Time: Limits and Constraints

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CHAPTER TWO

THE BATTLE FOR TIME IN THE BRAIN

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> "Living backward!" Alice repeated in great astonishment. "I never heard of such a thing!"
>
> "—but there's one great advantage in it, that one's memory works both ways."
>
> "I'm sure *mine* only works one way," Alice remarked. "I can't remember things before they happen."
>
> "It's a poor sort of memory that only works backward," the Queen remarked.
>
> —Lewis Carroll, (1871) *Through the Looking-Glass, and What Alice Found There.*

SUMMARY

All our conceptions of time spring from our brains. However, the brain itself is a structure that has evolved over several millions of years. In the process of evolution, nature often has to erect and integrate newer structures and functionalities on existing systems and capacities. I argue that many fundamental dimensions of human response such as memory, dreaming, and the persistence of the consciousness of self derive from the interplay attendant on the integration of these stages of brain development. I argue that time has played a central role in this progression. From the earliest notion of physiological time as simple duration through the complexities of the spatio-temporal coordination of action to the ability of the frontal cortex to anticipate future conditions a river runs through it and that river is time. Provocatively, I have termed these sequential epochs of evolutionary integration as the 'battle' for time in the brain.

1. PREAMBLE

It is quite possible that physicists, at some future point, will solve the problem of duration. Indeed, this is one of their manifest aspirations (Hawking 1988). A closed-end description, at some level of analysis, of the interrelationship between object and object would seem to represent at least an intellectually feasible goal. However, physics (in its present incarnation at least) will never resolve the problem of time. This impasse derives from the fact that, unlike duration, time is

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not a property of object-to-object relations but is rather an intrinsic property of the living observer (that is subject-object relations; and see Gibson 1975; also Russell 1915). Indeed, from the special and general theory of relativity, we understand the critical requirement for the presence of a living, intelligent observer (Einstein 1905, 1950). Consequently, if we wish to address the mystery of time, and especially if we wish to understand the subtleties and nuances of the human apperception of time, we have to look in the human brain. Even referring to this organ as *the* brain encourages us to the view that it is a single, discrete entity. Certainly this is how the brain is conceived of in the everyday world. However, the brain is a multi-leveled, multi-structured, modular assemblage. It is an evolutionary palimpsest in which newer structures have developed and have subsequently been overlaid upon older ones. Thus, progressively more complex response strategies have been super-imposed upon simpler and more primitive behavior patterns. Our own personal phenomenological experience tells us that this hybrid system "works" and indeed many would say that the brain works harmoniously. However, this perception of normality is largely an illusion of everyday experience. As with the purported unity of consciousness itself, this belief in the normality of experience is a result of habituation rather than understanding. In this chapter, I suggest that there is actually a continuing battle for control within the brain. The landscape of this conflict is time (Fraser 1966, 1). To illustrate this argument at a general level, I use a popular tripartite division of the brain. However, in actuality there are many modular elements within the brain that bid for control. In the process of human evolution, each modular advance has conferred a sequentially increasing survival advantage. Through juxtaposition of these respective brain systems, I shall look here to resolve some fundamental paradoxes and conundrums in basic behavioral phenomena such as sleep and memory, as well as to explore the further ramifications of what I have asserted for a greater understanding of time itself.

2. Introduction

All time, as we know it, is a product of the mind enacted in the brain. Our experience of time and our understanding of it result from the interaction between several, somewhat discrete brain structures. These deal with the temporal processing of changes in the pattern of environmental stimulation and engage in efforts to anticipate future conditions. Intrinsic evolutionary constraints are placed upon later brain structures because they are necessarily erected on existing components. The earliest of these mechanisms subserves a capacity that is shared by all living organisms (Schrödinger 1944, 1), namely, the ability to retain information concerning the persistence of self. As all living organisms possess both spatial and temporal extent, a vital survival requirement is that they be able to distinguish self from non-self. Spatially, this distinction is accomplished at the respective boundary layers between the organism and its ambient environment (but see Ehrsson 2007). However, in addition to spatial separation, a comparable temporal distinction must also be sustained. In humans the most evident emergent action of this imperative is found in the supra-chiasmatic nucleus (SCN) of the anterior hypothalamus. However, as a necessary character of all living things, this function of sustained spatio-temporal independence is almost certainly cellular in its most primitive form. Unfortunately, the categorical confusion between time as a subject-object relationship and duration as an object-object relationship (see Russell 1915) has led to the inappropriate naming of this mechanism in humans as—the "internal clock" (and see Hancock 1993).

