Frederic Peters (Ph.D.)

Consciousness as Recursive, Spatiotemporal Self-Location

Email fhpeters@aapt.net.au

PH (612) 6771 4066

FAX (612) 6771 1478

Abstract

At the phenomenal level, consciousness arises in a consistently coherent fashion as a singular, unified field of recursive self-awareness (subjectivity) with explicitly orientational characteristics —that of a subject located both spatially and temporally in an egocentrically-extended domain. Understanding these twin elements of consciousness begins with the recognition that ultimately (and most primitively), cognitive systems serve the biological self-regulatory regime in which they subsist. The psychological structures supporting self-located subjectivity involve an evolutionary elaboration of the two basic elements necessary for extending self-regulation into behavioral interaction with the environment: an orientative reference frame which consistently structures ongoing interaction in terms of controllable spatiotemporal parameters, and processing architecture that relates behavior to homeostatic needs via feedback. Over time, constant evolutionary pressures for energy efficiency have encouraged the emergence of anticipative feedforward processing mechanisms, and the elaboration, at the apex of the sensorimotor processing hierarchy, of self-activating, highly attenuated recursively-feedforward circuitry processing the basic orientational schema independent of external action output. As the primary reference frame of active waking cognition, this recursive self-locational schema processing generates a zone of subjective self-awareness in terms of which it feels like something to be oneself here and now. This is consciousness-as-subjectivity.

Keywords

Consciousness, theory of consciousness, self regulation, subjectivity, path integration, forward

models, intentionality

Introduction: The Mystery of Consciousness

The study of consciousness has proved notoriously erratic regarding the definition of its subject matter. Titchener complained that the philosopher Alexander Bain, writing in the 1880's, listed no fewer than 13 meanings of the term (Titchener, 1915); a half century later, philosophers Gilbert Ryle, Alan White and John Wisdom have each offered half a dozen senses of the term "consciousness"--all different. In the 1980's, Thomas Natsoulas (1983) methodically analyzed six distinct senses of the word found in the Oxford English Dictionary, to which Ned Block has most recently (1995) added a further four. This confusion shows itself most poignantly (and detrimentally) in the important consideration of the evolution of consciousness, where the initial emergence of recursive cognition—simple reflexive awareness—needs to be clearly distinguished from the subsequent development of a more elaborate "self-consciousness" involving metacognitive mechanisms for second-order representation of and attentional focus upon the organism's own mental states (or of mental states in other organisms) by means of such capacities as attention, short term memory, language, the ability to recognize oneself as an object (mirror self-recognition), and the capacity to ascribe mental states in other creatures (particularly conspecifics).

In consonance with the longstanding focus on subjectivity as the primary phenomenal characteristic of consciousness, as well as its most primitive evolutionary form (Weiskrantz, 1985; Farthing, 1992; Reber, 1992 ; Flanagan, 1992; Meijsing, 1997; Bermudez, 1998), consciousness as subjectivity will be the focus of this proposal and its explanation framed in terms of the evolutionary emergence of recursive processing circuitry. Using the term "self" with its connotation of reflexive autoreferentiality, "consciousness" will be referred to variously as *recursive self-awareness*, or *consciousness-as-subjectivity* or simply *subjectivity*. All these terms

are intended to encapsulate Nagel's sense of consciousness-as-subjectivity wherein there is

something it is like for that creature to be that creature (1974).

As for the more fully evolved level of conscious awareness normally ascribed at least to

humans and some, primates, following both Baars (1992) and Reber (1992), this would be

understood to involve not the further development of subjectivity per se, but the addition of

metacognitive capacities to represent one's own and other's states of mind and attentionally direct

recursive self-awareness onto such representations in the form of introspection, abstract

reasoning and elaborate planning and so on. Thus, though not discussed here for reasons of

space, the more fully evolved form of consciousness should be seen not as an expanded,

upgraded or changed form of self-consciousness, but a case of subjective self-awareness

augmented by an entirely different, separate and independent set of cognitive mechanisms.

Phenomenal Properties of Consciousness-as-Subjectivity

Conscious cognitive processing is consistently coherent in certain distinctive ways. Significant

psychological features include its cyclical activation over the sleep/wake cycle, distal

representational format, limited processing capacity, seriality and close association with short

term memory, attention, and the detection of novelty. However, vociferous debate as to the

critical qualities of consciousness has established a consensual recognition that no explanation of

consciousness-as-subjectivity can be considered complete without addressing a specific set of

core *phenomenal* properties. Unity, recursive processing style and egocentric perspective are

among the features most frequently cited as basic phenomenal characteristics of consciousness

(for summaries of phenomenal properties see Searle, 1992; Metzinger, 1995; de Sousa, 2002;

Revonsuo, 2005; Weisberg, 2005). A fourth essential phenomenal ingredient of conscious self-

awareness, the self, calls attention to the fact that the (egocentric) first-person perspective is not expressed in the abstract–as merely an egocentric point of view–but is represented in concrete spatiotemporal terms as a distinctly-perceived self construct, which is not merely oriented spatially and temporally from the first-person perspective, but orientationaly situated – as a "this" (or at the more developed human level as "I") situated "here" and "now" (de Sousa 2002, p. 150; Nagel, 1986, p. 61; Metzinger, 1995, p. 16; Revonsuo, 2005, p.133).

Subjectivity, the distinctly recursive, referring-back-upon-itself processing regime which manifests phenomenally as subjective self-awareness, constitutes the central defining characteristic of consciousness for most analysts. Accounting for this recursive, autonoetic capacity in terms of a credible cognitive mechanism constitutes, arguably, *the* major challenge for any theory of consciousness. Subjectivity, in its turn, provides the functional basis for "raw feels" or qualia, the capacity to experience inner feelings (love, hope, fear), thoughts (plans, opinions) and unadorned sensory feels like the redness of a ripe tomato, the smell of gasoline or the discomfort of a pebble in the shoe (Block, 2007).

In the following proposal, this complex of phenomenal properties, which comprise consciousness-as-subjectivity, will be accounted for in terms of a tonically activated self-locating event schema configuring the continuous self-to-environment interaction as a single ongoing event. The architecture within which this egocentric event schema is continuously processed, involves feedback processing necessary to relate action output to homeostatic needs. This processing mechanism will be seen to have developed into a highly-attenuated recursive feedforward circuit as a result of evolutionary pressures for energy-saving forms of processing (Figure 3, panels 'b' and 'c'). The tonic recursive processing of the interactive event schema supports subjective self-awareness such that it feels like something to be oneself here and now.

Cognitive Elements Comprising the Content of Consciousness-as-Subjectivity

Cognition can be fruitfully understood in terms of its connection to the biological sphere (Jordan 2008; Revonsuo, 2005), most specifically as an extension of biological self-regulation. Cognitive systems are to be found not in physical stuff (air, water, rocks, gas), but exclusively within biological organisms. This is crucial for understanding why cognition exists and what it actually does. The fundamental challenge for all biological organisms is to survive by sustaining homeostasis–the internal conditions supporting life–in the midst of ongoing interaction with an ever-changing, often-threatening environment (Cannon, 1932). Cognition provides a means of extending the biological capacity to maintain homeostasis beyond the organism to the organism-environment interaction by developing the capacity to control that interactivity. Cognition, then provides a basis not simply for self-movement, but for self-movement serving homeostatic self-regulation (Panksepp, 1982; Cisek, 1999; Bickhard, 2008; Parvizi and Damasio, 2001).

Cognition then, is essentially an adaptive extension of the organism's self-regulative functionality into the realm of behavioral interaction. But to survive, a cognitive organism must be able to relate its behavior directly to its homeostatic needs (Churchland, 2002ab). Thus, cognition is of necessity configured most basically as a control system that relates ongoing action outcomes to current homeostatic requirements. A cognitive organism self-regulates by *controlled* self-to-environment interaction. This vital control aspect of cognition finds expression in two ways: (a) the central data structure or reference frame configures ongoing interaction in a controllable form—as spatiotemporal self-location of the agent in relation to the environment; and (b) cognitive processing architecture functions as a control system relating action output to required perceptual inputs (and ultimately thereby to homeostatic needs). These two elements,

the data structure and the control architecture, constitute central ingredients of the explanation of consciousness-as-subjectivity proposed here.

