hippocampus, the role of consolidation, etc. By “amnesia” here, I intend to refer specifically to Amnestic Syndrome, as opposed to other patterns of memory disorder, for example Mild Cognitive Impairment. I will try to make at least a *prima facie* case that as far as requiring storage of experience in the brain, current models are not at all compelling, and further, that current research on amnesia equally does not compel us to the conclusion that experience is stored in the brain and is, rather, commensurate with a position seeing amnesia as the result of damage to mechanisms underlying a symbolic function.

A word on some necessary limits in the ensuing discussion is needed. First, this will be a sketch confined within the once-traditional “rules of the game” in cognitive science, in that it will not be addressing the emotional dimension of past events and its relation to retrieval. Though the emotional charge of events is clearly important, the redintegrative mechanism I will be assuming has enough explanatory power, *ceteris paribus*, to (temporarily) neglect this dimension. Secondly, I will not be addressing the role of imitation, pretense, play or language in the developmental story we will follow in Piaget. The appeal to imitation, pretending and play as part of developing a “sense of self” is common in the developmental literature in explaining the escape from childhood amnesia into the explicit, but it entirely misses the point of the truly critical development of causality, object, (classical or constructed) space and time underlying both cognition and this very sense of self as an "object" in a field of causal forces among other objects. Language will be neglected precisely because, as we shall see, it is not language that underlies the birth of the explicit, rather, it is the general ability underlying language itself, and this is COST and the symbolic function. Though it is a somewhat common conception that it is language that gives rise to access consciousness (e.g., Rakison, 2007), and by implication explicit consciousness of a past event, the developmental trajectory supporting the explicit about to be reviewed nowhere relies on language; it is language that relies on COST.

Explicit Memory in Piaget

Let us begin at a more advanced point on the developmental trajectory, a point which illustrates what can be termed the *dynamical lens on events* inherent in Piaget's view. Piaget (1968) describes a simple memory experiment with children aged 3 to 8. They are shown a configuration of ten small sticks (Figure 1 [A]). They are asked to have a good look so they can draw it again later. A week later, without having seen the configuration again, they are asked to draw what they were shown before. Six months later they are asked to do the same thing.

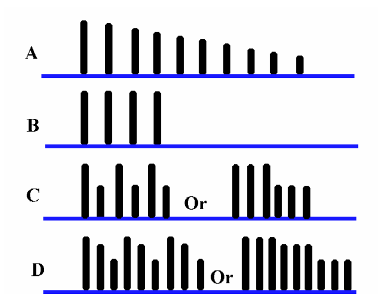

Figure 1. Stick Series

In the one week interval case, the reconstruction of the event is dependent, in Piaget's terms, on the operational schemata to which the child assimilated the event. The memory is dependent, in other words, on the child's current ability to coordinate actions. At around 3-4, the series is reproduced as in Figure 1[B]. Slightly older children (4-5) remember the form in Figure 1[C]. Figure 1[D] is a slightly more advanced reproduction, while at 6-7, the child remembers the original series. After six months, as Piaget describes, children of each age group claimed they remembered very well what they had seen, yet the drawing was changing. The changes generally, with rare exceptions, moved in small jumps, e.g., from A to C, or from C to D, or from D to A.

The drawing of a series – the process of seriation – requires concrete operations. To order a simple series, A, B, C (where A is longer than B, B longer than C), one must simultaneously relate or coordinate the height of B relative to A, the height of B relative to C. This is fundamentally based on the inter-coordination of action. As the child follows this developmental trajectory, Piaget argues, the available dynamics supports successively different "de-codings" of the memory, i.e., the events are reconstructed with an increasingly sophisticated logical structure. The past event is seen through this dynamical lens. But simultaneously then, when the series is a perceived event, it is being perceived through this same dynamical lens. The events gain increasingly complex *symbolic* structure.

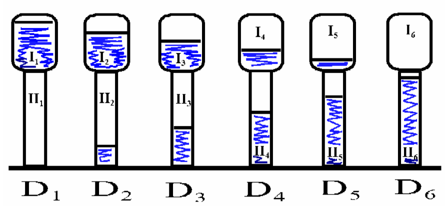

Figure 2. Two flows at different velocities. In a series of stages, the water is gradually emptied from the top beaker (I), while the lower beaker (II) gradually fills.

This is but one of a large number of such examples of events treated by Piaget where we see this developing dynamical lens, and the need for a *simultaneous* relation of magnitudes. In another, more dynamic event (*The Child's Conception of Time*, 1927/1969), the experimental apparatus consists simply of two differently shaped flasks, one placed atop the other, with a tap or valve between the two (Figure 2). The top flask is initially filled with liquid. The child (age 5-9) is provided with a set of drawings of the two flasks (with no liquid levels filled in). At regular intervals or stages a fixed quantity of liquid is allowed to run from the top flask into bottom until the top is empty. Because the flasks are differently shaped, the one empties at a different velocity than that at which the other fills. At each stage, starting at the beginning, the child is asked, using a fresh drawing, to draw a line on each flask indicating the level of the liquid.

The drawings are now shuffled and questions ensue:

1) The child is asked to reconstruct the series, putting the first drawing made down, the next to the right, and so on.
2) Every sheet is now cut in half and the drawings shuffled. The child is again asked to put them in order.

The children again go through stages. At first they cannot order the uncut drawings (the D's of Figure 2). Then they achieve this (uncut) ordering but fail ordering the cut drawings. The child may come up with an arrangement of the cut drawings such as I_3, I_1, I_2, I_5, I_6 above II_1, II_5, II_6, II_3, II_2. Even with coaching, he cannot achieve a correct order. Beneath these failures lies a certain mental rigidity. The child is required here to move mentally against the irreversible, experiential flow of time. Regardless of the irreversible flow of the water, they must perform a reversible operation. They must construct a series A -> B -> C… where the arrows carry a *dual or simultaneous meaning* standing for "precedes" as well as "follows." *It is a pure problem of representation*. The child must also grasp the causal connections within and between the two flows. Ultimately, the children will surely and securely order this double series with its causal link as the operating principle. The operations involved in this coordination of two motions, participating in the logic of objects we call causality, underlie our "schema" of time. This schema, supporting our memory operations, our retrieval of events, is again a lens upon our experience. It is a cognitive capability that develops over several years, based on the coordination of actions, first sensori-motor, then mental – and something that must be subject to disruption via a traumatic injury or disease.

I have alluded to the fact that over this developmental trajectory, events become increasingly symbolic. The nature of the symbolic is key to explicit memory. Within Piaget is a theory of the symbolic, and somewhat buried there as well, a vision of the development of explicit memory in the child. The "explicit" in Piaget goes by his phrase, "the localization of events in time," and we will be asking if Piaget is describing the growth trajectory of a cognitive structure, even before the latter point of this trajectory we have just been viewing involving the advent of "operations," that supports this "localization."

The Stage Growth of the Explicit

Perhaps some are wondering why I am focusing on this particular subject, namely, Piaget. To a certain extent, it is fair to say that he has been written off by cognitive science. Gopnik (1996), in a piece entitled "The Post-Piaget Era," expressed an apparently common view that Piaget's theories are increasingly implausible, and explored the various contenders for alternatives, to include the information processing approach. Yet in the same year, Lourenco and Machado (1996) published a strong defense of Piagetian theory, arguing that its critics had approached the theory "from without, rather than from within," or to be more straightforward, that there was insufficient grasp of the theory and its implications, and that elementary mistakes in interpretation were being made.

Piaget is, in vast proportion, phenomenology. There is not a great deal of mechanism underlying his theory, mainly his insistence on the importance of action (assimilation, accommodation), and the growth and ability of inter-coordinated actions to support mathematical group relations. It is a search for a "*law of evolution*," and as Piaget notes, "It is only in relation to such a law of evolution that an attempt at differential analysis of behavior patterns acquires some meaning" (1954, p. 381). This apparent reliance on phenomenology would generate criticism (Brainerd, 1978) that the theory is merely a redescription of manifest behavior with no explanatory value. Yet all this is being superseded by the awareness that in his “stages,” Piaget is describing the necessary result of the evolution of a system characterized by non-linear dynamics with its natural bifurcations (cf. van der Maas & Molenaar, 1992; Raijmakers, van

Koten, & Molenaar, 1996; Molenaar & Raijamkers, 2000). We are looking at the natural result of a self-organizing system.

To the phenomenologist, on the other hand, assimilating what might appear Piaget's radical cognitivism seems contradictory. Yet Piaget's emphasis on the group relations underlying cognition was preceded by Cassirer (1944) – the underlying structure of the cognitive life is a legitimate aspect of the phenomenological. But a yet more important point of this assimilation rests in a stance which must be left implicit here, but has been developed elsewhere (Robbins, 2002, 2006b), namely that the very "device" required to support Piaget's vision of cognition is neither the neural network nor the symbolic manipulation computer metaphor, bur rather the Bergson/Gibson model.

We are going to review Piaget's stages. I apologize if for some it is the nth time, but I must presume that not many have perused Piaget for his implicit theory of explicit memory.

The First Two Stages (0-4 months)

In the first two stages identified by Piaget, everything, he argues, takes place as though time were completely reduced to impressions of expectation, desire, success or failure. The world virtually emanates from one's actions. "Objects" do not yet exist. There is the beginning of *sequence* linked with the development of different phases of the same act. But each sequence is a whole isolated from the others. *Nothing yet enables the subject to reconstruct his own history*, and to consider these acts succeeding one another. Each sequence consists in a gliding from the preliminary phase of desire or effort, experienced as a present without a past. Finally, he argues, "this completely psychological *duration*, is not accompanied by a seriation of events external and independent of the self – since no boundary yet exists" (1954, p. 393, emphasis added).

