Objects of Thought, Thoughts of Objects ?

From object-orientation to Process Physics

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Abstract

To resolve the current impasse between realistic and anti-realistic thought, I'd like to explore their latent neurocognitive origin. Since our brain's self-referential neurocognitive mechanisms generate neural and mental patterns that ultimately pose as object-oriented units, they predetermine our mental modelling of reality, thus usually making us firmly believe that reality *is* ultimately object-based. This firm belief is the actual instigator of the strict, but imaginary boundary between physical and mental reality. By discussing self-organizing selectionist threshold models of complex systems, I will illustrate an alternative for the traditional object-oriented realistic and antirealistic schemes: process-oriented reflexive monism, which facilitates a framework for consciousness based on complexity science and is compatible with the recently developed pioneering paradigm of Process Physics. Moreover, an evolutionary account of an autopoietic (i.e., self-creating) natural universe is presented which is fully compatible with the pioneering paradigm of Process Physics.

CONTENTS:

1 INTRODUCTION

Historically, the concept of knowledge has always been a central topic in the philosophical arena. Although there is reasonably common agreement that knowledge should be justified, true and believed, there's ongoing debate on how these criteria should be met, if they're sufficient, and how they relate to one another. Consequently, many competing philosophical doctrines have put forward their own foundationalist account of the nature and origin of knowledge as the only possible and correct one [Fumerton 2000, 2005]. Over the years, this has caused realism (claiming that the natural world exists independently of perception) and antirealism (claiming that the existence of 'the natural world' cannot be verified beyond experience) to end up in a seemingly inescapable impasse. Furthermore, till present date, the contemporary methods of knowledge analysis (for instance: JTB-analysis[1], linguistic analysis, constitutive analysis, analytic and synthetic analysis [Shope 2004, 283-286]) have not been able to provide us with any convincing clues on whether knowledge should be considered in a realistic or anti-realistic sense.

To find a way out of this standstill situation, I'd like to explore the latent neurocognitive origin of realistic and anti-realistic thought. Executing a program like this would honour Steven Wolfram's suggestion that: "To explain our actual experience of the natural world, we need to consider not only how phenomena are produced in nature, but also how we perceive and analyse these phenomena" [Wolfram 2002]. So, instead of only investigating *natural phenomena, their origins, and propositions about them*, Wolfram thinks we should also take into account the *mechanisms through which we become aware of the natural phenomena*.

Additionally, since many foundationalists have stated that basic belief emerges from non-doxastic mental states[2], cognitive neuroscience could supply us with important clues on how to overcome the impasse between realism and antirealism. After all, in suggesting that the body/mind problem implies a nonexistent gap, Max Velmans has already advocated that 'physical phenomena' and the 'phenomena we experience' cannot be seen separate of one another [Velmans 1995, 2000]. Hence, the ability of our neurocognitive mechanisms to discriminate upon somatosensory input (as found in perceptual categorization, pattern recognition, focal attention, etcetera) could very well be the actual creator of this artificial border line, and correspondingly the gap between realistic and anti-realistic thought may very well have been caused by the neurocognitive origin of knowledge itself.

For sake of clarity and comprehensiveness, this paper will commence with a *definitions* section, followed by a more focussed account of *realism and antirealism*. Subsequently, *neurocognitive mechanisms of discrimination* are reviewed – including a survey on the neurocognitive origin of 'objects' to be discriminated upon. How this 'object-orientation' permeates and contaminates the conventional paradigms of *dualism and reductionism* is discussed in section 2.1. Then – following the introduction of *emergentism* and *supervenience* (section 2.2) as an interesting, but deficient alternative to dualism and reductionism – self-organizing dynamics are put under closer scrutiny by discussing the self-organizing mechanisms of *mutual entrainment* (an effect in oscillatory systems), *brain plasticity* (a mechanism in brain ontogeny), and *reentry* (large-scale neural self-reference) throughout sections 2.3 to 2.5. Culminating towards the end, in chapter 3 it is examined how embodiment could unify *body and mind* to yield conscious experience and non-representational memory. A *threshold model for higher-order patterning* is introduced, to illustrate how truly complex systems could self-organize towards a critical state, where conditions for system-wide sentience can be sustained. Finally then, it is shown how autopoiesis (self-creation) can provide efficacious process-oriented foundations for the natural universe and its phenomena (including experiential consciousness).

[1] Knowledge analysis which focuses on justification, truth and belief.