Cognition Represents

Electrotonically-based nervous systems, on the other hand, provide several advantages over movement-producing molecular chains available to plants, amoeba and paramecium: (1) a capacity for spontaneous endogenous activation; (2) faster signal propagation; (3) signal amplification through spike propagation; (4) more selective activation based on sensory pattern recognition; and (5) a capacity to coordinate the action of multiple effectors, underwriting a capacity for more complex movements through multiple dendrites and axon corollaries (Mackie, 1970). But arguably the biggest advantage is that nervous systems can represent, they can generate mediating informational states (Markman and Dietrich, 2000) that carry & display information about something other than itself – information about the external environment and internal bodily homeostasis. Representation remains a somewhat controversial issue[1] (reviews include Gallistel, 2006; Markman and Dietrich, 2000; Haselager, de Groot and van Rappard, 2003). However, it is difficult if not impossible to adequately account for a host of cognitive functions without some notion of representation, particularly in the case of hallucination, and dreaming where there is no external input at all (Revonsuo, 2001).

Cognition Represents Ongoing Mobile Interaction of the Self-Moving Agent with the Environment

   If cognition operates in terms of representations, what, precisely, do representations represent? Is the representational system a kind of *Treisman Machine*, involved primarily in the

manipulation of cobbled-together surface features of objects (Treisman, 1996); or by contrast, is it designed to operate in terms of a portrayal of dynamic action events (Zacks and Tversky, 2001). If the latter, is representation configured at base in terms of the singular ongoing dynamic self-movement event involving the organism as it interacts continuously with its environment? Evidence suggests that cognition provides biological organisms with the means to extend homeostatic self-regulation through the provision of a self-movement capacity. This means that cognitive systems are self-movement systems, designed to operate while moving, to represent in terms of interaction while *on the hoof* as it were (Clark, 1997), as a moving platform (Merker, 2005). Within the embodied cognition and dynamical systems literature, the understanding that cognition manages interaction and does so while mobile is referred to as *situated activity* (Wilson, 2002). This designed-for-motility or *situated* character of cognition underwrites the design of cognitive processing in several critical dimensions. From the perspective of Evolutionary Psychology, perceptual systems first emerge to detect the self-movement of the agent through the environment (Milner and Goodale, 1998), and virtually all perceptual channels anticipatively adjust their output for this ongoing self-movement through the environment in order to maintain the stability of the egocentric perceptual display. Moreover, object recognition requires interactive self-movement both to develop properly (Held and Hein, 1963), and to function optimally when developed (Jokisch and Troje, 2003).

Indeed the entire perceptual process is configured in terms of motile agent-to-environment interaction. Studies show that entities are first perceptually "individuated" as locus-of-movement (Spelke, 1990), and then initially identified through categorization in terms of kinds of movement (Csibra et al, 1999). Ensuing interpretation, in turn, focuses significantly on action potential–how the subject can/should interact with the object, what the object offers or affords in terms of the potential-for-action (Gibson, 1979). As a result, the knowledge base drawn upon in this

affordance-identification process is configured in terms of a privileged interactive "basic level" of categorization (Rosch, 1973) reflecting the distinctive actions we perform on particular classes of objects. Indeed, the entire spatiotemporal manifold in which behavioral output takes place is inherently meaningful to the cognitive system only by virtue of bodily interaction, the history of self-motion in terms of spatiotemporal parameters. Primitive meaning schemas relating to space (up/down, in/out, front/back, left/right, near/far), motility (momentum, source-path-goal, towards/away from), force (compulsion, blockage, counterforce, resistance, enablement, attraction), and particularly temporal (then/now) and spatiotemporal schemas (fast/slow, change) are all action-oriented and derived from self-movement through the environment (Grush, 2000).

Most significantly, the distal "out there" representational format itself serves the agent-to-environment interactional purpose. Events as a whole (including objects and agent) are represented as positioned beyond the sense organs, in a way that satisfies the needs of action control (Rosenberg and Anderson, 2008). And this distal format is itself further configured in terms of an interaction-oriented first-person perspective that involves the perspective of an agent in relation to the environment in which he is situated. In this sense, cognitive processes configured to facilitate and manage agent-to-environment interaction, can be said to be "embodied". They arise from bodily interactions with the world (Lakoff and Johnson, 1980) and act as "controller of embodied action" (Clark, 1997) or agent-to-environment interaction.

The fact that sensory individuation, perceptual identification, the memory knowledge base and representational format are all configured in interactional terms, indicates not simply that cognition is designed to guide action but that the cognitive system is designed to operate under action-oriented circumstances (ongoing agent-to-environment interaction). The organization of motor output is similarly structured to operate in the midst of ongoing mobility. Action output is more or less continuous, commencing immediately upon perceptual input, and continuing in

successive waves of adjustment and realignment as action proceeds (Eriksen et al., 1985).

Consequent upon this commitment to ongoing motility, interactional cognition bears the marks of

being time-pressured, of having to function under the pressures of real-time interaction

("runtime") with the environment (Wilson, 2002).

Ongoing Mobile Interaction is Represented Cognitively as <u>One</u> Ongoing Interaction Managed as

Self-Location

The fact that cognition is designed to operate as a moving platform, in terms of *ongoing*

interaction, suggests that this process is configured cognitively as one singular, temporally

extended action event. That is to say, ongoing interaction is represented not simply as a series of

events, but in terms of its basic structure, as the same event with the same representational

structure at every successive moment. That basic data structure can be understood as a primary

reference frame configured in terms of a kind of "self schemata", which in cognitive theory is

understood to serve as the basis both for perception and the regulation of behavior (Neisser,

1976; Markus & Smith, 1981). For purposes of managed behavior serving biological self-

regulation, then, this foundational cognitive structure is configured in terms of the manageable

spatiotemporal parameters of self-location of the agent in relation to the environment. This

primitive self-locational basis to the self schemata could be said then, to underlie the dictum that

self-knowledge regulates behavior (Carver and Scheier, 1982).

Continuous self-locational computation is operationalized as spatiotemporal updating.

Gallistel (2006) points out that direct electrophysiological observation of neural activity has

shown that the nervous system represents where the animal is and has been within the

environment, how it is oriented in terms of both its spatial and temporal relationship to the

environment (Wallentin, 2008). That is to say, the cognitive system manages the ongoing interactional event in terms of a continuously updated computation of spatiotemporal self-location. In order to represent self-to-environment interaction, cognition constructs an egocentric reference frame (Franklin and Tversky, 1990) which is continuously and automatically updated (Riecke et al, 2007) in relation to ongoing self-movement through the landscape. The reference frame is self-locating because it is constituted by continuous updating through a combination of external sensory, as well as internal proprioceptive and vestibular feedback from self-movement to yield an ongoing sense where and when the organism is in relation to the environment (Wirth et al, 2007). The spatial aspect of self-locational functionality, which is computed on the basis of self-motion cues rather than with reference to external visual or acoustic landmarks is referred to as *path integration* (Etienne and Jeffery, 2004). The temporal aspect of self-location is referred to as *scalar timing* (or interval timing), which involves the computing of rate of motion and time spent traveling in a certain direction (Eagleman et al., 2005). Phylogenetically, this spatiotemporal self-locating navigational functionality has been identified in virtually all species of animal from humans to crustaceans.

Because the cognitive system is designed for constant interactivity, it is designed, ipso facto, to constantly track this ongoing interaction. Consequently, egocentric self-locational updating in terms of the self-locating schema can be considered as constituting the primary ongoing reference frame (Hartley and Burgess, 2002; Avraamides and Sofroniou, 2006; Briscoe, 2008; Wirth et al., 2007), and as such, can be accounted, in some sense, the functional heart of the cognitive system (much as the more elaborate self as executive planner and decision-maker is accounted the heart of a self-regulating system (Carver and Sheier, 1981).