He comments then:

> The only form of memory evidenced by the behavior patterns of the first two stages is the *memory of recognition* in contradistinction to the *memory of localization* or evocation. …it is not proved that recognition transcends a global

> sensation of the familiar which does not entail any clear differentiation between past and present but only the qualitative extension of the past into the present (1954, p. 369, emphasis added).

This latter comment on recognition – the "qualitative extension" – I would presume, derives from Piaget's mentor of sorts, Bergson (1896/1912), who saw recognition as the familiarity produced by an "automatic motor accompaniment" (as when we walk up our own driveway for the nth time). The "duration" in which the child dwells also is an invocation of Bergson's "duration" – the qualitative, non-differentiable flow of time which cannot be defined as a series of "instants."

Stage 3 (5-7 months)

Piaget describes in the next stages how actions lead to *localization in time*. Thus he describes Laurent (at 8 months):

> Laurent sees his mother enter the room and watches her until she seats herself behind him. Then he resumes playing but turns around several times in succession to look at her again. However there is no sound or noise to remind him of her presence. Hence this is the beginning of object formation analogous to what we have cited in connection with the third stage of objectification. This process is on a par with a beginning of memory or localization in time. (1954, p. 375)

Piaget sees here an elementary concept of before and after. But Laurent's turning around is not yet "evocation," for it is by virtue of the movement of turning around in order to see that the child forms his nascent memory. But however "motor" and however little representative, it is the beginning of localization.

But is there an orderly arrangement of memories relating to external events? The child yet fails to note anything regarding the sequential positions of objects – the object has no spatial permanence.

> Laurent immediately, after the behavior pattern [noted above] reveals an action which clarifies its meaning. His mother having risen and left the room, Laurent watches her until she reaches the door, then, as soon as she disappears, again looks for her behind him in the place where she was at first! (1954, p. 377)

Laurent's mother is not yet a permanent object, moving from place to place, but rather a memory image capable of reappearing precisely where it was previously perceived. The order is a function only of Laurent's action, as though, using Piaget's example, having laid my watch on the desk, then covered it with a manuscript, and now having forgotten these displacements of my watch, I look for it again in my pocket where I always reach for it. In essence, the child perceives the order of phenomena/events only when he himself has been the cause. *A universe without causality externalized in things cannot comprise a temporal series other than those relating to acts of the subject*.

Stage 4 (8-11 months)

In this stage, the before-after relation begins to be applied to the object, not just actions. The object disappears behind a screen, but while perceiving the screen, the child retains the image of the object and acts accordingly. The child is now recalling events, not merely actions. But this is extremely unstable. The object is hidden originally at A, and found by the child at A (e.g., under a pillow). The object is then moved in full view to B, and hidden, under another pillow (B). The child goes to B, but if the object is not found immediately, goes back to A, where the *action* was originally successful. The child's memory is now such that he can reconstruct short (but only short) sequences of events independent of the self.

The searching phenomenon described above is commonly termed the *A-not-B* error in the developmental literature, and has been the subject of extensive research (see reviews for example by Markovitch & Zelazo, 1999; Munakata, 1998), including the development of dynamical mechanisms to explain it (Thelen et al., 2001). In my opinion, the dynamic systems models fall well short, partially for the reason that A-not-B cannot be isolated from the whole developmental complex – here being (only minimally) described – of which it is a part. We will touch on this debate after discussing the next stage.

Stage 5 (12-18 months)

In this stage:

> Time definitely transcends the *duration* inherent in personal activity, to be applied to *things* themselves and to form the continuous systematic link which unites the events of the external world to one another. (1954, p. 385, emphasis added)

There is now systematic search for the vanished object, taking into account multiple displacements. An object hidden in A, found in A, hidden now in B, is no longer looked for in A (the former source of practical, action-issued success), but directly in B (though only for visible displacements). For the first time, the child seems capable of elaborating an "objective series."

Causality too is becoming "objectified." Such causality, on permanent objects, in an ordered space, entails the order of events in time. Jacqueline is watching a toy comprised of a revolving ball with chickens. The slightest movement of the ball puts the chickens in a pecking motion.

> Jacqueline, after examining for a moment the toy which I put into action by displacing it gently, first touches the ball and notes the concomitant movement of the chickens. She then systematically moves the ball as she watches the chickens. Thus convinced of the existence of a relationship which she does not understand in detail, she pushes the ball very delicately with her right index finger each time the swinging stops completely… She definitely conceives the activity of the ball as causing that of the chickens… Moreover the ball is not, to her, a mere extension of her manual action. (p. 310).

The self has now become an object among other objects, just one source of force among other forces:

> Jacqueline, instead of pushing the object, or even giving it a shake by a simple touch, makes every effort to put it [a toy] down as rapidly as possible and let go of it immediately, as though her intervention would impede the toy's spontaneous movements instead of aiding them! After several fruitless attempts she changes method… finally she places it on a sloping cushion and lets it roll. (1954, p. 309)

Or:

> Jacqueline places a red ball on the floor and waits for it to roll. Only after five or six attempts does she push it slightly. The ball, like the plush toy, has therefore become an autonomous center of forces, causality thus being detached from the action of pushing to be transferred onto the object itself. (1954, p. 309)

Objects are seen in causal relation to other objects:

> Jacqueline touches with her stick a plush cat placed on the floor, but does not know how to pull it to her. The spatial and optical contact between the object and the stick seem to her sufficient to displace the object. Causality is therefore spatialized but without yet making allowance for the mechanical and physical laws that experience will reveal (need for pressure of the stick in certain directions, etc., resistance of the moving object, etc.). Finally (two months later) she uses the stick correctly. (p. 321)

The sticks, the strings used to make objects move, etc., are no longer only symbols of personal activity, but objects inserted into the web of events, therefore into conditions of time and place. Laurent, trying to reach an object, revolves a box serving as its support. The concepts "before/after" are no longer limited to her acts, but are applied to the phenomena – to their displacements, perceived and remembered.

Finally, the symbolic is itself emerging, where the symbol is at the level of action. Piaget is playing with his 16 month old daughter Lucienne, and has hidden an attractive watch chain inside a matchbox, reducing the opening to a very small slit. Lucienne tries to open it with two "schemas" or plans for action she already possesses, turning the box over to empty it and then attempting to slide her finger in the slit and extract the coveted item. Both fail.

> She looks at the slit with great attention; then, several times in succession she opens and shuts her mouth, at first slightly, and then wider and wider...But due to the inability to think out the situation in words or clear visual images, she uses a simple motor indication as "signifier" or symbol...Soon after this phase of plastic reflection, Lucienne unhesitatingly puts her finger into the slit... pulls to enlarge the opening. (Piaget, 1952)

Having arrived at this point in the advent of the symbol, let us return briefly to the A-not-B error. Thelen et al. (2001) attempt to treat this by modeling the decision as a dynamic field which evolves continuously under the influence of the specifications of the task environment, the specific cue to reach A or B (which must be remembered), and after the first reach, the memory dynamics which bias the field (almost as though biasing the release of a mass-spring) on a subsequent reach. The field represents the relative activation states of the parameters appropriate to planning and executing a reach in a specific direction to the right (A) or left (B). But consider the reflections of the authors in trying to account for the reasons for change of, and the origins of, the critical parameter (*h*, or cooperativity) values in their model that determine a reach to A or to B:

> They learn to shape their hands in anticipation of objects to be reached and then to differentiate the fingers to pick up small items…They start to incorporate manual actions with locomotion such as crawling and walking. And they begin to have highly differentiated manual activities with objects of different properties, such as squeezing soft toys and banging noisy ones. It is a time of *active exploration of the properties of objects by acting on them* and of active exploration of space by moving through it. (p.31, emphasis added)

This is exactly what we viewed Jacqueline, Lucienne and Laurent doing, but the above description simply strips out the embedding in the larger dynamic trajectory Piaget is trying systematically to describe. It is, yes, but a weak "redescription" of Piaget. The simple activities Thelen et al. note, when viewed as we have above from a larger perspective, are part of the emergence of causality, of sequence in time, of the self as object among other objects, of the body as a force among other forces, i.e., an emerging complex of base concepts. .

Despite this weakness, Thelen et al. proposed that this general dynamical model will ultimately apply to *all* Piagetian tasks. This would include the stick seriation task and the ordering of two liquid flows discussed above, and many others equally and more complex. This is a severe undervaluing of the problem of representation, i.e., of explicit, conscious thought. Given the task of predicting the order in which three colored beads on a wire (call them ABC) will emerge after entering a little tunnel and the tunnel is given n 180 degree rotations, the dynamic trajectory the children follow requires years to represent these beads/tunnel rotations as images, images which grow increasingly schematic, i.e., "operational," until the odd-even "rule" (invariance) securely emerges (Piaget, 1946, cf. Robbins, 2002, 2006b). The children in fact come to a stage where they can predict three or four semi-rotations, but literally exhaust themselves trying to represent (imagine) the results of additional semi-turns, failing then on the general rule. Piaget's theory of operational thought is above all a theory of explicit thought, where images become increasingly schematic symbols of potential actions. The basis of it begins in the dynamic supporting explicit memory.

Stage 6 (19+ months)

The child can now handle even invisible displacements. The elaboration of the temporal field requires the development of images, i.e., representations. This is why the earlier series are so short! These operations are nothing other than evocative memory.