First then, as a characteristic perhaps of life itself, there is a necessity for an awareness of self-persistence. However, simply sustaining some form of differentiation between the self and the rest of the environment (non-self) is to remain vulnerable to all of the vagaries of that environment. The next step of progress in securing greater adaptive capabilities is for the self to attain a degree of self-direction. This enhanced capacity for flexible, self-directed response is clearly an evolutionary advantage, and indeed most such living organisms now act with differing degrees of self-control. However, such a perception-action advantage comes at a cost since it now implies the necessary imperative to synchronize the organism's activities with the spatial and temporal constraints of the environment (Gibson 1975, 1979). To work efficiently, this perception-action system must permit the organism to achieve critical synchronous responses. Such synchronizations can be, and in their primitive forms obviously are, independent of any necessity to reference external and arbitrary time-keeping conventions (see Hancock 2005; Hancock & de Ridder 2003; Hancock & Manser

1997).[1] With the selective evolutionary advantage of social interaction, humans have developed external formalized referents such as clocks, watches and timekeepers of all forms of fabrication (Cippola 1967, 1). These creations are obviously useful tools. However, their output in the form of a train of homogenous intervals such as seconds is still incompletely integrated with the intrinsic human perception-action responses (Hancock 2002). In essence, the innate human capabilities to "time" their actions in the environment have been around for many millions of years, while the formal methods of "clocking" our world are only millennia old at best (Fraser 1987, 45). Thus, while we have the capacity to "time" our environmental actions, we do not necessarily need to do so.[2] If the lowest level function of the brain provides recognition of self-persistence in space and time and the next super-imposed perception-action system deals with the imperative of synchronized responses to the immediacy of present demands, where is evolution to go in order to improve any organism's temporal capacities? The answer nature returns in the human brain has been to find a way to go faster than so-called real time.[3] Largely centered in the frontal cortex, humans exceed the constraints of "real time" by generating "what-if" scenarios that permit the anticipation of possible future courses of events, especially under stressful and threatening conditions (Hancock and Weaver 2005). This highest level temporal mechanism, which acts to project, compare, and confirm possible courses of future action, also shows that most of memory itself is largely created by the functional requirement to anticipate the future (and see Hancock 2005; Nairne, Pandeirada, and Thompson 2008). This modular division within the brain also explains the nature and function of the types of sleep we experience and particularly how these respective modular

[1] It might well be observed that only human beings "keep" time, although almost all living organisms still have to synchronize their activities to match the external environmental conditions.

[2] For example, in athletic competition it is necessary to use an external referent to establish a world record, which record is then open to challenge by all. In contrast, the winner of the Olympic Games has to beat all of his or her competition in the Games but not necessarily get anywhere near the world record to do so. Thus "relative" activities such as head-to-head competition (for example, predator vs. prey) need no reference to any external timing system. Absolute, social actions (such as breaking world records), obviously need this common, external, and socially acceptable measure.

[3] This is not to imply that many other members of the animal kingdom do not possess anticipatory capacities; they assuredly do (see Wang and Yuwono 1995; Wilkie, Carr, Galloway, Parker, and Aiko 1997).

elements periodically form a truce in the battle for time in the brain. It is to the explicit consideration of this "battle" scenario that I now wish to turn.[4]

3. Let Battle Commence

The foregoing is essentially an introduction but what follows represents a largely non-technical account of the concerns at hand. Thus, although reference is made to various contemporary theories and notions in the cognitive and neurosciences, it is explicitly written in order to be accessible to a more general audience. Therefore, while the brain is modular in its structure, containing multiple interacting components, I here use a three-part division, or the notion of the triune brain (MacLean 1990), largely for explanatory convenience. In respect to time in the brain, the traditional and accepted account is that each part of the brain cooperates fairly seamlessly with the others in order to produce what we experience as an apparently harmonious and integrated temporal experience expressed as normal consciousness. This conception is confirmed directly in our own personal experience as an internal observer of our own being. In such experience, we do not encounter any obvious discontinuities, disruptions, or dysfunctions that might lead us to suspect otherwise. Obviously, there are neuropathologies of time in which some individuals do experience clinical problems, but these are, by definition, non-normal states (see Cohen 1967; Fischer, Griffin, and Liss 1962). Thus, disorders such as schizophrenia (Spencer et al. 2004) and Korsakov's syndrome (Mimura, Kinsbourne, and O'Connor 2000), among others, are of interest as "windows" on the way in which "normal" perception has somehow been altered or perverted.

4. The Molyneux Problem

However, there is an alternative to the idea of harmony that can perhaps be illustrated through consideration of a classic issue in perceptual psychology that is generally known as the 'Molyneux' problem

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[4] The term "battle" is used expressly here to stimulate a degree of controversy. Many see the brain as working as an harmonious whole, and indeed it is this traditional perspective that I wish to challenge.