The Primitive Self Schema Which Captures the Ongoing Self-Locational Event is Configured in

Terms of a Single Set of Egocentric Orientational Parameters – this-here-now

Spatiotemporal updating of ongoing interaction is consistently structured in terms of a basic self-locating action-event schema configured in the form of spatiotemporal self-location of the causal agent, the self-mover in relation to the environment. The three primary parameters of interactional event representation, spatial, temporal and causal are configured in agent-centric terms, because computations designed to generate and control self-movement in relation to the environment must necessarily be framed in terms of the perspective of said self-movement–the first-person or egocentric perspective of the agent. The structural parameters of the interactive event are, then, causal, spatial and temporal. Casting these in the perspective of the self-moving agent: the egocentric depiction of the self-moving causal agent (the self-mover) at every moment is **"this"** (or, at the biographically-elaborated human level, "I"); the egocentric representation of real space, actual spatial location of the agent-in-relation-to-the-environment is always **"here";** and the egocentric representation of real time, the actual temporal location of the agent-in-relation-to-the-environment at every interactional moment is **"now"**. Collectively, these three egocentric parameters structure the self-locational reference frame (and consequently the content of subjective space) as ***this-here-now***. The extraction of the three critical parameters from the continuous processing of the ongoing interactional event to form a single, self-locational schema involves a process of schema-abstraction operated by the cognitive system as part of the normal process of memory consolidation, whereby the structure of interactive events is abstracted and retained as a skeletal event-schema. (Alba and Hasher, 1983). Experienced events are constantly configured (and consistently coherent) in terms of the egocentric self-location of the agent (Wallentin, 2008) within a spatiotemporal manifold of subjective presence (Metzinger, 1995;

Revonsuo, 2005) because the configuration of events is consistently engineered (and constantly

updated) in terms of this basic schematic spatiotemporal reference frame.

Because the three structural parameters of the self-locational schema constitute the basic

content of consciousness-as-subjectivity, it is important to clarify precisely what they represent.

As the *this-here-now* reference frame models an ongoing dynamic relational process between

agent and environment, a relationship rather than *things* or *objects* themselves, it cannot properly

be considered a model of the self *and* the environment (Edelman, 2003; Damasio, 2000;

Churchland and Churchland, 2002) or a representation of the self model *nested in* a map of the

environment, as has also been proposed (Metzinger, 2000). Nor, lastly, should the self-locational

schema be equated with a Melzack-like template of the body (see note 2) such as to yield an

ongoing conscious "feel" of bodily presence in space-time (Vandervert, 1995; Jordan, 1998).[2]

The self-locational schema is a tripartite data structure which functions to consistently configure

the internal representational product of self-locational event processing, and as such, it captures

the controllable parameters of an interactional event from the perspective of the agent. In so

doing, it does conjure up a kind of self and thus can be said to constitute a self schema. What sort

of self, then, is this intrinsically orientational, self-located self?

The self has been described here not as a cognitive structure referencing the self alone (as

either psychic or bodily monad), but a self engendered as part of the self-locating process, an

ongoing, moment by moment self-locational event. This self constitutes an intrinsically situated

self. It has been suggested that the self-schema is tripartite (*this-here-now*) because it comprises

the abstracted structural parameters of the ongoing interactional event, the reference frame

necessary to structure ongoing organism-to-environment interaction in a continuously coherent

fashion. But there is a more substantial cause: the self arises as part of a tripartite self-locational

schema fundamentally because the cognitive system must be able to manage the interaction in order that behavior can fulfill its fundamental purpose of serving homeostatic needs.

This is the element missing in competing accounts for the origin of the self as a preconscious or 'core' cognitive structure (as opposed to a conscious, biographically elaborated identity). Opinion is divided as to the fundamental nature of the core self structure. Following Gibson (1979), there is continuing support for the notion that the core sense of self is inferred from the character of direct sensory input.[3] But the self so inferred appears fundamentally vacuous, functionally without purpose. Others maintain that the core self represents the body (Llinas, 2001; Damasio, 2000; Churchland, 2002ab; Legrand, 2006; Newton, 1991; Metzinger, 1995; Vandervert, 1995). However at the neurological level, the medial fronto-posterior axis dedicated to self-related processing can be distinguished from the somatosensory and posterior parietal cortices which house specific aspects of the body image (Berlucci & Anglioti 1997). Moreover, the sense of self remains active in somatically deafferented subjects (Meijsing 2000), and quite distinct from the body sense both in cases of denial of ownership of body parts, and instances of the spatial transposition of the self-sense in relation to the body (Blanke & Arzy, (2005).

Within the context of agent-to-environment interaction, social constructivist theory traces the emergence of the self structure specifically to *social* interactivity (see Stets & Burke, 2002 for review), to the elaboration of internal intentional states, including the distinction between self and virtual others, as a result of social interaction (Jordan, 2008). But while there can be little doubt that social interactivity constitutes a strong (perhaps even the primary) contributor to the development of a biographically elaborated self-concept or identity, the most primitive or basic interactive reference frame must articulate the self-to-environment relationship as such (as both physical and social), and cannot, therefore, originate in specifically social interaction.

In this more basic, preconscious sense of interactivity, it is tempting to envisage the necessity of a self-other distinction as the primary and essential underpinning for the self structure (variously envisaged as distinguishing figure from ground (Vandervert, 1995); the need to distinguish self-generated virtual content (thoughts) from other-generated virtual content (Prinz, 2003; Jordan, 2008); distinguishing self action from other action (Hohwy, 2007; Boyer et al., 2005). Churchland has rightly observed, however, that an organism lacking the capacity to relate energy expending actions to homeostatic needs is a dead organism (2002a). Similarly a cognitive organism that simply distinguishes itself from the environment without the capacity to configure and thereby manage its interaction with that environment is likewise, a dead organism. Differentiating self from environment does not suffice for survival. Management of the interaction is essential.

It is this management principle which fundamentally informs the character of the "core" self stucture. Control of the ongoing self-to-environment interaction requires representation in terms of controllable parameters, organizing perception of ongoing interactivity in terms of controllable spatiotemporal terms--in terms of the self-location of the organism vis a vis the environment as such. The self-locating event schema embodies the fact that self-regulating organisms have developed cognition in a form which extends that capacity for self-regulation through controlled self-movement, or controlled self-to-environment interaction (and this self-regulative character of cognition extends also to the configuration of its architecture as a feedback system relating action to metabolic needs).

Thus, while the cognitive system is designed to operate as an ongoing interactive platform, suggesting an agental core self (see Gecas, 1982 for a review), this is not the complete story. Ultimately, as part of a tripartite self-locating event schema, the minimal self operates to configure interactive experience in a way that permits self-regulation, it enables the self-

sustaining metabolic system to self-regulate (Ghin, 2005, p. 8), and on this basis, like its architectural counterpart (the feedback system), the minimal self structure must be accounted essentially a self-regulatory device permitting managed interaction. As the abstracted foundational structure of interactional event cognition, this paradigmatic self-locating event schema has become part of the innate heritage of the vertebrate cognitive system in much the same way as the innate domain-specific learning device (Carey and Spelke, 1994) and the language-acquisition device (Chomsky, 1975). Beyond this, its significance to cognition lies in the fact that if activated on its own within a tightly recursive processing architecture, this self-locational schema has the potential to manifest cognitively as a primitive form of subjective self-awareness (consciousness-as-subjectivity). The evolutionary development of just such a recursive processing circuit forms the focus of the following section.

Evolution of the Architecture of Consciousness-as-Subjectivity

While the self-locational *this-here-now* schema underwrites the distinctive self-orientating content of consciousness, it is the autoreferential or recursive quality (or processing style) of conscious self-awareness (consciousness-as-subjectivity) which constitutes what most analysts consider its defining characteristic. Self-referencing is not an intrinsic characteristic of mental representation as such, and will be explained here as the consequence of a predictive processing architecture which develops, as a consequence of evolutionary pressure for greater energy efficiency, a recursively-predictive circuit for processing the self-locational *this-here-now* schema. The recursive processing architecture supporting conscious subjectivity, then, does not appear like a miracle *de novo*. It evolves from existing feedforward, and prior to that, feedback processing architectures. Whence a cognitive processing architecture based initially on feedback?