> … such representative series relating to external events encompass at the outset the memory of personal activity, no longer the purely practical memory of

> the primitive series, but an evocation properly so called, *making it possible to locate in time the actions of the self amidst the other events*. (1954, p. 392, emphasis added)

Infantile Amnesia, the COST of Explicit Memory, and the Symbolic

If we sum up what is being said about the development of explicit memory, it might be said simply: there is no full explicit memory without at least some COST. Here COST stands for Causality, Object, Space, and Time. Together these concepts form an interrelated, supporting group, and together they grow from inter-coordination of actions. As Piaget describes it from the perspective of the development of one of these, namely from the concept of the *object*, from a mere extension of the child's activity, the object is gradually dissociated from activity. Resistance initiates this dissociation, e.g., obstacles or complications of the field of action as in the appearance of a screen obscuring the favorite toy (1954, p. 103). Action gradually becomes a factor among other factors, and the child comes to treat his own movements on a par with those of other bodies.

> To the extent that *things* are detached from *actions* and that action is placed among the totality of the series of surrounding events, the subject has the power to construct a system of relations to understand these series and to understand himself in relation to them…To organize such series is to form simultaneously a spatio-temporal network and a system consisting of substances and of relations of cause and effect…Hence the construction of the object is inseparable from that of space, time and causality. (1954, p. 103)

The emergence of COST, Piaget argues, is the event that supports true explicit memory. This occurs gradually, emerging in Piaget's sixth stage, at 18-24 months.

The current literature on infantile amnesia, from what I can see, is unaware of this or unimpressed. Howe (2000), in an excellent book reviewing the subject, contains *one* small reference to Piaget. Infantile "amnesia" is the curious phenomenon wherein adults have little ability to recall experiences that occurred before the age of two or three years. Howe & Courage (1993) rejected explanations that relied on retrieval failures (e.g., repression, mismatches between initial encoding and later retrieval contexts) or storage failures (perceptual or neurological immaturity, inadequate "encoding"). To account for this discontinuity, and the sudden growth of memories past the age of two, they evoke the emergence of the "cognitive self" around this age. Taking a page from connectionist theory, they argue that once the self develops its "features" (as though the self is a “vector” of features), these features can be incorporated into the memory “trace” along with features of the (external) event in which the child is participating. As more features of the self are accumulated, the more the probability of sampling a set of these features and including them in the memory "trace."

Howe and Courage are perhaps not so committed to the "feature" theory as they are to the general proposition that autobiographical memories can be accounted for by general properties of contemporary memory models, where the self takes its place "as a system of knowledge that organizes memories like any other knowledge structure" (1993, p. 513). The "features" of this self are not at all articulated, but noted are the interpersonal self, the ecological self (fundamentally the infant's response to Gibson's invariants), and the conceptual self. The conceptual self "enables infants to take themselves as *objects* of thought" (p. 507). Here parent-child interactions are discussed, fostering the child's awareness of himself as an object of attention. Piaget's perceptive theory of causality, object, space and time, and the dynamic developmental trajectory implied, which truly provides an analysis of the development necessary to support this "self as an object of thought," i.e., the very meaning of this phrase, is unmentioned.

Let us take perspective. The brain is initially presented an undifferentiated external field (environment). The field is an extensity (not abstract or constructed space, i.e., not a continuum of “positions”), a non-differentiable flow or duration (not abstract time, i.e., an abstract series of “instants”), qualitative (not quantity), a subjective event field (without external "causes"). From this the brain must carve its invariance laws – its "object language" (cf. Robbins, 2002. 2006b, 2007). Invariants are isolated by transformations upon this field, and the transformations are naturally effected through actions. It is actions that drive the developmental dynamics, and this dynamics drives towards a base set of constructs. The base set of fundamental constructs of object, causality, (classical) space and time in which the self takes it place as an object among others, is foundational to the entire structure of thought, which is to say, this set lies at the core of *representation*. Explicit memory, in its developed form, is at its heart a problem of representation.

Simultaneously, then, this dynamical trajectory is driving towards liberation from perception, a going beyond the present as Piaget insists (1954, p. 390), towards *representation by an image*, emerging only at the sixth stage.

> That is why the temporal series just described are revealed as so short and so dependent on the constructions characteristic of object, space, and causality; it is why, *for lack of representations properly so called*, the time developed by the series necessarily remained linked with present perceptions, with practical memories derived from recent action, and anticipations in accord with action in progress. (1954, p. 391, emphasis added.)

The "objective series," where the permanence and displacements of objects are gradually embodied in practical action, are now extended as the representative series. It is the same operations, now performed on the mental, the representative level. To Piaget, this is nothing other than *evocative* memory, but equally, this evocative memory is not a special faculty, but only mental or "reproductive assimilation" (i.e., a relation of object-images to actions), to the extent that it constructs mentally, not in the physical world, a more extensive past. And indeed, this reproductive ability had to be present from the beginning; it is the fundamental basis of explicit memory; it is the ability of the brain to redintegrate a past experience. *There is no necessary implication here at all that the events of an infant's or young child's past are lost, or never stored.*

The resultant of this dynamical development towards COST that Piaget is trying to describe is a *representative* form, the ability to treat these events as *symbols* within a localized past.

> Jacqueline (19 months) picks up a blade of grass which she puts in a pail as if it were one of the grasshoppers a little cousin brought her a few days before. She says "Totelle [sauterelle, or grasshopper] totelle, jump, boy [her cousin]." In other words, perception of an object which *reminds her symbolically* of a grasshopper enables her to evoke past events and reconstruct them in sequence. (1952, p. 391, emphasis added)

The developed explicit memory, the symbolic function and COST are all inter-related, mutually supportive. The infant brain can create neural patterns redintegrating past events until the cows come home, but until these past events can become symbolic, until they take their place within a conceptual past, they are little more than present phantoms.

The Simultaneity of the Symbolic State - Cassirer

I wish to underline the critical aspect of this symbolic representation, namely the articulated simultaneity noted in my introductory comments. It is not only the events of the past that become symbolic. For Cassirer (1929/1957) it is the events of perception as well. The pathologies, he thought, indicate that, "the contents of certain sensory spheres seem somehow to lose their power of functioning as pure means of representation…"(p. 236). Some aphasics cannot make a simple sketch of their room, marking in it the positions of objects. Many patients can orient themselves on a sketch if the basic schema is already laid down, e.g., the doctor prepares the sketch and indicates by an X where the patient is. But the truly difficult operation is the spontaneous choice of a plane as well as a center of coordinates. Thus, one of Head's (1926) patients would express his problem as the "starting point, but once it was given him everything was much easier."

The same principle operates in the aphasic's dealing with number and time. One patient could recite the days of the week or the months of the year, but given an arbitrary day or month, could not state what came before or after. Though he could recite the numbers in order, he could not count a quantity. Given a set of things to count, he could not progress in order, but frequently went back again. If he had arrived, for example, at "six," he had no comprehension that he had a designation for the quantity thus far achieved, i.e., a cardinal number. When asked which of two numbers are larger, say 12 or 25, many aphasics can do so only by counting through the whole series, determining that in this process the word 25 came after the word 12.

As Cassirer notes, "where quantity no longer stands before us as a sharply articulated multiplicity, it cannot be strictly apprehended as a unity, as a whole built up of parts" (p. 250). But to achieve this, exactly as in the seriated set of flows of Piaget, every number must carry a *dual* role. Thus to find the sum of 7 + 5, or the difference 7 - 5, the decisive factor is that the number 7, while retaining its position in the first series of 7, now is taken in a new meaning, becoming the starting point of a new series where it assumes the role of zero (Figure 3). Again, as in the representation of space, we have a free positing of a center of coordinates. "*The fundamental unities must be kept fixated, but precisely in this fixation be kept mobile, so that it remains possible to change from one to the other*" (p. 250, emphasis added). The number 7 must maintain its meaning as 7, yet *simultaneously* assume the meaning of zero. This is a pure problem of representation in time. More precisely, as I will discuss below, it is a problem of representation in an *extended* time supporting true simultaneity.

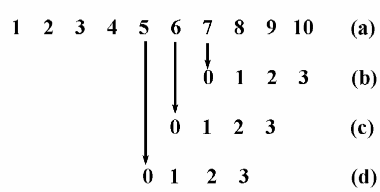

Figure 3. The problems: 7 + 3 = 10, 6 + 3 = 9, 5 + 3 = 8. The number 7 functions simultaneously as zero in (b), 6 functions as zero in (c), and 5 as zero in (d). (After Cassirer, 1929/1957)

This extends to the sphere of action, in the apraxias. One patient (Gelb and Goldstein, 1918) could knock on the door if the door was within reach, but the movement, though begun, was halted at once if he was asked to move one step away from the door. He could hammer a nail if, hammer in hand, he stood near the wall, but if the nail was taken away and he was asked to merely indicate the act, he was frozen. He could blow away a scrap of paper on the table, but if there was no paper, he could not blow. This is not the loss of memory images, as was once widely held. He just blew the paper, how could the image have been lost? It is not a failure to create a sensuous "optical space" as Gelb and Goldstein thought. He is staring at the door, and still cannot act. It is the inability to create an abstract, free space for these movements.

> For this latter is the product of the "productive imagination": it demands an ability *to interchange present and non-present,* the real and the possible. A normal individual can perform the movement of hammering a nail just as well into a merely imagined wall, because in free activity he can vary the elements sensuously given; by thought he can exchange the here and now with something else that is not present… [this] requires a schematic space. (1929/1957, p. 271, emphasis added).