(Molyneux 1688; 1693). Understanding the Molyneux problem requires a temporary but critical excursion away from the main theme of the present work. However, it is an excursion that repays a brief interruption. The Molyneux problem is named after an Irishman, William Molyneux, who posed the following question to the philosopher John Locke in relation to some of his statements made in reference to his pivotal text *An Essay Concerning Human Understanding* (Locke 1690).[5] Molyneux asked the following question. Suppose a person had been blind from birth but knew the difference between a cube and a sphere from his or her experience of touch alone. If that individual now gained the capacity for sight, would he or she be able to tell the cube from the sphere simply by sight alone? It is a question related to what we now refer to as the "binding" problem, which asks how ongoing and accumulated sensory experience is combined into a single reality (and see Hancock 2005). What is perhaps most interesting is that one can go much further than the question that Molyneux posed. Such an extension could be stated as follows. Could an individual, denied from birth all forms of external sensory experience, actually think? In essence, what could be known from pure contemplation of self? It is an issue that philosophers will readily recognize as one of their own special conundrums (and see Kant 1781, 1). One answer is that any impoverished observer who was doomed to such a fate could possess a primitive sense of time. That is, as a living being, an individual would have access to an internal sense of the persistence of self. What they could further make of, or from, this persistence is a most interesting line of philosophical inquiry, but it is one for another occasion. However, it is this primitive persistence of self that triggers a subsequent line of thought. For example, where is this persistence encoded precisely? Further, how does this capacity for persistence function in complex, multi-cellular organisms. Finally, is this sense of persistence a fundamental characteristic of life itself (and see Schrödinger 1944, 1), as I have suggested? Indeed, from a personal perspective, it was the notion that any subsequent sensory integration would have to be erected upon this primal capacity that caused me to once again re-visit basic assumptions about the seamlessness of integration of "normal" experience. This line of exploration naturally leads to an explicit con-

[5] Further specific information on the Molyneux problem, its motivation and origin can be found at: http://plato.stanford.edu/entries/molyneux-problem/.

sideration of what it would be like if these two general brain mechanisms of temporal experience did not cooperate harmoniously? What would be the case if they actually battled for control of time in the brain?

To derive an account of what that battle might look like, we have first to examine the gross morphology of the human brain. As can be seen from Figure 1, the brain is no homogenous medium but shows indications of parsing between a number of obviously differentiated structures. Conceptually, this perspective can be conceived as an assembly of modular structures (and/or processes). Such modules and processes would provide a strong degree of response flexibility to counter the uncertainties of the future against which evolution struggles (see Barrett and Kurzban 2006). Here is not the place to go into a detailed exposition of neuro-anatomy (but see Nolte 2001). Thus the following argument is based on the general proposition that the brain can be differentiated vertically into three general regions (see Maclean 1990). First, the structure at the base of the brain is the brain stem (see Figure 1). Second, the structure that surmounts the brain stem is the limbic system. Finally, the structure that is super-imposed on the limbic system is the neo-cortex. This general differentiation has been refereed to as the 'triune' brain (MacLean 1990). This conception postulates the division into the R-Complex, the Limbic system, and the neo-cortex. For the sake of didactic simplicity I shall here refer to these as the "lower," "middle," and "upper" level of the brain, although this refers to their physical location, not necessarily their place in the hierarchy of control.

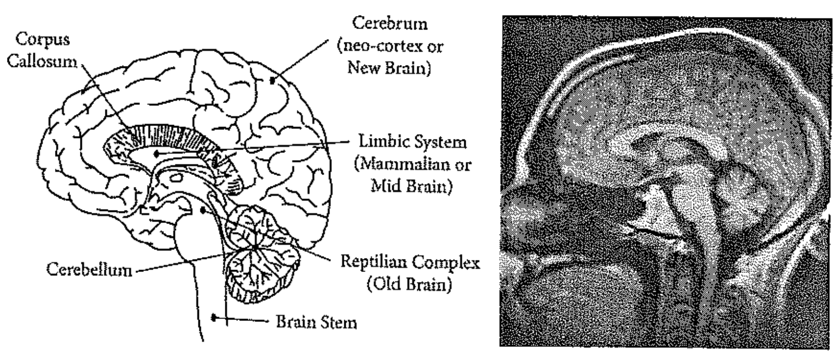

Figure 1: Gross anatomy of the human brain as shown in saggital section. The primary point of present interest is the manifest vertical differentiation of the structures shown.

5. Sleep and the Battle for Control

The brain stem, which is primarily of reptilian origin, has the advantage of being first in existence. In both the law and the brain, possession is nine-tenths of the battle. This seminal form of the brain owns the metaphorical high ground, especially in terms of the "basic" drives for sustenance, sex, or more generally, survival. The middle level, that is the limbic system, must necessarily then battle this pre-existing structure for its own periodic (and attemptedly exclusive) control of the brain. This event occurs daily but in its evolutionary origin this longer-term struggle for control of the brain is inextricably linked with the growth of thermal self-regulation, or homeothermy (and see Hancock 1981; Prosser 1991, 984). Homeothermy is the anatomical expression of the next step, or saltation, in evolution (Gould and Eldredge 1993). Not only does this capacity for homeothermy permit the general exploration of different spatial and temporal opportunities (Crompton, Taylor, and Jagger 1978), but it represents the site in the brain at which control of general circadian functioning of the organism is housed. It is little wonder that these structures and the evolutionary struggles they represent occur neuroanatomically at the interface between the reptilian brain and the limbic system. Thus the long-term integration of the brain stem and the limbic system is actually a type of warfare, while the short-term conflict represents a daily battle for control. This battle, unlike an all-out conflict, must be tempered with the needs of the organism to survive. So, in general, various levels of the brain *do* live in an uneasy alliance, but periodically (and that is, on a daily basis) each fights for and succeeds to supremacy. The middle level, limbic system begins to win its own individual battle as the lower-level reptilian brain starts to weaken.[6] This weakening occurs as the sun goes down.