This question relates directly to what cognitive systems essentially do. The preceding section provided an extensive review of evidence indicating that cognition is designed to guide action, and to do so during the course of ongoing agent-to-environment interaction. But even more fundamentally, cognition is necessarily designed to guide action in relation to homeostatic needs (Churchland, 2002a). As an adaptive extension of the organism's self-regulative functionality into the realm of behavioral interaction, the cognitive system is of necessity configured most basically as a control system relating ongoing action outcomes to current homeostatic requirements. This self-regulative character finds expression both in the central data structure or reference frame--the self-locating event schema--as well as in a processing architecture configured as a feedback control system (see Figure 1).

But survival and reproductive success depend not only on a self-regulatory operating regime, but on the regime's ability to operate in an energy efficient manner, because motor output is energy expensive. And biological organisms can be viewed most basically as energy regimes (over half the body's weight is devoted to cellular elements that manufacture energy), so that 'any organism that can capture prey, escape predators and achieve goals with a minimum demand on metabolic energy, has an evolutionary advantage' (Neilson and Neilson, 2005). Thus, whatever the somatic and neurological changes engineered by the need to meet specific environmental challenges, the essential ongoing challenge is always to operate with maximum energy efficiency. In the evolutionary kingdom, energy is the coin of the realm, as it were, and several theorists cast the critical agent-to-environment interaction specifically in these terms, such that phylogeneticly-emergent energy-transformation regimes interact with an environment-as-energy-gradient in order to sustain themselves (Odum, 1988; Vandervert, 1995). In terms of the critical relation between action and homeostasis, cognitive systems can thus be viewed as managers, not simply of ongoing homeostatic balance, but of the energy budget available to

maintain that balance through action. Consequently the brain is in large measure devoted to reducing the risk of energy expenditure through action, and recursive orientational processing that requires virtually no physical action-output will become one of its most significant evolutionary achievements (see below).

The evolutionary pressure for ever-greater energy-efficiency has driven elaboration at several functional levels of the neurocognitive system. At the molecular level, the energy cost of information transfer has been found to constitute a significant constraint on the number of signaling molecules and synapses used by neurons (Schreiber, 2002). In terms of neuronal interconnectivity, it has been suggested that energetic costs could limit absolute numbers of neurons and synaptic connections (information channels) in the brain (Laughlin, 1998). Within the context of the general notion of an evolutionary perceptuo-motor hierarchy in the forebrain, the management of self-to-environment interaction in terms of spatiotemporal self-location can be understood as a core function and the primary reference frame for the ongoing cognitive level control of perceptuo-motor processing. Most significant in this regard is the fact that evolutionary pressures for increased energy efficiencies have encouraged not only the emergence of successive levels (or tiers) of control, but also the elaborative changes in the control mechanism itself, which, studies indicate, has evolved from feedback (Figure 1), to feedforward (Figure 2), and finally, within the spatiotemporal self-location (path integration) module, to a simplified, recursively-feedforward circuitry (Figure 3, panels 'b' and 'c'). In so doing, the hierarchical perceptuo-motor control system is provided with an energy-saving default state of cognitive activation in its top tier which does not require physical motor-output for its completion. As discussed below, it is this recursive processing circuit in the top tier that underwrites the state of consciousness.

Feedback Provides the Link Between Homeostasis and Self-Movement

In the 19th century, French physiologist Claude Bernard highlighted the necessity of biological organisms to maintain a consistent internal physico-chemical environment (the *milieu intérieur*), which permits internal vital processes to continue functioning, independent of physicochemical perturbations in the external environment (Cannon, 1932). Self-movement is one means to that end–adopted in some form by most biological organisms (Richter, 1942-3). The earliest self-regulatory processing mechanism that serves to maintain a tight relationship between behavioral motor output and internal homeostatic needs, comprises a simple negative feedback control mechanism (Figure 1). Within such a system, behavior is no longer simply a kneejerk reaction to external stimuli, but a reaction geared to the maintenance of critical internal conditions. The fundamental self-regulative operating principle linking motor output to homeostatic needs is initially embodied within cognitive functionality in the form of feedback control, which acts to restore deviations from regulated internal set points through corrective external actions. In this way, the brain exercises control over homeostasis by using motor output to produce desired homeostasis-regulating inputs (Cisek, 1999).

——— FIGURE 1 HERE ———

In Figure 1, this feedback control processing architecture is illustrated in terms of a representation of current state (CS), which is compared to that of desired homeostatically-based goal state (DS) in a comparator "X", with the disparity driving continued motor output until CS more closely approximates DS. Simpler versions of this architecture often omit a principled representation of the current state, which must be coherently represented in order to be compared to desired state (DS), particularly when the CS of this particular processing module is not a simple biological marker such as glucose level, but the current spatiotemporal self-location of the agent

in relation to the environment. The ongoing coherence of this Current-State-of-Spatiotemporal-Orientation representation is maintained by the continuous structuring input from a memory buffer (Merfeld, 2001; Bridgeman et al., 1994; Neilson and Neilson, 2005) containing the self-locating event schema (SL EVENT SCHEMA). As explained, the *this-here-now* self-locating event schema, is an abstracted generalization over ongoing interactive experience which serves to organize ongoing phenomenal experience (Current State) in terms of an extended spatiotemporal manifold, or more fully, in terms of a self-moving causal agent continuously located spatially and temporally within such a manifold. The continuous activation of this schema configures experience as spatiotemporally-calibrated interaction between agent and environment such that self-movement can be calculated. But over time, evolutionary pressure has encouraged the exploitation of the potential discontinuity between orientational schema activation and the actual output of action, and consciousness-as-subjectivity is the result.

Due to Time and Energy-Efficiency Pressures, Self-Regulative Processing Architecture Evolves from Feedback to Feedforward

Cognitively endowed self-regulating biological organisms are particularly exposed to evolutionary pressures for energy efficiency because of the dedication of cognition to regulating homeostatic levels via energy-expensive motor output. Cognition essentially regulates homeostasis via action output. But the fact that the cognitive system has been constituted to function as a continuously moving platform presents two significant problems for the maintenance of homeostasis via self-movement: feedback processing is too slow for accurate control of a constantly-mobile cognitive organism (Churchland, 2002a), and in addition, too costly in terms of the energy-expensive of corrective actions. To overcome multiple delays in sensorimotor feedback loops (Miall and Wolpert,

1996), and eliminate the need for further corrective movements as far as possible, fast motor control must necessarily be anticipative as far as possible, involving a combination of predictive (anticipative) feedforward models of both muscle kinematics and the perceptual outcome of movement. On the energy-expense front, physical activity of any kind risks depletion of scarce energy reserves with no guarantee of replenishment. As a means of minimizing this risk, the central self-regulatory-processing mechanism has evolved from a feedback mechanism that corrects for homeostatic deviations, to feedforward processing that operates proactively through anticipatory actions to defend internal homeostatic conditions from becoming deviated.

Feedforward processing provides increased energy efficiency in several significant ways: most basically, predictive adjustment to ongoing motor output saves energy through improved accuracy and minimization of the motor trajectory (Wolpert and Flanagan, 2001). Anticipation of (rather than feedback from) environmental change reduces the ultimate effect and thereby, the amount of compensatory adjustment required (Brosilow and Joseph, 2002). In the case of anticipated danger for example, predictive feedforward circuitry provides the facility for complete avoidance (Prescott, Redgrave and Gurney, 1998). The capacity, in feedforward architecture, to represent the expected results of upcoming actions provides the basis for replacing aimless wandering with proactive, goal-focused foraging (Glasauer, 1992), as well as the anticipatory orientation of attention toward stimuli which are relevant for action in general (Mehta and Schaal, 2002). In addition, feedforward representation provides the capacity to completely replace energy-expensive external trial-and-error activity with internal mental planning (Mandler, 2002). Finally, feedforward goal representation supports not just trajectory minimization, but action minimization, the replacement of attack with threat (of attack), of extended bodily movement with gesture as the initial basis of communication.