This extends to analogy. Thus the psychic blindness patient of Gelb and Goldstein was utterly unable to comprehend linguistic analogy or metaphor. He made no use of either in his speech, in fact, rejected them entirely. He dealt only in realities. Asked by Cassirer, on a bright, sunny day, to repeat, "It is a bad, rainy weather day," he was unable to do so. Again, analogy requires precisely the same achievement of representation. To say, "The spoon is a catapult," (after using it to launch a pea) the spoon must be taken simultaneously in two different modes. One must place oneself simultaneously now in one, now in another meaning, yet maintain a vision of the whole. It is this "articulation of one and the same element of experience with different, equally possible relations, and *simultaneous* orientation in and by these relations, [that] is a basic operation essential to thinking in analogies as well as intelligent operation with numbers…"(1929/1957, p. 257). While computer models, it should be noted, have been advanced for this capacity of mind, not only have they been heavily critiqued for giving away the problem (cf. French, 1999; Robbins, 2002), this simultaneous articulation represents yet another dimension that must be supported.

It is this simultaneous articulation that supports little Jacqueline and her "grasshopper." Again, as Cassirer argued, there is an interchange of present and non-present, i.e., of present and past. The little piece of grass can now be a symbol; it can be simultaneously both a piece of grass – a *perceptual image* – and a "grasshopper" which once she saw hopping around. But now we find ourselves inevitably relating this to the problem of Weiskrantz and his "product" (present x past event). When H.M. looks at the mirror tracing apparatus, should it not be simultaneously both the present apparatus and the past apparatus upon which he once worked? Sitting on the porch, the wind chimes instantly become a "symbol," simultaneously both of themselves and the memory of buying other chimes for my wife for an anniversary. All such surrounding objects can become *symbolic* of the past. But now we see this apparently simple ability through the underlying complexity of the dynamic that must support it.

The physical organism spends several years and a great deal of effort following this “law of evolution” or developmental trajectory to produce this dynamical possibility. In the sphere of explicit memory, and in the spheres Cassirer discussed – sketching, analogy, numbers, time, voluntary actions – an essential feature of the underlying dynamic in each is the articulated simultaneity supporting the symbolic nature of these functions. This can apparently be disrupted in each. In the case of amnesia, I would argue, damage to the neural circuitry underlying the concrete dynamics required for explicit recall is effectively disrupting the ability to sustain the articulated simultaneity in time necessary for the present event to be simultaneously in a symbolic relation to the past.

In one of the cases above, Cassirer discussed ideomotor apraxia, often defined as “inability to carry out a motor command, e.g., act as if you are brushing your teeth.” It is a phenomenon for which lesions to the dorsal stream (the “how” system) are currently implicated, or perhaps the ventro-dorsal as Gallese (2007) recently argues. Gallese, in his review, argues that different and parallel parieto-premotor networks which receive visual information processed within one part of the dorsal stream create internal representations of actions, to include action preparation, action understanding, space and action conscious awareness. But again, the simple notion of an "information stream" (or its disruption) is insufficient to explain the specific problem Cassirer is discussing in relation to action, or for that matter, in the problems relating to sketching, analogy, number and time which all appear to share the same cause. We are asking how "the unities can be fixated, yet simultaneously be kept mobile," or how one and the same element can oscillate between one meaning and another, while comprising a whole. This bespeaks of a dynamic, in the very concrete sense I have indicated, which is intrinsically participating in the concrete, indivisible or non-differentiable motion of the matter-field in time.

The Phenomenon and Theories of Amnesia

If we see damage to the dynamics supporting a symbolic relationship as an underlying cause of amnesia, the implication is that this is a general deficit that should affect the memory of *all* events of our past experience. The gradient of retrograde amnesia (RA) should be flat. Given this, there are some major questions that must be answered if this view is to have any plausibility. There is first the widely accepted phenomenon of limited retrograde amnesia, where for example, memories of two years immediately previous to the damage are lost, but earlier memories are retained. This already stands as a selective effect to which a general deficit does not seem to apply. There is, secondly, the phenomenon of graded RA. In this case, if we measure decade by decade from the point of the trauma, there is an increase in the number of events remembered the further back in time we move. Again, we would ask why a general deficit has such a graded effect. And thirdly, we might ask if this view can be reconciled at all to current views on the cause of amnesia and concepts of the role of the hippocampus in this disability. This is especially critical relative to the somewhat dominant idea that loss of memory is a *storage* problem, and the aligned hypothesis that memories are being "consolidated" via some chemical process and that it is this process that has been disrupted in amnesia.

Retrograde Amnesia – Limited or Unlimited?

The existence of extensive graded (as opposed to limited) RA is well-supported. Brown (2002), in a review of an extensive number of studies, showed this conclusively. Figure 4 shows the performance on remembering both events and people taken across decades. Performance gets increasingly better for events as the decades from the point of trauma recede into the past. This is true, it should be noted, for semantic memories as well. It should also be noted that this same graded pattern exists for normal controls.

The curves confirm what is termed the “Ribot” effect, following a tenet of Ribot (1881), namely that in the dissolution of memory, the "new perishes before the old," advancing "from the stable to the unstable."

> It begins with the most recent recollections, which, lightly impressed upon the nervous elements, rarely repeated and consequently having no permanent associations, represent organization in its feeblest form. It ends with the sensorial, instinctive memory, which, becoming a permanent and integral part of the organism, represents organization in its most highly developed stage. (p. 131 ff.)

Something about memories appears to be “consolidated” over the years. Brown suggests that this be interpreted as “a progressive reduction in *fragility*.” As we shall discuss shortly, the standard version of this strengthening (until recently) has the experience ultimately stored in the areas of the cortex which were originally involved, with the hippocampus updating the cortical “sites” via a consolidation process over time. Just what this consolidation actually is has become an issue we shall discuss below. As a difficulty for the notion that it is destruction to these consolidated memories that is responsible for amnesia, cases are reported in which memories apparently return gradually in the reverse order of Ribot – oldest to finally youngest. Further, in an embarrassment to consolidation theory, the hippocampus appears to be driving this consolidation process for *years*, for all events ever experienced, with no limit.

The existence of temporally limited RA has become increasingly questioned. Warrington and Weiskrantz (1973) already suggested that the duration of RA may be underestimated, that memory deficits may extend throughout the amnesic's entire existence. Citing findings of Warrington and Sanders (1971) that remote memories in older subjects (70-79) were not selectively preserved, they argued for a unitary functional disorder which could account for both anterograde and retrograde effects. Based on his 1997 work, Weiskrantz yet holds to this position – any memory task that requires the *present x past* product is seen as being at risk.

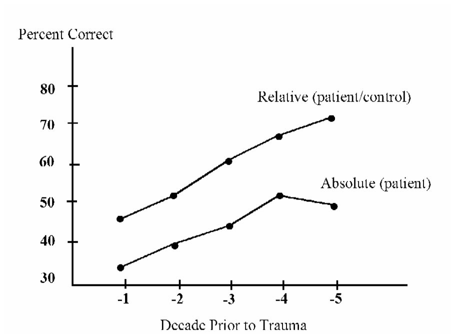

Figure 4. Patient's memory performance for decades. The "relative" line is a measure of amnesic performance adjusted relative to normal subject performance (since normal memory also improves as events recede into the past). (After Brown, 2002).

Nadel and Bohbot (2001) have voiced similar reservations. In the consolidation view, the hippocampus is only temporarily critical. If we wait a sufficient interval for consolidation to complete, then lesion the hippocampus, there should be no effect on the memory. This existence of graded RA, where the memory can be destroyed if the lesion is performed soon after the experience, but appears to remain if the lesion is done at a later period, has been taken as the strongest proof of this consolidation model. Nadel and Bohbot have argued that studies in fact show that degraded memory performance exists *at all points in time*. For example, consider Kubie et. al (1999). Their rats, after learning a spatial task, were given a long interval before a subsequent surgery which removed the hippocampus. The rats appeared to still perform well on the spatial task, making it appear that consolidation had been achieved, and the hippocampus was indeed no longer necessary, the cortex having taken over. But it was discovered that in fact these rats were performing quite differently. Instead of using an integrated or map-like representation of the environment, the rats without a hippocampus (a la Cassirer's observations of aphasics) fell back on a "vector-like" system that can support considerable spatial behavior, but lacks the flexibility of the hippocampus-supported spatial maps. This is a qualitatively different form of memory, and Nadel and Borbot argue that this form of cortex-embedded memory may take longer to form. In the human realm, Squire et al. (2000) reported for a patient with extensive medial temporal lobe damage that in retrieving autobiographical memories from early life, "neither the quantity or quality of his recollections can be distinguished from those of controls." Yet Rosenbaum et al. (2000), after examining K. C. (discussed by Tulving, 2001b), a patient with similar damage, showed that there were persisting deficits in some aspects of spatial and autobiographical memory.

Assuming the questionable existence of limited RA, and before examining the meaning of graded RA, let us turn to the theories of the hippocampal function.

Theories of the Hippocampus

Many theories recently have centered on the proposed role for the medial temporal lobe in memory – the hippocampus and associated structures. As a structure, the hippocampal area receives input from nearly all regions of the cerebral cortex, and then sends return loops back out to the original sending area. It is tempting to visualize this structure as a central station into which trains of "present" information flow, then to be directed into the great past-holding storage areas of the brain. Burgess et al. (2001) note the origins of this concept in Marr (1971): "A strict interpretation of its principal motivation, that the hippocampus acts as a temporary store from which all information is transferred into neo-cortical long-term memory, remains unsupported by convincing experimental data to this day" (p. 263). According to this conception, destroying this structure stops the flow of events into long-term storage.