The lower level brain stem can be influenced by the oscillation of the circadian cycle (Marshall and Donchin 1981). Such mutual influences show that although I have characterized this as a battle, there is

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[6] The reptilian portion of the brain is of poikilothermic origin. That is, in its earlier stage of existence it derived its motive power largely from the heat of the natural environment. In its later incarnation with its homeothermic characteristic, the organism has been selected for its freedom of action. However, homeothermism, or self-generated constant body temperature, actually comes at great cost. To sustain this constant internal body-temperature the organism must be in continual search of food as the source of the calories to fuel this constant internal fire.

a strong degree of inter-dependency and indeed integration between such levels. It also illustrates how elusive the idea of "control" is itself. The limbic system starts to dominate as the circadian cycle descends toward its lowest point in the very late hours of the evening and the very early hours of the morning. The morphology of this rhythm is certainly related to the light-dark (diurnal) cycle associated with the Earth's rotation, but the organism's circadian cycle itself is not inflexibly locked to this period of rotation. Indeed, a completely inflexible association would inhibit opportunities for evolutionary adaptation of the form of spatio-temporal exploration indicated by Crompton and his colleagues (1978). Such immalleability would, for example, preclude extensive migration across multiple time zones and so curtail the opportunity to explore other diverse and accommodating ecological niches.

The ascendancy of the middle level occurs then in the very late hours of the night and the earliest hours of the morning when the ambient temperature of the surrounding environment itself reaches its lowest levels. This correlation is no coincidence and is causal. The take-over by the limbic system is, however, largely a pyrrhic victory. A degree of supremacy is only gained during the hours of sleep and quiescence. Therefore, this first characteristic of sleep could be considered as an uneasy truce between the lower and middle levels of the brain. This accord is fundamentally dictated by the issues of energy conservation and also the concurrent and critical necessity to cement memory for the learning of basic psycho-motor sequences (and see Huber et al. 2004; and see also Stickgold 2006). Many organisms exhibit such slow-wave sleep and use this self-same truce as an opportunity to enhance the permanence of learning (see Smith 1985). During sleep, each of these brain components tacitly agree to this armistice. The lower level does this by diminishing part of its influence (which to some degree is inevitable given the state of the sun as the source of energy). The middle level cooperates in this enterprise by seeking a quiet place in which there is no stimulation for the ears, closing off light from the eyes, reducing the temperature differential between the skin and the immediate thermal surround while cushioning acute tactile stimulation in order to enhance perceived comfort and to reduce the response demands of the surrounding environment (that is, making a bed, nest, etc). These pro-survival conditions optimize the facilitation of the processing of psycho-motor learning in the absence of competing "noise" from an otherwise very active central nervous system (see Stickgold

2006; Stickgold and Walker 2007). To illustrate this effect, a number of the cited studies have shown that sleep, not the passage of time per se, can greatly improve one's perceptual motor skill acquisition. Simplistically speaking, sleep, a respite in the battle for time in the brain, provides a landscape wherein the brain can concentrate mostly on learning and novel ways of adaptation (Huber, Gilardi, Massimini, and Tononi 2004). The body is not inert at this juncture but is very energy efficient, and movements here are a combination of those required for learning and those required to maintain optimal comfort for sleeping. It is at this time when some individuals "sleepwalk." In so doing, they often engage in routine behaviors. It is as though the underlying learning process is actually being played out in full orchestration, rather than the more horizontal tossing and turning of what are termed more normal individuals. Virtually all animals experience some form of sleep[7], and this, as noted, is partially the result of the compromise between intrinsic poikilothermic tendencies and the later addition of homeothermic independence. However, this low-level skirmish is not the only battle for time in the brain.

As is shown in accompanying illustrations, the three-level division of the brain can be presented either as a general descriptive relationship (Figure 2) or a more formal interconnected model (Figure 3). The uppermost level of this three-part description is here referred to as the cognitive clock. As to function, the cognitive clock is largely located in the frontal cortex. This temporal element of the brain bids for control in order to run a series of critical "what if" simulations. The running of these simulations subsequently permit a "faster than real-time" response in complex circumstances that require instantaneous response in the waking state (and see Hancock and Weaver 2005). Consciousness itself can well be characterized as a series of constant comparisons between what is currently being experienced and what has been previously anticipated by such "what-if" simulations. However, if these pattern-matching experiences do connote consciousness, it is not possible to create (and run simulations of) such scenarios on top of reality itself. If such a process were attempted, the individual would become disoriented with respect to reality and eventually show

[7] Indeed, it is most interesting that, for example, horses spend over 90% of each day standing and can sleep while standing and yet they must lie down during REM sleep (see Morrison 2003).