The net result of these avenues to improved energy efficiency is a cognitive system capable of anticipatively self-regulating for homeostasis by means of feedforward processing mechanisms. The universality of this anticipatory feedforward architecture is reflected at several levels, including sensory processing (Glasauer, 1992), attention (Mehta and Schaal, 2002), motor control (Miall & Wolpert, 1996), including anticipatory postural adjustment for upcoming self-movement, and mental imagery (Kosslyn and Sussman, 1994). Consequently, several theories of cognition have been proposed (Cotterill, 1998; Hesslow, 2002; Barsalou, 1999; Grush, 2004; Jordan, 1998; Vandervert, 1995), based on the notion that cognitive representation is essentially engaging in simulated interaction with the environment by means of internal predictive internal models.

Most significantly, as regards the central claim of the theory outlined here, the dedication of cognitive architecture to an anticipative feedforward processing format (for speed and energy efficiency) implies that the recursive circuitry required to underwrite conscious subjectivity is most likely to have evolved out of such predictive cognitive architecture. Specifically, this theory proposes that evolutionary pressures for ever more energy-efficient sensory-motor processing has encouraged the progressive attenuation of feedforward processing circuitry into a simplified recursive feedforward circuit capable of underwriting autoreferential conscious self-awareness.

The architecture customarily used to model predictive feedforward processing casts the perceptuo-motor control system as a Markov processor whereby the current states of a process lead to its own future states when current motor commands exert their effect. These future states, in turn, update the current state (Grush, 2004, sec 2.1). Markov process models explain the mechanical operations involved in guiding the transition of present state into the next present state. These anticipatory processing mechanisms use predictive or "forward" perceptual models of what the future state will be (if we go ahead and execute this action) as a way of guiding the transition from

present moment to next present moment. Specifically, anticipatory self-regulatory-processing

architecture (as illustrated in Figure 2) utilizes four internal models to represent the various elements

of the predictive Markhov control system: models for the desired state (DS), the actual current state

(CS), the predicted future state (forward model FM) and a structuring schema which acts to configure

both CS and FM into a consistent event representation–the self-locating event schema (SL EVENT

SCHEMA) abstracted from the ongoing agent-to-environment interaction.

————— FIGURE 2 HERE —————

Within the feedforward control circuit (as with negative feedback loop), the desired

homeostatic state (DS) is constantly compared ("X") with the actual current state (CS), and actions

are generated on the basis of the difference between the two. But action generation necessary to

close the gap between DS and CS is not random trial and error. The system makes use of an

Inverse Controller (or inverse model) to provide motor commands specifically tailored to achieve

a desired sensory outcome state. When connected to a memory system that stores sensory-input

to motor-output conjunctions, the Inverse Controller is capable of retrieving motor output likely

to produce required sensory inputs (Held, 1968), of taking as input a perceptual representation of

the required adjustment and producing as output the motor movement that will result in

perceptual feedback incorporating that adjustment so that Current State (CS) becomes more

closely aligned with Desired State (DS). The Inverse Controller, in other words, translates the

desired perceptually-represented goal of a movement into the set of actions (a motor command)

needed to achieve that movement (Neilson and Neilson, 2005).

The Inverse Controller also produces a copy of its motor command (corollary discharge, efference copy) which provides the basis for a predictive or "forward" model (FM) of the expected perceptual result of that action. The forward model, in other words, uses efference copy of the motor command to predict the sensory consequences of those commands whenever movements are made (Miall and Wolpert, 1996). The forward model is able to feed into a DS comparator ("X") and anticipatively adjust ongoing action; at the same time, the forward model predictively updates CS in advance of feedback from actual motor output. There are thus three processing loops in this system: two fast internal feedforward loops from Inverse Controller to Forward Model which then (1) updates Current State as well as (2) feeding forward into a DS comparator to effect correction to motor output on the run. A third time-delayed loop (3) proceeds from the Inverse Comparator to motor output and feeds back to CS via the sensory systems.

The current state (CS) is the central representation in this control system because it is the end result that is being controlled for (or more correctly, its proximity to DS is being controlled for). Current State (CS) is constituted by three inputs: (1) continuous feedforward updating from the Forward Model; (2) periodic feedback from the sensory systems (as gated by expected feedback represented by the FM); and finally (3), CS is consistently structured as the representation of an interaction event by the structuring input from a memory buffer (Merfeld, 2001; Bridgeman et al., 1994; Neilson and Neilson, 2005) consisting of the self-locating event schema (SL EVENT SCHEMA). Based on brain imaging studies consistently identifying the posteromedial cortex as the neural source for conscious cognition (Laureys, 2004), and the direct innervation of this area by the wake/sleep arousal system sourced from the postero-lateral hypothalamus via the basal forebrain (Saper, Scammell and Lu, 2005), it is postulated that this structure-providing SL EVENT SCHEMA memory buffer is independently activated by the sleep/wake

innervation system, thus providing a self-activating base to the interactional configuration of waking experience.

The functional independence, as it were, of the SL EVENT SCHEMA feed is of particular importance, given that CS is a computation of spatiotemporal self-location updated moment to moment from self-movement feedback (as well as anticipatory FM of expected feedback). Without the initial structural input from the SL EVENT SCHEMA feed, CS would be utterly dependent on continuous movement for its activation. As the primary reference frame of the cognitive system, this would, in effect, hold the entire cognitive economy hostage to ongoing movement, both large limb ambulatory movement and tonic postural adjustment. The SL EVENT SCHEMA memory buffer is relatively independent of sensory feedback for its activation, and as a result of continuous evolutionary pressure to reduce energy-expensive physical activity to a minimum, it is encouraged to become more so, to sustain its activity through self cueing. Self-activation of ES accounts for the twin facts that (a) orientative self-locating spatial updating is automatic and continuous (Rieke et al., 2007), and (b) that self-location is still operative in deafferented individuals where there is no active sensory feedback from self movement (Meijsing, 2000). Additional evidence for the independent self-activation of ES can be gleaned from phenomena such as change blindness (Grimes, 1996), which indicates that the cognitive system does not depend on external feedback to maintain a consistently activated, self-located perceptual state. The driver for this continuity must be top-down, originating in its self-activated structural matrix, the SL EVENT SCHEMA.

Self-Regulative Processing Evolves from Feedforward to Recursively Feedforward

As noted in our initial treatment of the explanadum, it is the phenomenal properties of conscious self-awareness that need to be explained, and primary amongst these, the self-referring or recursive quality of subjective self-awareness, which underwrites the feelings and sensations of qualia. Several existing explanations of phenomenal subjectivity refer to psychological processing mechanisms which are not, in themselves, recursive in nature, such as Daniel Dennett's multiple drafts (a series of static updates), or secondary processing theories such as higher-order thought (Dretske, 1993), attentional highlighting of representational content (Crick, 1984), linguistic coding (Edelman, 1989) or global accessibility (Dennett, 2001; Baars, 1988), where the additional processing of a perceptual representation somehow confers qualia-like status upon it. But in each case, the process doing the consciousness-conferring work does not employ autoreferential processing circuitry and is not itself self-consciously aware. A more credible candidate for the generation of autoreferential self-awareness (consciousness-as-subjectivity) would be a self-referring cognitive mechanism, a processing circuit which is itself recursive, continuously and anticipatively feeding forward into or 'referring to' or 'recognizing' itself. This is the solution proposed here. In a nutshell, everything currently known about he evolution of cognition points to a consistent increase in attenuated processing of existing circuitry as a more energy-efficient way of maintaining homeostatic self-regulation through self-movement. Attenuation of feedforward circuitry (Figure 2) leads to fully *recursive* feedforward circuitry (Figure 3).