The hippocampal literature is complex. Some theories (Eichenbaum et al., 1994) see the hippocampal area as a type of "intermediate" memory (ITM), a holding or buffer area which retains "events" slightly longer than STM until they are stored in long-term areas (LTM). But the purpose of this holding area is ultimately and inexorably linked to a "time-binding" function in these models. Kesner (1994) argued (Eichenbaum et. al concurring) that the hippocampus is an integral component in memory for duration and *temporal order* of events – duration requiring the relation of beginning and end points of an event over time, temporal order requiring "comparisons" among events to establish their ordering in time. A rat with hippocampal damage cannot perform a task, e.g., a radial maze, that requires memory of the temporal order of spatial locations. H.M. cannot relate one mirror tracing event in order with another, nor even with respect to any previous events in his history. Eichenbaum et al. in effect state this time-binding role in seeing the hippocampal function as “abstracting relationships between the current event and previous events.” Squire (1987) spoke of a hippocampal role in maintaining the "coherence" of an event across multiple memory sites for "content, place and time" in the context of memory consolidation processes.

There are likely orders of complexity in the instantiation of COST and the symbolic, from the rat (very low, virtually pre-wired), to the ape (more sophisticated, very limited linguistic ability), to the human. But “time-binding,” or “abstracting relationships between the current event and previous events, ” or “maintaining coherence for content, place and time,” are in effect shorthand phrases for the endpoint of the trajectory that we reviewed in Piaget. This warns us that the framework in which the function of the hippocampus is viewed must be considerably expanded. Even in the best of scientific circumstances, in trying to understand the role of the hippocampus, we know very well that we are in the classic situation of destroying a component in a complex device such as radio, then trying to infer, either from a dead or badly functioning radio, what function the component might have performed. Thus Fuster noted:

> Neither Rawlins nor these authors [Eichenbaum et al., 1994] however, seems to have taken note of the fact that their relational role in the time domain is practically identical to the role that this commentator (Fuster, 1980; 1985) earlier

> attributed to the prefrontal cortex. Perhaps we are dealing with the same memory processing function at different levels of the representational hierarchy. The *cross-temporal binding* role of the prefrontal cortex would take place at a higher – more cognitive – level, and broader schemes of memory than that of the hippocampus… the time-binding function of the prefrontal cortex derives from its representational function – that is, from the role of this cortex in representation of temporal gestalts – plans and programs of motor actions. (Fuster, 1994, p. 476, emphasis added)

In such case, the hippocampus is simply failing to do its part in a larger scheme orchestrated from the prefrontal cortex – a view that appears to have become the consensus. Warrington and Weiskrantz (1982) speculated also that it is a disconnexion between the medial temporal lobe structures and the prefrontal cortex that precipitated the amnesic syndrome, and Shallice et al. (1994) also propose that episodic memory involves frontal control of the hippocampal function. But again, when we actually unpack the phrase "cross-temporal binding," I suspect we find there again a COST. Kopelman & Kapur (2001) note that subjects' ability in pre-frontal tests is an important factor in recall. Further, they too note that large frontal lobe lesions can also produce retrograde memory loss.

The Connectionist Models

The connectionist models of the hippocampus (Alvarez & Squire, 1994; McClelland et al., 1995; O'Reilly and Rudy, 2001) have taken point position in the theoretical attack. The standard or original form of these models views the cortex as the ultimate storage point of experienced events. The neurons of the cortex, however, form associations slowly, while the hippocampal neurons are structured to associate patterns extremely quickly. The role of the hippocampus is to hold the pattern and feed it, slowly, over time, to the various areas of the cortex that store aspects of the event. McClelland et al. (1995) see the original event *entirely* stored in the hippocampus initially. The hippocampus is needed for a while until gradually the storage in the cortex is sufficient. Upon damage to the hippocampus, this model implies short duration, temporally graded RA. Recent events still held in the hippocampus or events not yet well consolidated in the cortex (also relatively recent) are destroyed. Consolidated memories remain, and the better consolidated, the stronger the memory, thus supporting the Ribot curves.

But we have seen that short term temporally graded RA is very questionable. Noting the little evidence for this form of RA, Nadel and Moscovitch (1997) have proposed a major alternative – the multiple trace model. In this model, the hippocampus is needed for the retrieval of *all* memories, regardless of age. The hippocampus yet acts as an "index" to the related cortical areas involved in the event, but whereas the standard model ultimately sees the creation of an independent cortically-based memory via consolidation, the multiple trace model sees repeated events creating redundant traces within the whole hippocampal complex. Older memories are more resistant to damage because they are more distributed. A neuropsychological study (Viskontas et al., 2000) on patients who underwent a unilateral temporal lobectomy showed extensive RA back to childhood. Nadel et al. (2000) also demonstrated that, in the model, the extent of the damage implies degrees of RA. Again, the Ribot curves are supported. The greater the damage, the greater the RA, while the most resistant (or best remembered events) are indeed the oldest.

The Ribot curves initially appear to pose a problem for a model of a unitary dynamic such as COST supporting all explicit memory, for one could ask why older events are explicitly remembered better than younger events if the same process is operative. However, there are at least two poles to the dynamic, the foundational being the redintegration of the past experience in the first place. If the hippocampus is integrally involved in this retrieval process and if indeed redundant traces of the experience facilitate the survival of some composite form of the event, then there can indeed be graded performance on explicit memory.

There are other possible sources contributing to the gradation. If indeed the further we move along the past dimension, the more copies of the memory exist, then we equally and simultaneously are moving towards a *semantic* form of memory. The terms "copies of a memory" and "redundant traces" here are denoting re-living or re-experiencing an event multiple times via different occasions of recall. Semantic memory has been proposed as a form of invariance defined over multiple episodic memories (e.g., Rovee-Collier et al., 2000; Robbins, 2002). The argument (Tulving, 2001a) that the semantic cannot be an invariance over episodic events because the very young child learns many semantic facts before he can explicitly remember past events is simply wrong when seen in the context of the developmental dynamic underlying COST that we have just reviewed. The fact that the child cannot explicitly recall the events does not mean the events have not been "stored," and most certainly does not mean that they have not been experienced, which is all that is required for this view of the semantic. Given the abysmal performance of the amnesic on anything involving the *past x present* product, this semantic interpretation gains an even greater weight than the multiple trace model. The semantic interpretation, however, calls into question the notion that these curves represent an increasing amount of explicit memory along the past dimension at all.

To take stock, then, for a theory that sees explicit memory supported by the dynamic underlying COST, presume, consonant with Fuster's higher level "temporal gestalts," that the pre-frontal area is a necessary component supporting this dynamic. We would then, as is the consensus, have two major components or poles required in explicit retrieval, the hippocampal complex and the pre-frontal. Damage the hippocampal area: this still allows some basic redintegration, memory can still be haltingly supported, the Ribot curves can occur. Damage a critical component in the hippocampal area required for interaction with the prefrontal, or leave the hippocampal complex intact and damage the prefrontal component supporting COST: redintegration still occurs, priming still occurs, the past element of the correlation is available to be brought into play, but the symbolic function required for its use in the explicit is unsupported. There is no explicit memory in this case.

There are many subtleties here; I am painting a broad picture, enough to support a feasibility argument for the COST thesis. Let me address one major question yet with respect to the possible independence of anterograde and retrograde amnesia. The model above implies they cannot truly be independent. Destruction to either or both masts (prefrontal or hippocampal) of the explicit ship sinks explicit memory, both for events to be experienced and events already experienced. Whether anterograde and retrograde are in fact independent is a rather debated issue (cf. Murre et al., 2001). Murre et al. note that studies have shown they are at least highly correlated. One case where there truly is independence is the result of cholinergic blockade. This results in severe anterograde, with virtually no retrograde amnesia. They argue however that this likely undermines some system, perhaps the nucleus basalis with its cholinergic inputs, which modulates the plasticity of the hippocampal neurons. But it could equally be said, given the hippocampal complex is involved in the ongoing perception of an event, that we could wonder what the nature of the perceived event is in the first place. Perhaps it is incapable of normal redintegration, for recurrence of the external event with its inherent pattern or structure (to be discussed further below) simply does not evoke the same pattern over a now normal (non-blockaded) brain.

The Connectionist Limitations

This last topic – the involvement of the hippocampal complex in an ongoing event – raises a serious question on the adequacy of our conceptions. Connectionist models such as McClelland et al. (1995) and memory theory in general, live in a static world (cf. Robbins, in press). Time, particularly in the form of dynamic events, has not yet appeared on the horizon. To Mayes and Roberts (2001), "[Events] are experienced as a continuous series of linked scenes, each made of several objects…. located in particular spatial positions" (p. 86). To Barsalou (1993), a 'biting' transformation would be stored in discrete, schematic states – ''a mouth closed next to the object, followed by a mouth open, and then the mouth around the object" (p. 53). All proceeds as if it is sufficient to theorize on how the hippocampus (and/or other structures) might store some static event, e.g., a snapshot or series of snapshots of a person with a spoon stirring a cup of coffee (cf. Robbins, 2006a). Further, current theory tends to hold not only that selective aspects of events are stored, but even that only selective events are stored. Say Mayes and Roberts (2001), "Only a tiny fraction of experienced episodes are put into long term storage…" (p. 91). There is absolutely no principled theory as to how the brain makes such a selection, either of events, or of aspects of an event.

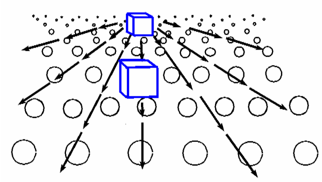

Figure 5. Texture density gradient (Gibson, 1950) and flow field. The cubes on the gradient can be viewed as the same cube in two different positions. As the observer moves towards the cubes, a flow field is created with velocity vectors, $v \propto 1/D^2$.