Cognitive Clock

(Second Order)

Future-Anticipative

Dennett Schacter

[Mismatch Comparator of
Possible vs. Actual Information]

**Sensory
Chronocomparator**

(First Order)

Fast-Responsive

Iberall Poppell

[Rate of Change of Sensor Systems]

Internal Clock

(Zero Order)

Slow-Continuous

Hoagland Hancock

[Continuous Duration Propagation]

Figure 2: Tri-level description of the model of human temporal capacities and their respective interconnections (after Hancock et al. 2005). The lowest level, the "internal clock" dispenses a continuous, analog signal whose role is the sustenance of the persistence of self. It is very rare that this capacity is suspended, that is, someone believes that no time has passed, even though a sidereal interval has actually passed. The second level, the sensory chronocomparator, provides comparison capacities across differing forms of sensory input and effector systems (Hancock 2005). That these systems *can* interact in reference to external temporal mechanisms is a tribute to their adaptive capability, not an operational necessity. The main function of this level is the synchronization of perception-action with the external spatio-temporal constraints of the world (and see Calvin 1983). Finally, the third level is the "cognitive clock." In terms of function, its role is to go "faster than real-time" by anticipating the future. It cannot do this in terms of responding but it can look to anticipate future probable events. This anticipation is only helpful if it can lead to appropriate response. The cognitive clock spends its existence searching through perception for anticipation matches. In non-real time—that is, in dreams—it tries all sorts of possibilities and unlikely courses of events. Thus the perplexing nature of dreaming. It is this "cognitive clock" and the ramifications of detailed future predictions that represent the essential characteristic of the human condition.

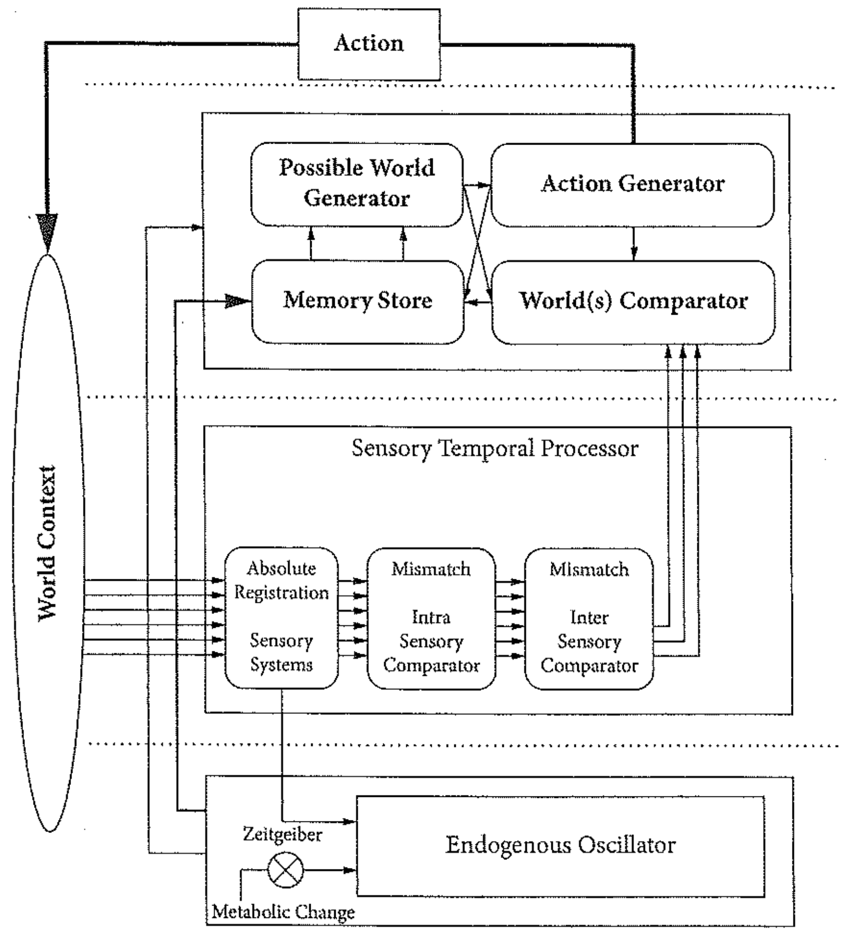

Figure 3: Model of human temporal capacities and their respective interconnections (after Hancock et al. 2005). This expresses the same basic conception as the previous descriptive illustration except that the differing levels are now articulated in more detail. The lowest level responds to internal and external zeitgebers; the middle level is now responsive to the context of the external world and through sensory integration provides perceptual displays that are used for the world comparator at the upper level. Interacting with memory stores and possible worlds, actions are resolved either by an immediate pattern match or a piecemeal solution based upon reactive response.

schizophrenic tendencies (Pearl and Berg 1963). This same form of disorientation is evident also in the behavior patterns of those who are sleep deprived.[8] Therefore, the cognitive clock must have its chance to run the more bizarre (that is, those scenarios further away from the probability of reality-matching) simulations in order to refine its arsenal of "what-if" propositions that primarily allows humans to go "faster than real-time" (and see Hobson, Pace-Schott, and Stickgold 2000). These are dreams. Thus, the cognitive clock must be refined and tuned, but it cannot do this whilst actually working on the imperative dynamics of the world itself, that is, while responding to the demands that it faces during conscious experience (Horne 2000). Thus, in most circumstances, we dream while we are asleep.