Attentuation plays a major role in the metamorphosis of the self-locational updating module from a merely anticipatory feedforward mechanism to a recursively-feedforward processor. For cognitive organisms, where cognition is essentially designed to maintain homeostasis through self-movement, the drive toward improved energy efficiency necessarily involves both brain and body operating efficiencies. In both instances, *attenuation* constitutes a

common theme. When somatically active, all movements are constructed on a minimum-trajectory basis which is managed by last-minute, only-as-much-as needed adjustments (Todorov, 2004). Periods of behavioral torpor (sleep, hibernation) can be seen as a way of limiting active self-to-environment interaction to only the most energy-rewarding periods. Proactive foraging that deploys top-down feedforward circuitry to focus activity on specific targets is, again, a form of attenuated activity. And the development of communication from bodily gesture can also be seen as embodying this tendency toward attenuated somatic activation. Undoubtedly, the most extreme form of behavioral attenuation is exhibited in surviving species of primitive tunicates which abandon both somatic (tail, tail musculature) and cognitive (brain, nervous system) capacity for motility altogether. Surviving forms develop a gut, gills and brachial structures which are present but no longer operative (Llinas, 2001), indicating that these creatures have regressed from what was once a more actively-motile life, to a highly-attenuated 1-day excursion to find a suitable substrate to attach itself before resuming a permanently sessile existence.

Attenuation is particularly critical for cognitive processing, because the brain, unlike the body, expends most of its energy on active information processing, not metabolism. Where the soma devotes 70% of its energy budget to ongoing metabolism and the balance to behavioral activity (posture, locomotion, mating), cognitive costs are the reverse. The brain expends 80% of its energy on information processing as opposed to purely metabolic activity (Attwell and Laughlin, 2001). Thus, the achievement of energy economies in the way information is processed have a significant impact on the overall energy expenditure (Attwell and Laughlin, 2001) and the cognitive economy, as a result, is replete with cost effective information-processing mechanisms such as sparse coding (Churchland, Ramachandran and Sejnowski, 1994) and minimal updating of scene (Rensink, 2000), schema abstraction for memory storage (Hess and Flannagan, 1992),

and attentional limitation (Mack and Rock, 1998). Attenuation of the feedforward processing architecture leads to the development of recursive processing circuitry.

This evolutionary attenuation is facilitated by the hierarchical organization of sensorimotor functionality. Introduced by Hughlings Jackson (1884/1958), the hierarchical understanding of the neurocognitive system, in which the brain is seen as implementing multiple levels of sensorimotor competence, has been supported by anatomical, physiological and behavioral research (Prescott, Redgrave and Gurney, 1998). Both sensory input feeds and motor output are arranged in a hierarchy of successively more complex processing channels, and behavior itself can be decomposed into successively simpler units as levels of the neuraxis are surgically removed. Included within this sensorimotor hierarchy, orientational mechanisms (spatial updating and path integration) have been located at several levels of the neuraxis, including the cortex, mammalian hippocampus and brainstem superior colliculus. This hierarchical layering of sensorimotor functionality, including self-orientative processing, allows for the evolutionary attenuation of circuity at the most senior level of the hierarchy toward the simplified, fully recursive circuitry that generates consciousness as subjectivity, leaving lower levels unchanged, where they continue to function in an unconscious mode.

Understood in terms of the ongoing interactive event, which consists of an initial self-locational calibration (*this-here-now*) followed by action output, attenuation of the senior level of sensorimotor processing proceeds on three fronts: (a) an extension of the initial orientative phase of interactional processing while minimizing the subsequent physical action component; (b) the development an extremely truncated feedforward processing circuit within the orientational phase itself, facilitated by decreasing dependence on feedback from self-movement as major driver of the circuitry, and an increased capacity to complete its feedforward processing loop internally; and (c), decreased input from movement-related external feedback and internal

feedforward content, allows the two principal data structures (CS and FM) to consist increasingly

of the structural input of the orientational self schema (Figure 3, panel 'b') . This attenuated

circuitry consists eventually, at the seniormost level, of the orientational schema feeding forward

immediately into itself, independent of additional representational feedback from self-movement

(panel 'c'). This recursive self-conversation, as it were, constitutes the rudiments of subjectivity,

so that the recursive processing underwriting conscious subjectivity emerges, in effect, from the

increased evolutionary fitness derived from the capacity to remain cognitively alert while

physically inert, exchanging energy expensive physical activity for low-cost pre-physical

orientative processing. Thus, the primary (but certainly not the sole) adaptive value of recursive

conscious processing is energy efficiency.

Figure 3 illustrates the specifics of this evolutionary development from feedforward to

recursively feeedforward processing circuitry. Here, cs constitutes the final representative

product—the current state—of the self-locational feedforward processing architecture. It is

normally understood that continuous spatiotemporal updating involved in this process is driven

largely by external sensory and internal proprioceptive feedback from self-movement. But given

the hierarchical character of orientational processing consisting of a series of such feedback

calculations, it is possible for the top tier of the processing circuitry to evolve away from absolute

dependence on feedback from physical self-movement without the entire motor control hierarchy

grinding to a halt. Evolution encourages development in this direction because it produces

cognitive circuitry that can remain activated without reliance on actual energy-expensive

physical movement. Organisms than can remain cognitively alert while minimally active at the

physical level have increased fitness.

————————— FIGURE 3 HERE —————————

Increased reliance of the self-locational processor on internal drivers for continuous activation begins, as we have noted above, with the self-cueing EVENT SCHEMA that provides the basic structure of first the CS and eventually both CS and FM representations. Continued evolutionary pressure for increased energy efficiency then, encourages further development in the familiar form of attenuated processing. In the particular case of self-locational updating, this consists of decreased reliance on feedback from external physical self-movement (shown in Figure 3 as a change from heavy to light connectivity in the external loop) along with increased emphasis on the internal processing circuit comprised of the reciprocal CS-FM circuit. Decreased external self-movement also means that both CS and FM can be envisaged as consisting to an ever-greater extent of the structural input from the SL EVENT SCHEMA memory buffer. As it does so, the CS-FM circuit is able to become ever more tightly interlocked because more completely based on its own arousal feed for self-activation, and less dependent upon the DS comparators as drivers. Essentially, this enables the self-locational calculation to complete its cycle within the CS-FM circuit alone. CS drives FM, and FM drives CS where each, eventually consists solely of the 3-parameter SL EVENT SCHEMA.

This highly attenuated positive feedback loop is now completely recursive, and driven by a self-activating memory buffer which is directly linked to the wake-sleep cycle of its principal arousal feed sourced in the lateral hypothalamus. The recursively-processed content consists essentially of the same SL EVENT SCHEMA represented as current *this-here-now* state (CS) and the expected next current *this-here-now* state (FM).[4] The CS-FM circuit has emerged as a stand-alone recursive working memory loop or reverberatory circuit consisting of the *this-here-now* Event Schema referring continuously back upon itself. Because it is self-activating and thus tonically sustainable as well as supremely energy efficient, this new form of self-locational

alertness becomes the default processing state of active cognition; a default state of recursive *this–here-now* schema processing which manifests at the phenomenal level as subjectivity, conscious self-awareness.

Consciousness-as-subjectivity, therefore, can be considered the by-product of incessant evolutionary pressure on cognitive organisms for greater energy efficiency, pressure that has driven the existing self-regulatory FC architecture toward greater attenuation via a more tightly recursive format involving the CS-FM-CS working memory loop such that the orientational schema phasing between an immediate present (CS) and immediate future (FM) as itself, is simultaneously anticipating and recognizing itself, or tonically monitoring itself in the form of *i-here-now.*

In terms of Nagel's sense of subjectivity wherein there is always "something it is like to *be* that organism, something *for* that organism (Nagel, 1974); that "something it is like to be" is everywhere and always primarily what it is like for that organism to be an *this-here-now.* The recursive *this-here-now* is always what subjectivity is like. As outlined in the first section of this proposal, subjectivity consists in experiencing oneself as here and now at every moment in every circumstance. This being oneself here and now has an immediacy which, even at the level of a primitively subjective creature would manifest as both agency (*this is (or "I am") performing this act*) and ownership (*this body is part of me*) such that before initiating any intellectual operations or discursive thought (in the case of humans), or without any metacognitive processing in a primitively subjective creature, I am already "directly" acquainted with the contents of my self-consciousness. Self recognition entails self-discernment: I always know which one is me, which one I am (even without the additional metacognitive capacity to reflect upon that fact) as distinct from the landscape and other conspecifics. Even at a primitive level of conscious subjectivity then, a creature with self-awareness would never be unfamiliar with itself, never surprised by its

own presence, and would experience itself as being *identical* through time (although, again, without the capacity for metacognitive representation of its own states, it would not actively notice or reflect upon this continuity). A creature with subjectivity experiences its body parts as part of itself, and experiences its acts as initiated and performed by itself.