For all intents and purposes, current memory theory appears to have given virtually no thought to the nature of the events that it is attempting to parse and store as slices, i.e., no thought to the rich mathematics and transformational dynamics of event phenomenology. If a cube rests on a rug or a tiled surface, it rests on a texture gradient (Figure 5). The tiles or rug tufts are our texture "units" and have a decreasing horizontal separation (S) as a function of the distance, $S \propto 1/D$, and vertically as $S \propto 1/D^2$. If the cube is moved towards us across this gradient, the size constancy of the cube as it moves is being specified, *over time*, by the invariant proportion, $S \propto 1/N$, where S is the (increasing) vertical size of the cube on the retina, N the (decreasing) number of texture units it occludes (SN=k). When the gradient itself is put in motion, as the subject moves towards the cube, it becomes an optical flow field – a gradient of velocity vectors where there is an increasing point velocity as the distance from the eye decreases, $v \propto 1/d^2$, all radiating from a single point, the point of optical expansion. Over this flow field and its velocity vectors a value, τ, is defined by taking the ratio of the surface (or angular projection) of the field at the retina, r(t), to its velocity of expansion at the retina, v(t), and its time derivative. This invariant, τ (or tau), specifies time to impending contact with an object or surface, and has a critical role in controlling action (Kim et al., 1993), for example to grasp to the cube as it moves towards us.

If the cube is rotated, then as a side rotates in view, an expanding flow gradient over the side is defined, and as the side rotates away, a contracting flow gradient is defined (cf. Domini et al., 2002). The top surface becomes a radial flow field. As I have reviewed and discussed elsewhere (Robbins, 2004a), it is only over these velocity flows that the form of the cube is computed. The static "features" of the cube that connectionism likes to visualize as indicated as present or absent [+1, 0, 0 +1, 0] in its "vectors," for example the cube's rigid straight-line edges and vertices, are simply sharp discontinuities in these velocity flows (cf. Robbins, 2004a). In fact, under the proper dynamic conditions, this very rigidity and its straight-line features can transform to a plastic non-rigidity, the "cube" becoming a wobbly, non-rigid not-cube, for there are symmetry or invariance laws supporting the *form* of the cube *over time*; the form is a function of its symmetry period (cf. Robbins, 2004a, 2006a).

Let the cubes become cups of coffee on a table surface/gradient and imagine we are stirring the coffee. The stirring motion of the hand is a complex of forces. The use of the spoon is a form of "wielding," described (cf. Turvey and Carello, 1995) under the concept of the "inertia tensor" defining the various moments of mass, resistance to angular acceleration, etc., within a coordinate system. Also involved in this periodic motion is a haptic flowfield carrying an adiabatic invariant which preserves the ratio of the energy of oscillation to the frequency of oscillation (Kugler & Turvey, 1987). There are invariants in other modalities – the clinking sound of the spoon is coordinate with its circling motion. When we poured the coffee into the cup, the rate of increase of the pitch of the sound as the cup fills with liquid is an invariant specifying the time it will take for the cup to visually fill to the brim (Cabe & Pittenger, 2000).

All of this is involving multiple areas of the brain – visual areas, motor areas, auditory areas, haptic areas, with the hippocampal area presumably interconnecting with them all, perhaps employing these inter-modal invariants. Even the action-goal of "stirring" must be supported by the pre-frontal areas. Over these, we have a resonant feedback from the multiple re-entrant projections between all areas which supports a dynamical pattern occurring over time. For practical purposes, we have a near-global, time-extended pattern supported over the brain. The pattern itself, in some form, must support the ongoing invariance structure of the coffee-stirring event and/or the translating/rotating cube being specified in perception. We must wonder then, when looked at in this dynamic context, how much memorizing is actually going on in the hippocampal complex? Perhaps it has all it can do just to support the ongoing event! Where are the breaks in this dynamic flow wherein "snapshot" processing and storage could occur? To say the whole event (as per McClelland et al.) is stored in the hippocampal area is extremely problematic, in fact, impossible. The static "features" which comprise connectionism's vectors do not exist in an instantaneous cross section of time; they are simply invariants over flows. It is the flows supported globally over the brain in all the modalities of the event that would have be to be reduced to storage in the hippocampus.

Certainly some strengthening of neural connections is occurring, but yet, if I re-present this same event, with its same invariance structure, say within the hour, I must expect that it will recreate the same global, dynamic neural pattern, and I have the basis for redintegration – without invoking or having any need for learned hippocampal connections. If so, and if my explicit memory dynamic is operative, we can achieve explicit recall, for both present and past are available for correlation. Simultaneously, if within the same hour, I damage the hippocampus, and if it is indeed integrally involved in the ongoing patterns of any present event, how could this same redintegrative pattern reoccur? The pattern and the event it specifies could no longer be supported. A more dynamic, event-based context will clearly cause reconsiderations of the function of the hippocampal complex.

But even if we can extend our connectionism to cover the re-instantiation of these dynamic, time-extended patterns supporting flows and the invariance structure of an event over these flows, we are still left with the fundamental problem of the gap: we have re-instantiated a complex neural pattern, but have we truly accounted for the re-construction of the past *experience*? How does the experiential image of the coffee-stirring, or Jacqueline's grasshopper, again arise? We have the symmetric problem to that of perception where we cannot explain how the same global neural dynamics results in the perceived external image of grasshopper in the first place. Without understanding this, I believe it questionable that we can grasp the *past x present* correlation underlying the explicit.

The General Framework Required to Support the Explicit

Let me discuss a conjecture on the next step I believe we must take. I have noted earlier that we can view this dynamic, feedback-resonant, global pattern as supporting a wave, and more precisely, a modulated reconstructive wave "passing through" the external, holographic matter-field. The modulation pattern of this wave is driven by the invariance structure of external events, where "invariance structure" is defined as the transformations and invariants specifying an event and rendering it a virtual action. This brain-supported reconstructive wave specifies the present perception (the coffee-stirring spoon) as a virtual image of a past, time-scaled extent of the non-dfferentiable motion of the matter-field (Robbins, 2004a, 2006b, 2007).

When an event with a similar invariance structure is presented again, the same reconstructive wave pattern is again evoked over the brain's dynamics and past experiences/events with similar invariance structures are reconstructed (Robbins, 2006a). As such, we have a powerful redintegrative mechanism that makes the past event, as image, at least available to the dynamic underlying the symbolic *past x present* correlation of the explicit. The redintegrative law implied, E'-> E, can be stated simply:

> A present event E' will reconstruct a previous event E when E' is defined by the same invariance structure or by a sufficient subset of this structure.

The model is arguably as explanatory of research on cued recall as current models (Robbins, 2006a), but nowhere does it require events or experience to be stored (in a yet unknown manner) within the brain. In fact, as noted earlier, since perception/experience is not occurring solely within the brain, experience cannot be solely stored there. But as we have seen, nowhere must we interpret the loss of the explicit memory of this experience in amnesias as the destruction of experience stored within the brain. Rather, in this latter case, we have damaged the ability of the brain to support the complex dynamic and modulated wave pattern required for explicit recall.

But even if we can now account for the redintegration of *experiences,* and if our COST/symbolic dynamic underlies the *past x present* correlation, there is yet a deep problem in the context of time.

Time and the Symbolic

Jacqueline sees the blade of grass and simultaneously sees the "grasshopper" of her past. She has placed herself, as Cassirer argued, simultaneously now in one, now in another meaning, and yet maintains a vision of the whole. I have already been drawing our attention here to the implications of this for our theory of consciousness. What does this phrase actually mean – "simultaneously, now in one, now in another?" When Weiskrantz (1997) proposes a basic "commentary" supporting his conscious *past x present* product, this same question lurks beneath. For our theories of cognition and memory, this is essential.

The elements of this problem have been examined in some depth in another context, namely that of the "primary memory" supporting our perception of form (Robbins, 2004a, 2007). We meet it again. Let us assume for the moment that experience is indeed stored in the brain. The brain, we agree, is composed of matter. Matter is what exists, and what exists is by definition that which is present. The past, then, is by definition the non-existent. All preservation of the past depends upon storage in the "present" brain. If our model of the motion of time is that of a sequence of instants, where the present instant is defined as that which exists, and the previous instant (or instants) by definition is that which is non-existent, then the brain, being ever-present matter, must preserve each previous instant in its memory store, before the instant falls into non-existence. Now the problem (one of many) begins.

Jacqueline sees the grass blade. Her brain, in this conception, stores this present (but now instantly past) instant. The brain fetches the past event – the grasshopper – via a redintegrative mechanism. It stores this event too. Both items are now stored in memory storage areas. The prefrontal area (for the sake of argument) now drives an access to the location of the grass blade/event. It will compare it or relate it with the grasshopper event. We are invoking here, in essence, Gray's (1995) "comparator" (which he felt to be the function of the hippocampus). But in the successive, state-to-state movement of the brain (which reflects our abstract notion of the motion of time) the just recent access to the grass blade is now in the past, and has ceased to exist. How, then, can the brain simultaneously dwell in one meaning, and then the other, yet maintain a whole? We are again in the realm of Zeno and his critique of our abstract representation of time as a series of instants. What, however, do we have to take its place?