It is in the frontal cortex that the meta-levels of adaptive capability are entrenched. Hence when\does the cognitive clock supersede the two lower levels of control? The answer is: When both are at their weakest at just past the lowest point of the circadian cycle. Thus, REM begins to dominate in the latter phase of the sleep cycle. However, there is a major problem. This upper level "cognitive clock" wants to run full-scale perception-action, gross body simulations—not just the simple movement based sequences of psycho-motor learning. It is not enough to just conceive of possible future scenarios; this upper level wants to "run" these cognitive simulations in all their full, action-based glory. The upper level wants to engage the body in order to do this. However, the two lower levels are both constrained by the issue of energy usage, as well as the concerns for the actions of diverse, nocturnal predators. If, for example, in sleeping the human starts to thrash about too wildly and erratically, then not only does the individual lose precious energy but that individual also becomes an obvious target for attack by some violent predator. Despite the presence of such benign, modern, ecological niches as suburban bedrooms, the upper level still has to run its simulations but without engaging the full muscular system. The brain still engenders output signals, as it normally would, but such signals are prevented from getting to the muscles. Thus, during REM sleep, the brain is extremely active, but the body is very largely inert. This is because the required learning is largely cognitive in nature and composed of context-contingent response strategies. These are not the psycho-motor sequences of learning enacted by the lower

[8] Parenthetically, this is why sleep deprivation is a common and, unfortunately, effective form of torture (and see Hancock 2003).

levels of control and referred to previously. This explanation of events serves to address at least two of the central mysteries of sleep. As night goes on, the upper level dominates, giving over more and more time to REM (simulation testing) sleep. If disturbed during REM, a person might, on regaining full consciousness, wake during one of these dreaming episodes. At such a juncture, the person is able consciously to survey the results of one of these running simulations. Such events are experienced as dreams and nightmares.[9] Nightmares foreshadow radical survival situations. They are aversive because they represent possible future encounters with survival-threatening situations. In contrast, dreams are the happier foreshadows of desired goal fulfillment. Slow Wave Sleep is primarily an energy and low-level learning compromise while REM is the comparative compromise in terms of cognitive energy.

Thus, the battle for time in the brain explains the two primary forms of sleep, which are superimposed one upon the other. It also explains why lack of sleep itself is, in general, not fatal. One doesn't die of failure to run "what-if" scenarios or the acquisition of psycho-motor skills. Rather, an individual deprived in this manner just gets more and more confused about reality and slower in anticipating and responding to possible (and actual) future threats. The demise of an individual under these conditions does not derive from a lack of energy per se. However, in a nasty world, the progressively more enervated individual becomes progressively more vulnerable. It is the capacity of any roaming predator (such as powered vehicles in the modern world) that now exploits tired and confused individuals' failure to respond. In this way fatigue is still very much a modern killer (see Desmond and Hancock 2001). Thus, strictly speaking, sleep is not obligatory. However, if the person wishes to function effectively, he or she is well advised to get a good night's rest (Meddis 1977, 1). As far as possible, the brain will compensate for degrees of sleep loss to the extent that it can. It is only when this becomes a radical and chronic level of deprivation that behavioral disturbance become evident. The failure experienced under sleep loss has an antithesis. That is, there are occasions when the top-down "what-if" scenarios practiced by the frontal cortex during

[9] Since, these simulations must necessarily consist of attempts to integrate our recent experiences with our capacities for prospective planning they almost inevitably focus on potential survival issues. Such simulations play "what if" scenarios with some of our greatest fears and greatest aspirations so that we might survive and indeed prosper if we have to actually meet them in the waking state.

sleeping match exactly with the bottom-up stimulation of a moment of reality. These perfect matches (which statistically we are justified in expecting) are experienced by the individual as episodes of "deja-vu" (see Cleary 2008). If such "top-down" projections over-dominate then an individual might experience sensory and perceptual distortion, perhaps similar to those reported in so-called "paranormal" experiences.

As with all forms of behavior, there are large individual differences. Thus, there are people for whom each respective level of control proves either very strong or very weak. As a consequence, a percentage of the populace are insomniacs while, in contrast, others such as neonates and teenagers sleep for extended intervals. These different behavioral outcomes depend upon which of the modules of the brain are most advanced at each stage of maturation. The REM sleep of babies for example, indicates a lot of simulation "run-time" but little scenario input data. The sleep of neonates must be even more of a "*blooming, buzzing confusion*" than their waking world (James 1890, 1). Teenagers also show the effects of an increasingly powerful cognitive clock and thus upper level adaptive learning through their extensive hours of sleep.