At the phenomenal level, consciousness-as-subjectivity arises as a singular unified field of self-awareness because underwritten by a single schema, processed continuously in an autoreferential or recursive style where "self" is always experienced, subjectively, as an "this" explicitly located "here" and "now". This recursive *this-here-now* processing provides the basis of subjective self-awareness, of what it feels like to be oneself here and now. Consciousness is essentially subjectively-experienced spatiotemporal self-location.

Conclusion

Consciousness bears the self-locational content that it does because orientation grounds the behavioral output of any self-moving cognitive platform and provides the crucial parameters by which behavior can be controlled. Framed in the egocentric perspective of that self-moving platform, the structural parameters (spatial, temporal and causal) of the ongoing, constantly-updated orientational event are abstracted and fused into a single schema, the activation of which provides the basic reference frame for ongoing cognitive experience. Based on the principle of neuropsychological identity, consciousness-as-subjectivity manifests as a unified singularity because it is the recursive processing of this single self-same schema.[5] Based on that same principle, the autoreferential character of conscious cognition can be said to arise directly in consequence of the recursive style in which the self-locating orientational schema is processed, a form of tightly self-referring circuitry which derives from attenuative evolution of feedforward architecture into recursively feedforward processing regime.

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Footnotes

1. Not least amongst these issues would be the largely unresolved question as to the precise neurological underpinings of representational content. As long as the relationship between the underlying neuro-physical processes and symbolic (representational) properties remains obscure, the notion of mental representation cannot be said to constitute a fully established explanatory primitive, although the principal of neuropsychological identity remains in effect. At the philosophical level, much attention has been directed to the related question regarding the necessary connection between cognitive (representational) experience and brain functionality. Philosophers have argued that because cognitive "zombies" (creatures possessing the requisite brain functionality without being consciously self-aware) are *logically* possible (Kirk, 1974; Chalmers, 1996), then it cannot be claimed that recursive self-awareness necessarily accompanies recursive brain functionality. But as Flanagan & Polger point out (1995, p.3; cf Churchland, 2002a: pp. 176-8; Heil, 2003: p. 229; Cottrell, 1999) and *even* Chalmers himself admits (1996, p.269), the credibility of this kind of argument, based as it is on the evidentiary force of logic alone, holds only outside a naturalistic framework. Within the naturalistic framework of empirical neurospsychology adopted in this proposal (see *Evolution of The Architecture of Consciousness* below), all properties and processes are understood to be natural properties and processes explainable in terms of naturalistic laws (physics, chemistry, biology), such that cognitive properties accompany neurological characteristics as part of a neuropsychological identity, and the evolutionary context of all biological phenomena (including cellular signalling in the form of nervous systems) is understood to answer to biological, chemical and physical but not logical imperatives. Logic <u>*in and of itself*</u> has no evidentiary force whatsoever within a naturalistic framework– things are not so simply and solely because it can be argued philosophically that it follows, logically, that they should be so, or that they can be imagined to be so. Empirical evidence

determines facts. Consequently, the zombie argument simply has no legitimacy and should never have been introduced.

2. A sophisticated theory of consciousness has been developed by Vandervert (1995) and Jordan (1998) construing consciousness as the ongoing activation of an internal body template (which they derive from Ronald Melzack's notion of a phantom limb sensation) yielding the conscious "feel" of bodily presence in space-time, including self ownership and location. This continuously generated feedforward template of the body in space-time (Vandervert 1995, p.113) is said to be generated by a primitive self-other discrimination comparator (Jordan, 1998, p. 168). With its emphasis on space-time self presence and anticipatory processing (see note 4 below), the Vandervert-Jordan theory resembles the explanation of consciousness as recursive, spatiotemporal self-location outlined here. It should be noted, however, that the theories differ significantly in regard to (1) the data structure *(body template vs self-location template),* (2) the processing mechanism *(self-other comparator/self-location),* and (3) the fact that, in concert with Revonsuo (2005), the Vandervert-Jordan theory assumes that spatiotemporal processing is conscious in and of itself, while the self-locational theory insists that consciousness-as-subjectivity requires the evolution of *recursive* anticipative processing circuitry.

3. Gibson (1979; cf. Neisser, 1988; Bermudez, 1998) insists that information about the self is directly perceived in the form of the boundedness of the field of vision as well as the occlusion of portions of the visual field by parts of the body such as the nose and hands.

4. The idea that consciousness consists of the merger of the immediate present with the immediate future can also be found in the philosophical explanation of the phenomenal present moment as a blend of past, present and future. Natika Newton and Ralph Ellis contend that the 'temporal thickness' of conscious awareness derives from a weaving together of new sensory input with the memory of immediate past input, along with

anticipations (expectations) of immediate future input. (Newton, 2001). Within the cognitive science field, several authors have indicated that anticipative internal simulation in the form of forward models will in some unspecified way be found to support conciousness (Haggard, 2005; Hesslow, 2002; Cleermans, 2005; Fourneret et al., 2002). Taylor has argued for a notion of consciousness as anticipatory attention (2002). A strong case for the anticipatory character of consciousness has also been developed by Vandervert, Hershberger and Jordan. In his original proposal regarding consciousness as "the experience of the body-in-space-time,Vandervert referred to the feedforward character of the processing. Hershberger-Jordan have further emphasized the anticipatory nature of the perceived body-in-space-time template which encodes the coordinates and generates a perception of the body in space-time, by styling it an "extrabody signal" (Jordan 1998:167) generated in the same way as the anticipatively perceived extra-retinal signal of upcoming eye position—the "Phantom Array" (Hershberger, 1997; Jordan, 1998).

5. Mandler (2002, p. 45) points out that 'experiences are seamless and unitary to the extent that they activate existing schemas'.
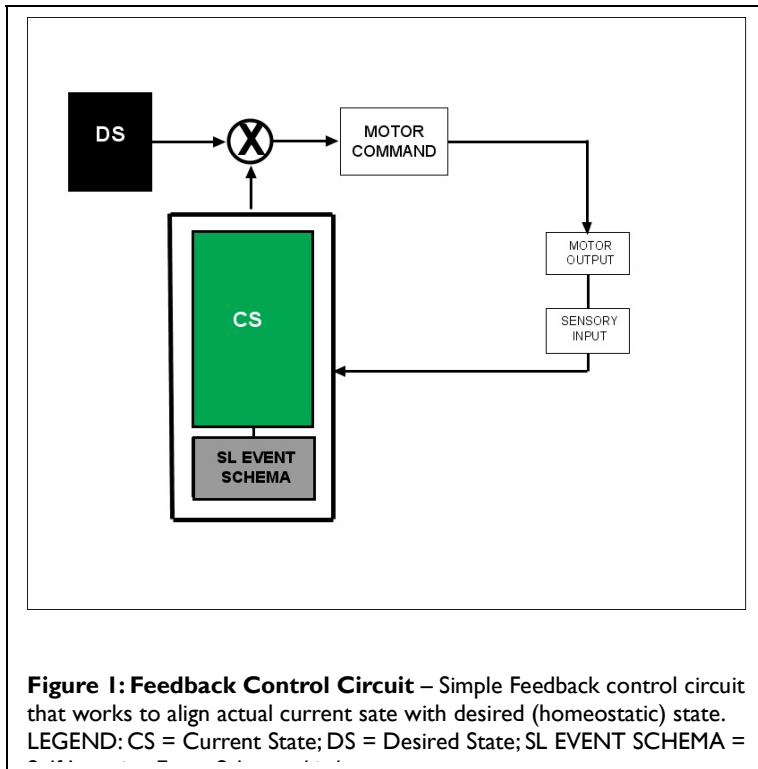
Figure 1: Feedback Control Circuit – Simple Feedback control circuit that works to align actual current sate with desired (homeostatic) state. LEGEND: CS = Current State; DS = Desired State; SL EVENT SCHEMA =