As I indicated in the opening comments, I believe that here we must conceptually embed the brain (and the brain's own dynamical motion) in an indivisible (Bergson, 1896/1912) or non-differentiable (Nottale, 1996) motion of time. In Bergson's metaphor, if our instants are "notes," then they are notes of a melody, where each note is not truly distinct, but interpenetrates the next, and each note reflects the whole preceding series. It is, in other words, a melodic flow, an organic continuity. In the perception of a "rotating" cube, a "stirring" spoon or the "singing" notes of a violin, we seek the ability to support a continuous *extent* of time; we seek to support a four-dimensional model of mind. And so to in explicit memory. In the explicit state, we have a dual specification via the brain's role as a reconstructive wave – the specification of the present, external event and the simultaneous specification of the (redintegrated) past event. Even given an intact dynamical state supporting COST, and the dynamic interaction of the two "poles" of memory, an indivisible time-extent is necessary to support the simultaneity of the present event with a retrieved past experience implied in the *present x past* correlation of Weiskrantz, an indivisible extent which resides at the base of explicit memory and the symbolic relationship it implies.

Conclusion

Let me summarize the difference between implicit and explicit memory. The implicit relies solely on the fundamental law of redintegration, E' -> E. This law operates without a functioning hippocampal-prefrontal system or the dynamic supporting the symbolic function. The law underlies priming effects (Robbins, 2006a). It is fundamentally mechanical. The explicit, for its development, rests in the development of COST and the symbolic function. It requires the integrity of a very concrete dynamics that participates integrally in the non-differentiable flow of time and thus supports the articulated simultaneity or temporal whole binding the past event with the present event taken as a symbol for the past. It has nothing to do with the destruction of experience stored in the brain.

Why, it can be asked, is COST not simply the cost of *all* cognition, not just explicit memory? For cognition, as Piaget clearly implied, it certainly is, but that it is equally the cost of explicit memory certainly has not been understood. If it were, we would not have seen the ongoing attempt over the last decade to prove the early onset of “access” consciousness, or the fairly simplistic explanations of the causes of the child’s emergence from childhood amnesia found in the literature, or for that matter, the writeoff of the relevance of Piaget. Robotics theorists would actually harbor a teensy worry about what the two year dynamic trajectory is actually accomplishing, why nature has chosen this method to achieve it, why therefore it might be necessary though robotics thinks it is unnecessary, preferring to believe that cognition can simply be hatched full blown. In turn, it was Cassirer that preceded Piaget in pointing to the significance of the concept of the mathematical group in cognition, but in Cassirer’s profound musings on the symbolic, there resides those “unities that can be fixated, yet simultaneously be kept mobile,” that bespeak of a dynamical implication that has been ignored. Finally, if it is COST, with the symbolic function it inherently supports, that underlies the explicit, then the precedence of this would be understood over the rather common thesis that it is the emergence of language that is required (as, for example, Rakison, 2007); it is not language that underlies the explicit, it is COST and the symbolic, even if there is no linguistic capability per se available.

In cognitive science, the question has lurked for some time: just what, if anything, does consciousness contribute to cognition? Neither the symbolic manipulation model nor the connectionist net appear to require it. For explicit memory, I have argued that a symbolic relationship is required and inherent in this, an articulated simultaneity which implies a global, temporal whole existing over a non-differentiable flow of time. Only a very concrete dynamics can be an intrinsic participant in this non-differentiable flow of the matter-field, allowing this form of representation. These same principles, following the lead of Cassirer, appear to reside beneath other cognitive functions – analogy, drawing, number, voluntary action. In all, I believe, the phenomenon of explicit memory contains a significant key in making the relationship of consciousness and cognition, shall we hope, more explicit.

References

Alvarez, P., & Squire, L.R. (1994). Memory consolidation and the medial temporal lobe: a simple network model. *Proceedings of the National Academy of Sciences*, 91, 7041-7045.

Barsalou, L. W. (1993). Flexibility, structure and linguistic vagary in concepts: Manifestations of a compositional system of perceptual symbols. In A Collins, S. Gathercole, M. Conway, & P. Morris (Eds.), *Theories of Memory*, New Jersey: Erlbaum.

Bergson, H. (1896/1912). *Matter and Memory*. New York: Macmillan.

Block, N. (1995). On a confusion about the function of consciousness. *Behavioral and Brain Sciences*, *18*, 227-247.

Bower, G. (1996). Reactivating a reactivation theory of implicit memory. *Consciousness and Cognition, 5*, 22-72.

Brainerd, C. J. (1978). The stage acquisition in cognitive developmental theory. *Behavioral Brain Sciences*, 2, 173-213.

Brown, A. S. (2002). Consolidation theory and retrograde amnesia in humans. *Psychonomic Bulletin & Review*, 9, 403-425.

Burgess, N., Becker, S., King, J.A., & O'Keefe, J. (2001). Memory for events and their spatial context: model and experiments. In A. Baddeley, M. Conway, & J. Aggleton (Eds.), *Episodic Memory: New Directions in Research*. New York: Oxford University Press.

Cabe, P. A. & Pittenger, J. B. (2000). Human sensitivity to acoustic information from vessel filling. *Journal of Experimental Psychology: Human Perception and Performance*, 26, 313-324.

Cassirer, E. (1929/1957). *The Philosophy of Symbolic Forms, Vol. 3: The Phenomenology of Knowledge.* New Haven: Yale University Press.

Cassirer, E (1944). Group concept and perception theory. *Philosophy and Phenomenological Research*, vol 5: 1-36.

Chrisley, R., & Parthmore, J. (2007). Synthetic phenomenology: Exploiting embodiment to specify the non-conceptual content of visual experience. *Journal of Consciousness Studies*, 14, 44-58.

Copeland, B. J. (2000). Narrow versus wide mechanism: including a re-examination of Turing's views on the mind-machine issue. *Journal of Philosophy*, XCVI, 1, 5-32.

Dienes, Z, & Perner, J. (1999) A theory of implicit and explicit knowledge. *Behavioral and Brain Sciences*, 22 (5): 735-808.

Domini, F., Vuong, Q. C., & Caudek, C. (2002). Temporal integration in structure from motion. *Journal of Experimental Psychology: Human Perception and Performance, 28* (4), 816-838.

Eichenbaum, H., Otto, T., and Cohen, N. (1994). Two functional components of the hippocampal memory system. *Behavioral and Brain Sciences. 17*, 449-518.

Feynman, R. P. & Hibbs, A. R. (1965). *Quantum Mechanics and Path Integrals.* New York: MacGraw-Hill.

French, R. M. (1999). When coffee cups are like old elephants, or why representation modules don't make sense. In A. Riegler, M. Peshl, & A. von Stein (Eds.), *Understanding Representation in the Cognitive Sciences*, New York: Plenum.

Fuster, J. M. (1980). *The Prefrontal Cortex: Anatomy, Physiology, and Neuropsychology of the Frontal Lobe*. Raven Press, New York.

Fuster, J. M. (1985). The prefrontal cortex and temporal integration. In A. Peters and E.G. Jones (Eds.), *Cerebral Cortex, 4: Association and Auditory Cortices*. Plenum, New York, 151-177.

Fuster, J. M. (1994). In search of the engrammer. *Behavioral and Brain Sciences. 17*, 476.

Gallese, V. (2007, April). The "conscious" dorsal stream: embodied simulation and its role in space and action conscious awareness. *Psyche*, 13 (1), 1-20.

Gelb, K., & Goldstein, K. (1918). Zur psychologie des optischen wahrnehmungs- und erkennungsvorgangs, *Zeitschrift fur die gesamte Neurologie und Psychiatrie*, 41.

Gibson, J. J. (1950) *The Perception of the Visual World.* Boston: Houghton-Mifflin.

Gopnik, A. (1996). The post-Piaget era. *Psychological Science*. 7(4), 221-225.

Graf, P. & Schacter, D. L. (1985). Implicit and explicit memory for new associations in normal subjects and amnesic patients. *Journal of Experimental Psychology: Learning, Memory, and Cognition*. *11*, 501-518.

Gray, J. A. (1995). The contents of consciousness: A neuropsychological conjecture. *Behavioral and Brain Sciences*, *18*, 659-722.

Grossberg, Stephen (1995). Neural dynamics of motion perception, recognition learning and spatial attention. In R. Port & T. Van Gelder (Eds.), *Mind as Motion*. Cambridge: MIT Press.

Head, H. (1926). *Aphasia and Kindred Disorders of Speech (Vols. I and II)*. Cambridge: Cambridge University Press.

Howe, M. (2001). *The Fate of Early Memories*. Washington, D.C.: The American Psychological Association.

Howe, M., & Courage, M. (1993). The emergence and early development of autobiographical memory. *Psychological Review*, 104 (3), 499-523.

Kesner, R. P. (1994). Hippocampus and memory for time. Response to Eichenbaum et al., p. 485. *Behavioral and Brain Sciences*. *17*, 449-518.

Kihlstrom, J., Dorfman, J., & Park, L. (2007). Implicit and explicit learning and memory. In M. Velmans and S. Schneider (Eds.). *A Companion to Consciousness*, Blackwell, 539-535..

Kim, N., Turvey, M., Carrelo, C. (1993), Optimal information about the severity of upcoming contacts. *Journal of Experimental Psychology: Human Perception and Performance*, 19(1), 179-193.

Kiverstein, J. (2007). Could a robot have a subjective point of view? *Journal of Consciousness Studies*, 14, 127-140.

Klein, D. B. (1970). *A History of Scientific Psychology*. New York: Basic Books.

Knowlton, B.J., Ramus, S.J., & Squire, L.R. (1992). Intact artificial grammar learning in amnesias: Dissociation of abstract knowledge and memory for specific instances. *Psychological Science, 3*, 172-179.

Kopelman, M. D., & Kapur, N. (2001). The loss of episodic memories in retrograde amnesia: single case and group studies. In A. Baddeley, M. Conway, & J. Aggleton. *Episodic Memory*. New York: Oxford University Press, 110-131.