6. The Mystery of Memory

One of the greatest of all conundrums with respect to time is the apparent memory paradox that life is lived forward but remembered backward. It is possible that an understanding of the function of the respective brain mechanisms of time that have been presented can serve to address and explain this paradox. First, it is obvious that human memory is not a complete and veridical record of all past events in the lifetime of the organism. Human memory is selective, sporadic, fallible, and evidently incomplete (Schacter 2001). Why is this so? It has been suggested that even the phenomenal storage capacities of the human brain could not contain all the information assimilated during a single lifetime. However, it is clear that memory is incomplete in rather special ways. We do not, for example, appear to forget on a consciously selective basis. Rather, what remains with us are special moments of particular pertinence and relevance.[10] It is true that we

[10] Interestingly, collective memory at a social level has the self-same principles, and we call this collective memory—history.

personally have a sense of autobiographical continuity, but when we are asked to recall our past, it is particular moments which stand out and not a detailed litany of any specific interval. Thus, we might well remember snapshots of events, such as birthdays, but not whether we had a cup of coffee on a particularly specified day. What is the purpose of this form of selectivity? The answer appears to lie in the general purpose of memory (and see Dudai and Carruthers 2005). From the perspective adopted here, the function of memory is overwhelmingly designed to anticipate the future (see Carroll 1871; Nairne and Pandeirada 2008; Schacter and Addis 2007).

Earlier it was indicated that the identification of the continuity of self in space-time was a primary function of all living systems. It is this level of functioning that underlies the autobiographical continuity of self. It allows us to continue to identify ourselves as ourselves on a moment-by-moment and day-by-day basis. This autobiographical capability supports the architecture of higher level functioning that informs our consciousness of this personal continuity in the face of the challenges of everyday life. However, memory for specific events (that is, episodic memory) is often tied to emotion. It is these emotion-contingent memories that are laid down at the crucial points in our existence. Such memories are often associated with extremes of all emotion but are often triggered at times of extreme stress (Hancock and Weaver 2005) when we are involved in battles for survival. That this stress may be either distress (as in adverse conditions) or eustress (in which something extremely pleasant is occurring) appears somewhat immaterial to the process of establishing discrete memories themselves. These occasions are often the subject of a form of after-action review in which the appraisal process is critical to the perception of stress itself and its subsequent memorial foundations. Thus our memory for specific episodes represents the way in which the survival process is gearing us toward dealing with stressful events in the future. The fact that the information so contained is exceptionally relevant to us as individuals in an autobiographical sense is immaterial to the more general progression of evolution itself. Evolution as a process only cares[11] about the past to the extent that knowledge of the past can help one anticipate and deal with the future. Thus memory can be con-

[11] In a true sense, evolution does not "care" about anything since that implies a teleology, which is almost certainly false in this case (and see Hancock 2009).

ceived of as a "string of pearls" in which the discrete events of episodic memory (the pearls) are strung out along the line of autobiographical continuity (the string). The analogy can be taken still further in that, in general, the size of the pearls (that is the intensity of the episodic memories) tend to covary with distance from the present in the same way that a string of pearls often has a large central pearl (James's 'specious present') with others of diminishing size on either side.

That memory itself is also distributed (generally) across the whole of the brain is a form of defense against discrete and drastic failure. That is, needing this information for survival to be available on demand, as future occasion requires, necessitates that it not be confined to any one single location. For if it was so confined and if this location were somehow damaged or immobilized, then one's ability to use the highest level of temporal capacities (what is referred to here as the "cognitive clock") would be largely obviated. An individual, constrained only to reactive response, would have a very limited chance of survival in a non-technical, non-supportive world. We see shades of this sad state in those individuals who suffer from Alzheimer's disease, which unfortunately and evidently influences this memory storage and retrieval function. Now the apparent paradox of memory that was noted earlier is laid bare and can be readily resolved. The fact that life is remembered backward is simply an artifact of our own personal consciousness, which recalls these events in an autobiographical trail. It is this autobiographical trail that is itself then formally elaborated into our general conception of time as composed of past, present, and future. This observation itself explains a number of allied observations in human as well as animal activity.[12] The conceptual framework that I

[12] One incident in my own life I found very instructive. I was present at the death of my Grandfather, who lived to the ripe old age of 100. I was sitting with him in the hospital room and he was murmuring to himself. My mother, never the most patient of individuals (even though a nurse herself) was desperately trying to talk with him and understand what he was saying. Presumably, she thought he was asking for something and her nursing instinct took over. Hearing him talk of some earlier part of his life, she assured me that he was 'losing it' and that this was not so unusual with terminally ill individuals. I listened carefully however and noted that he was muttering about his part in the invention of the rotary lawn-mower! Some time after his death I found out that indeed my grandfather had been employed in a carpet-weaving factory and had been involved in the development of a tool to cut and smooth the pile of each carpet, which was held vertically for this action to occur. Eventually, the horizontal version of this self-same instrument became the basis for the rotary lawn-mower. Of course, the full story is more complex than this. However, in retrospect I understood very well what was happening in that hospital room. My grandfather was dying and,

have advanced here thus helps explain certain puzzles associated with basic human processes such as memory and sleep. However, I do not wish to suggest that these are the only ramifications of the model I have put forward (cf. also, Cleeremans and Sarrazin 2007). Sleep and memory are the two aspects that have been discussed in this present paper. However, other temporal phenomena, such as decision-making, déjà vu, and dream content, can also be encompassed by the present form of explanation.