Figure 1

Figure 2: Feedforward FM to CS with Self-Cueing SL Event Schema for greater energy efficiency via improved accuracy of movement trajectory. The INVERSE CONTROLLER takes as input the *current state* (CS) of a system as compared to the *desired state* (DS) and produces as output the action required to eliminate disparity (outer loop), as well as corollary output consisting of a motor command which is then further transformed into prediction as to the *next perceptual state* (FM) of the system (inner loop). FM takes as input SC + IC motor command copy. CS takes as input EVENT SCHEMA parameters, the FM of upcoming self-movement, and external sensory feedback from self-movement. DS takes as input homeostatic needs. *(Adapted from Miall et al 1993; Neilson & Neilson 2005)*
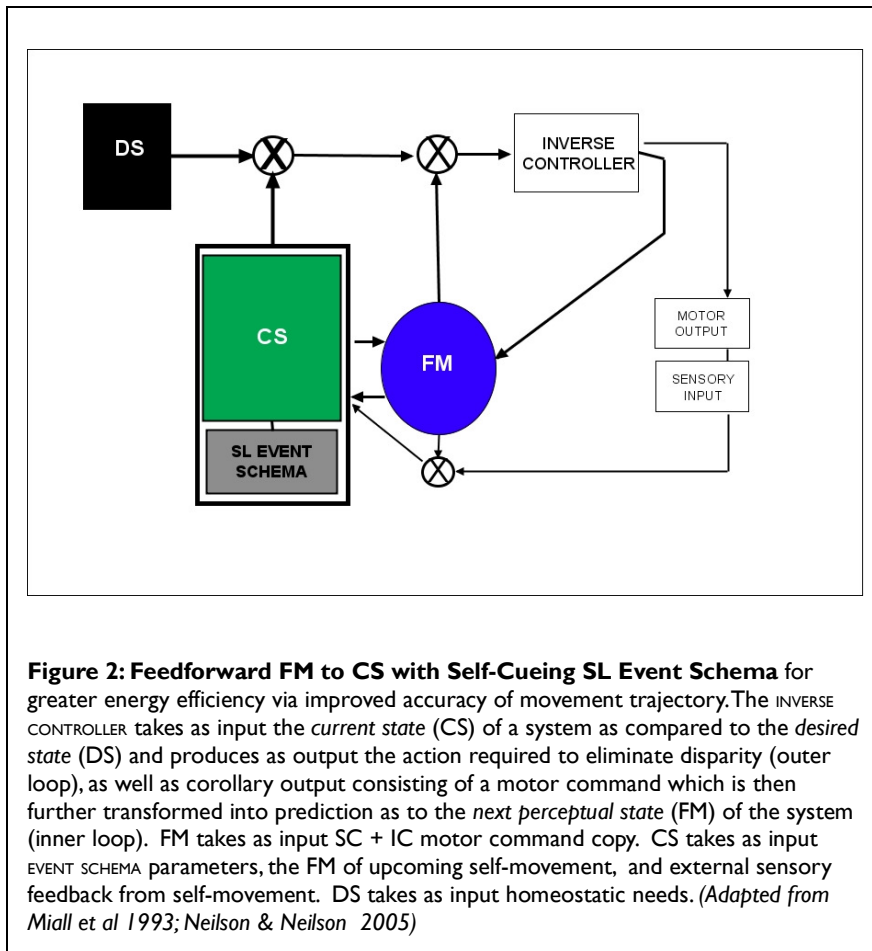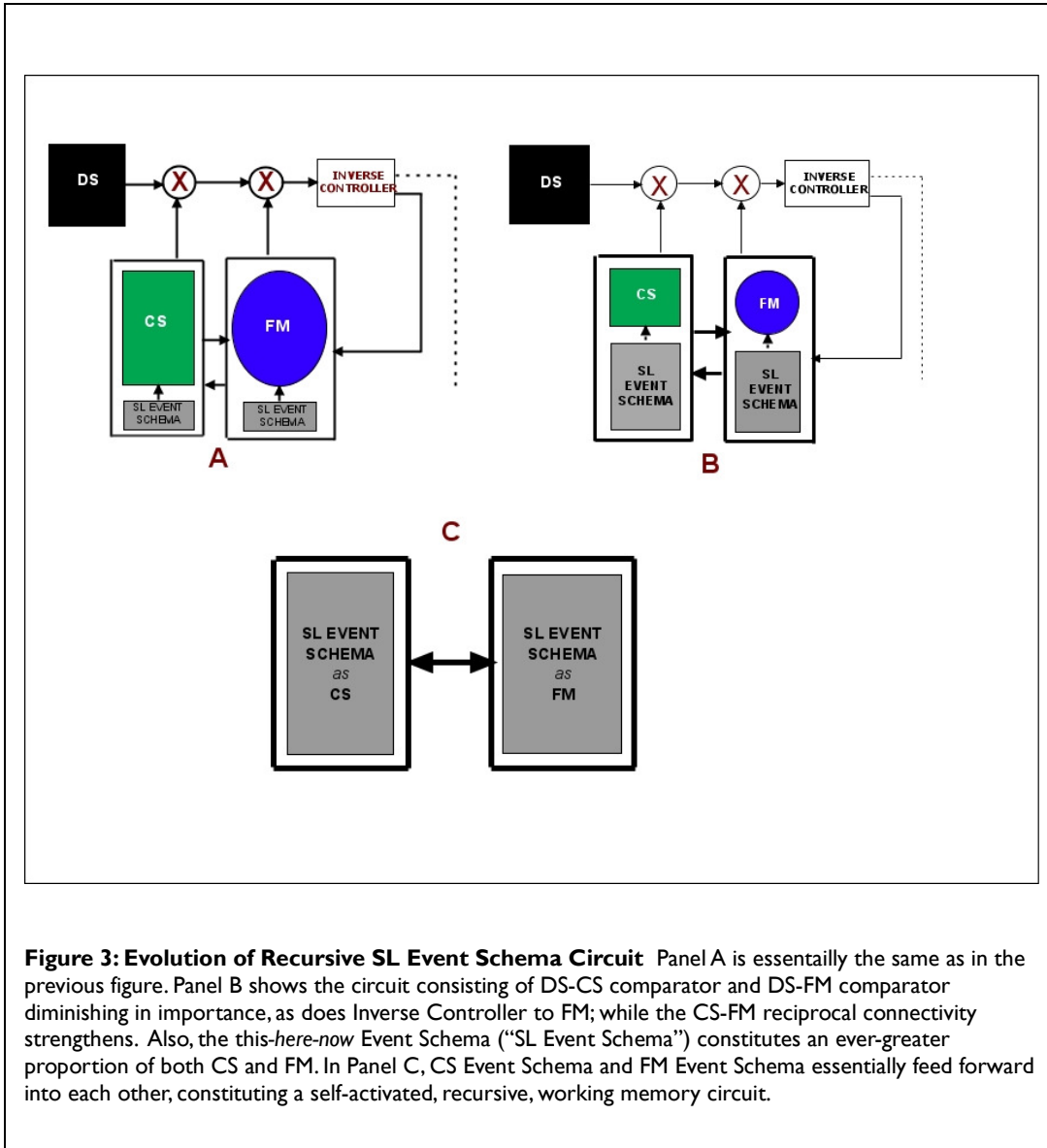
Figure 2

Figure 3: Evolution of Recursive SL Event Schema Circuit Panel A is essentailly the same as in the previous figure. Panel B shows the circuit consisting of DS-CS comparator and DS-FM comparator diminishing in importance, as does Inverse Controller to FM; while the CS-FM reciprocal connectivity strengthens. Also, the this-*here-now* Event Schema ("SL Event Schema") constitutes an ever-greater proportion of both CS and FM. In Panel C, CS Event Schema and FM Event Schema essentially feed forward into each other, constituting a self-activated, recursive, working memory circuit.

Figure 3