Kubie, J. L., Sutherland, & R. J., Muller, R. U. (1999). Hippocampal lesions produce a temporally graded retrograde amnesia on a dry version of the Morris swimming task. *Psychology*, 27, 313-330.

Kugler, P. & Turvey, M. (1987). *Information, Natural Law, and the Self-assembly of Rhythmic Movement*. Hillsdale, NJ: Erlbaum.

Light, L., Kennison, R. (1996). Guessing strategies in perceptual identification: Reply to Mckoon and Ratliff. *Consciousness and Cognition*, *5*, 512-524.

Lourenco, O., & Machado, A. (1996). In defense of Piaget's theory: A reply to 10 common criticisms. *Psychological Review*, *103* (1), 144-164.

Mayes, A. R., & Roberts, N. (2001). Theories of episodic memory. In A. Baddeley, M. Conway, & J. Aggleton. *Episodic Memory*. New York: Oxford University Press, 86-109.

Markovitch, S. & Zelaso, P. (1999). The A-not-B error: Results from a logistic meta-analysis. *Child Development*, *70*, 1297-1313.

Marr, D. (1971). Simple memory: a theory of the archicortex. *Philosophical Transactions of the Royal Society of London*, B262, 23-81.

McClelland, J.L., McNaughton, B.L., & O'Reilly, R.C. (1995). Why there are complementary learning systems in the hippocampus and neocortex: Insights from the successes and failures of connectionist models of learning and memory. *Psychological Review*, *103* (3), 419-457.

McKoon, G., & Ratliff, R. (1996). Separating implicit from explicit retrieval processes in perceptual identificagtion. *Consciousness and Cognition*, *5*, 500-511.

Molenaar, P., & Raijakers, M. (2000). A causal interpretation of Piaget's theory of cognitive development: Reflections on the relationship between epigenesis and non-linear dynamics. *New Ideas in Psychology*, 18, 41-55.

Munakata, Y. (1998). Infant preserverative and implications for object permanence theories: A PDP model of the A-not-B task. *Developmental Science, 1*, 161-184.

Murre, J. M., Graham, K. S., & Hodges, J. R. (2001). Semantic dementia: relevance to connectionist models of long-term memory. *Brain*, 124, 647-675.

Nadel, L., & Moscovitch, N. (1997). Memory consolidation, retrograde amnesia and the hippocampal complex. *Current Opinions in Neurobiology*, 7, 217-227.

Nadel, L., & Bohbot, V. (2001). Consolidation of Memory. *Hippocampus*, 11:56-9.

Nadel, L., Samsonovich, A., Ryan, L. & Moscovitch, V. (2000). Multiple trace theory of human memory: computational, neuroimaging, and neuropsychological results. *Hippocampus*, 10, 352-368.

Nottale, L. (1996). Scale relativity and fractal space-time: applications to quantum physics, cosmology and chaotic systems. *Chaos, Solitons and Fractals*, *7*, 877-938.

O'Reilly, R. & Rudy, J. (2001). Conjunctive representations in learning and memory: principles of cortical and hippocampal function. *Psychological Review*, 108 (2), 311-345.

Piaget, J. (1927/1969). *The Child's Conception of Time*. New York: Basic Books.

Piaget, J. (1946). *The Child's Conception of Movement and Speed.* New York: Ballentine.

Piaget, J. (1952). *The Origins of Intelligence in Children*. New York: International universities press.

Piaget, J. (1954). *The Construction of Reality in the Child*. New York: Ballentine.

Piaget, J. (1968). *On the Development of Memory and Identity*. Clark University Press.

Pylyshyn, Z. (2002). Mental imagery: In search of a theory. *Behavioral and Brain Sciences,* 25, 157-238.

Raijmakers, M. E. J., van Der Maas, H. L. J., & Molenaar, P.C.M. (199). On the validity of simulating stagewise development by means of PDP networks: Application of catastrophe analysis and an experimental test of rule-like network performance. *Cognitive Science*, 20, 101-136.

Rakison, D. (2007). Is consciousness in its infancy in infancy? *Journal of Consciousness Studies, 14*, 66-89.

Ribot, H. (1881) *Les maladies de la memoire*. Paris.

Robbins, S. E. (2000). Bergson, perception and Gibson. *Journal of Consciousness Studies*. *7* (5), 23-45.

Robbins, S. E. (2002). Semantics, experience and time. *Cognitive Systems Research*, *3*, 301-335.

Robbins, S. E. (2004a). On time, memory and dynamic form. *Consciousness and Cognition*, 13, 762-788.

Robbins, S. E. (2004b). Virtual action: O'Regan and Noë meet Bergson. *Behavioral and Brain Sciences*, 24(7), 906-907.

Robbins, S. E. (2006a). On the possibility of direct memory. In V. W. Fallio (Ed.), *New Developments in Consciousness Research.* New York: Nova Science Publishing, 1-64.

Robbins, S. E. (2006b). Bergson and the holographic theory of mind. *Phenomenology and the Cognitive Sciences*, 5, 365-394.

Robbins, S. E. (2007). Time, form and the limits of qualia. *Journal of Mind and Behavior*, 28(1), 19-43.

Robbins, S. E. (In press). Semantic redintegration: Ecological invariance. (Commentary on T. Rogers and J. McClelland, Precis of *Semantic Cognition: A Parallel Distributed Processing Approach*). *Behavioral and Brain Sciences*.

Rosenbaum, R. S., Priselac, S., Kohler, S., Black, S. E., Nadel, L., Moscovitch, M. (2000). Studies of remote spatial memory in an amnesic patient with extensive bilateral hippocampal lesions. *Nature Neuroscience*, 3, 1044-1048.

Rovee-Collier, C., Hayne, H., Colombo, M. (2000). *The Development of Implicit and Explicit Memory*. Amsterdam: John Benjamins.

Scoville, W. B., & Milner, B. (1957). Loss of recent memory after bi-lateral hippocampal lesions. *Journal of Neurology, Neurosurgery and Psychiatry, 20*, 11-21.

Schacter, D. L. (1987). Implicit memory: history and current status. *Journal of Experimental Psycholgoy: Learning, Memory and Cognition, 13*, 501-518.

Searle, J. R. (2000). Consciousness, Free Action and the Brain. *Journal of Consciousness Studies*. *7*, 3-22.

Shallice, T. Fletcher, P., Frith, C. D., Grasby, P. M., Frackowiak, R. S., & Dolan, R. J. (1994). Brain regions associated with acquisition and retrieval of verbal episodic memory. *Nature*, 368, 633-635.

Squire, L. R. (1987). *Memory and Brain*. Oxford: Oxford University Press.

Squire, L. R., & Knowlton, B. (1995). Leaning about categories in the absence of memory. *Proceedings of the National Academy of Sciences*, USA, 92, 12470-12474.

Squire, L. R., Clark, R. E., & Knowlton, B. J. (2000). Retrograde Amnesia. *Hippocampus*, 11, 61-78.

Thelen, E., Schoner, G., Scheler, C., & Smith, L. (2001). The dynamics of embodiment: A field theory of infant preseverative reaching. *Behavioral and Brain Sciences, 24*, 1-86.

Tulving, E. (2001a). The origin of autonoesis in episodic memory. In H. L. Roediger III, J. Nairne, I. Neath, A. Surprenant (Eds.), *The Nature of Remembering: Essays in Honor Robert G. Crowder*. Washington, D. C.: American Psyhcological Association.

Tulving, E. (2001b). Episodic memory and common sense: how far apart. In A. Baddeley, M. Conway, & J. Aggleton (Eds.), *Episodic Memory: New Directions in Research*. New York: Oxford University Press, 269-288.

Turvey, M., & Carello, C. (1995). Dynamic touch. In W. Epstein & S. Rogers (Eds.), *Perception of Space and Motion*, San Diego: Academic Press.

Van der Linden, M, & Coyette, F. (1995). Acquisition of word processing knowledge in an amnesic patient: implications for theory and rehabilitation. In R. Campbell & M. M. A. Conway (Eds.), *Broken Memories*. Oxford, UK: Blackwell.

Van deer Maas, H.L.J, & Molenaar, P. C. M. (1992). Stagewise cognitive development: an application of catastrophe theory. *Psychological Review*, 99, 395-417.

Viskontas, I. V. McAndrews, M. P., & Moskovitch, M. (2001). Remote episodic memory deficits in patients with unilateral temporal lobe epilepsy and exclusions. *Journal of Neuroscience*.

Warrington, E. K., & Weiskrantz, L. (1973). An analysis of short-term and long-term memory defects in man. In J. A. Deutsch (Ed.), *The Physiological Basis of Memory*. New York: Academic Press.

Warrington, E. K., & Sanders, H. I. (1971). The fate of old memories. *Quarterly Journal of Experimental Psychology*, *23*, 432-442.

Warrington, E. K., & Weiskrantz, L. (1982). Amnesia: A disconnexion syndrome? *Neuropsychogica*, 20, 233-248.

Weiskrantz, L. (1997). *Consciousness Lost and Found*. New York: Oxford.

Winocur, G., and Weiskrantz, L. (1976). An investigation of paired-associate learning in amnesiac patients. *Neuropsychologia*, *14*, 97-110.

Wood, F., Ebert, V., & Kinsbourne, M. (1982). The episodic-semantic memory distinction in memory and amnesia: Clinical and experimental observations. In L. Cermak (ed.), *Human Memory and Amnesia*, Hillsdale, NJ: Erlbaum.

Yasue, K., Jibu, M., & Pribram, K. H. (1991). A theory of non-local cortical processing in the brain, in K. H. Pribram (ed.), *Brain and Perception*, New Jersey: Erlbaum.