7. The Parliament of the Mind—The Congress of the Brain

The foregoing has largely represented time from a brain-based perspective. It has dealt with how some issues concerned with sleep, memory and associated phenomena may be approached by an examination of the evolution of the interaction of the modular structures in the brain. However, there is an alternative level of analysis with respect to human time as represented by the emergent property of mind. These respective levels of description (mind and brain) may be different in their form, but an integrated account of their actions must be a coherent one. The present case of sleep and time provides an interesting intersection. What has been described in the present chapter takes place largely in the absence of the conscious experience of time. So, for example, we are consciously aware when we wake up in the morning that time has passed since the onset of sleep (even in conditions where the external, environmental zeitgebers give us no clue as to the actual time of day or night; see Siffre 1965, 1). However, we are not directly aware of the content or even the duration of that passage of time (except in this very general sense). However, at some level, the

I assume, he knew it. My mother's actions were largely guided and oriented by an imperative for the future. But he had no future and he also knew that as well. In his last moments, both the future and even the present began to fade in importance and all that was left was for him to survey some of the most important moments of his past life. While this eventuality will come to us all, it is the fate of human beings, because of the functioning of the highest level cognitive clock, to know that they will individually and personally cease to exist at some point in their future. As this inevitable event approaches, the mandate of survival dissipates, and the evolution-induced by-product of adaptive living, which is autobiographical memory, assumes ascendancy in the very last vestiges of life. This selfsame process might be behind the anecdotal reports of individuals involved in highly dangerous near-miss emergencies who subsequently report that their life "flashed" before their eyes.

mind's understanding that time has passed must be informed by the continuity function (that is, the autobiographical persistence of self) discussed earlier. However, the absence of a sense of time-in-passing during sleep is due to the fact that no conscious episodic memories are being laid down. Indeed, this may be a necessity of sleep since it is the confirmation of previously learned episodic lessons that now occupy the brain. Thus, the mind's experience of time is itself largely limited to intervals of consciousness. That both the organization of the brain and the properties of the mind may each be the result of a collective emergence is an important aspect of human experience to be explored (and see Minsky 1988, 1).

8. Summary and Conclusion

The present view of time and duration is strongly influenced by Russell (1915) and more recently by the inherent challenges posed by Pirsig (1974) and Tarnas (1991). If we can, for the moment, accept Russell's perspective, then duration is a property of the relationship between object and object. It is thus quite reasonable to talk in physical terms about the properties of such duration(s) and thus believe in the proposition which distinguishes the A and B versions of time. The latter distinction has been discussed extensively (and see McTaggart 1993) and indeed is a central issue in all of the time literature. However, using Russell's resolution, the two perspectives are far from incompatible. If Russell is correct, then time itself is a property of living systems, being a relationship between subject and subject or equally between subject and object. If this is so, then it is a direct categorical error to talk about time in relation to non-living things. If it were not apparently tautological, it might be appropriate to specify time as one (if not the) characteristic of life itself. Thus time depends on an observer, whereas duration goes its merry way, independent of any need for any conscious or living entity. In this view, time is a truly multi-faceted construct since different forms of time will be experienced by different entities. I have here suggested that as evolution apparently creates ever-more complex forms of life, there is a comparable increase in the ever-more sophisticated forms of time, although this assertion lies in danger of the hubris that seems to accompany the human condition. The differentiation of time and duration, as well as the purported supremacy of human temporal experience, carries with it a natural attraction to ourselves as the ultimate reporters and auditors of knowledge (and see Hancock 2005). However, there may be important challenges to such a collective egocentric framework. In his highly popular text, Pirsig (1974) sought to challenge this division between self and other, arguing that it parsed existence inappropriately. The brisance derived from the dissolution of this division is informative but leaves behind no obvious structure by which understanding can progress. Pirsig's following text (Pirsig 1991) aspires towards this achievement of a new unity but, understandably, largely fails to reach it. In general, it seems that humans are constrained to divide experience in order to understand it. Looking to embrace the holistic life is currently much more of a spiritual journey toward progress than a scientific one. Perhaps that will change in our future. If anything can elicit that change it has to be the study of some fundamental facet of experience that ranges across the whole of human understanding. At present, the only effective topic that fulfills this criterion is time itself.

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