[2] In the *non-doxastic assumption* sense-perception (through somatosensory input and/or mere neural patterns) is thought *not* to contain any truth or falsehood in sense-perception, so accordingly, we shouldn't expect sense-perceptions or memories to be justified or justifiable. On the other hand, *doxastic coherentism* holds that every justified belief receives its justification from other beliefs in its epistemic neighbourhood. [Steup 2005, 2006]

1.1 THE NEED FOR DEFINITIONS?

The very purpose of a definition is to capture the essential properties and characteristics of the entities, objects, events or processes denoted by the concept to be defined. At the end of the day, definitions intend to grasp what uniquely and universally identifies the definiendum *from everything else* [Spuzic & Nouwens 2004]. However, the ability to distinguish between things – as is required when constituting definitions – is dependent on our abovementioned neurocognitive mechanisms. And since the possibility exists that these mechanisms – through comparative processing – construct recognizable structures that would otherwise be left 'unmarked' and '*indistinguishable*' (!) [3], the concept of 'definition' itself is at stake. For in that case, a definition would not simply identify an intended definiendum from everything else, but rather it would particularly denote the distinguished result of the interdependent dynamics between the inseparable whole of environment and neurocognitive system.

Put short, the employ of definitions actually requires the presumption that distinctive properties and characteristics are really '*out there*' to be captured – independent of our distinguishing neurocognitive mechanisms – otherwise there would be nothing to identify from anything else. However, such a view on definitions would deny the *inseparability* of 'physical phenomena' and the 'phenomena we experience' as mentioned by Max Velmans (see above; section 1). In fact, it is premature to use 'objects' (i.e., concepts, entities and the like, posing as stand-alone individuals that can be distinguished from everything else) in a definition *prior to* the confirmation if these object-oriented entities – as used in that definition – should actually occur '*out* there', or exist as such. Since this confirmation can ultimately only come from empirical experience (our cognition), while it is our very cognition *itself* which has provided us with this distinguishing, object-oriented experience of reality, this results in confusing circular reasoning.[4]

In mathematics such forbidden constructions are labelled impredicative. According to Henri Poincaré, the definition of a set or a totality is considered impredicative when it depends on the definition of the elements constituting the totality in question [Van Dalen 1978, 85]. Whenever exhaustive definitions are strived for, totalities are constructed that are fully dependent upon the definition of their elements and vice-versa. In Poincaré's view, whenever one is defining a set (or totality), the decision whether or not an element belongs to that set, should not depend on any results that become apparent later on within the set-theoretical universe [Ibid.]. In line with Poincaré, Russell prohibited impredicative definitions through his *vicious circle principle*: "No totality can contain members definable only in terms of this totality, or members presupposing this totality" [Ibid.]. This vicious circle principle led him to develop a *stratified* conception of set, to avoid the circularity of Russell's paradox[5]. However, Poincaré objected to employing the rule that self-reference and circularity in set theory is forbidden, *after* the application of the involved axioms provide the necessary knowledge that a ban on self-reference should be required. It is basically a *deus ex machina* measure to do so, and it undermines the requirements that are usually demanded for axioms (cf. the definition of "axiom" mentioned below):

Axiom: *An axiom is a proposition whose truth can immediately be comprehended, and which forms the basis of a formal system. Without the need or possibility of a more fundamental proof, an axiom is taken to be valid or even self-evident, and serves as a necessary starting point for deducing and inferring further results.*

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[3] Cf. William James's renowned 'big blooming buzzing confusion' [James 1911].

[4] Please note that this problem cannot be solved by referring to non-doxastic mental states (i.e., somatosensory input and/or mere neural patterns, which cannot contain any truth or falsehood), since identifying mental states, somatosensory input and/or neural patterns as object-oriented stand-alone indivduals is dependent upon our distinguishing cognitive abilities.

[5] On Russel's stratified conception [Boolos 1998, p.3], the elements of any set exclusively come from the immediately underlying level. In this way, the internally contradictory result of Russell's paradox can be avoided. That is, in Russell's paradox the set of all sets that do not contain themselves as an element seems to be an element of itself only, and only if it is not an element of itself.

On judging the requirements in the abovementioned definition Poincaré strongly believed that, in order to be called an axiom, a statement has to serve as a necessary starting point for deducing and inferring further results, *not the other way around*.

Analogously, in order to attain definitions that are truly purposeful with regard to the 'capturing capabilities' mentioned above, it requires fundamental elements to serve as a necessary starting point for the totality in question, not the other way around. That is to say, if our cognitive abilities are to be considered an inseparable part of the totality of reality, it would be improper to accept the existence of elements of this totality, solely based on the authority of an inseparable *part* of the totality: our distinguishing cognitive abilities. Such a construction can rightfully be considered impredicative in the way Poincaré envisioned.

In light of these findings, *exhaustive* definitions – exhaustively identifying the definiendum from everything else – should not be considered a possibility. Since these abovementioned definition difficulties particularly become manifest when definiendum and defining system overlap (i.e., when the idealisation of 'separateness' can no longer be sustained), in these cases an alternative mode of description would be illustrative and very valuable. For this purpose, it would seem appropriate to state (following a more process-oriented, 'Wolframian' route) that 'consciousness', 'mind', 'neural-mental patterns', and their ilk – in comparison to underlying physical and neuronal structures – simply denote a *more complex, higher-order level of organisation within the whole of reality's interacting dynamics*. This has already been pointed out similarly within the fields of developmental psychology [Fischer 2006; Fischer & Bidell 2006], dynamical systems theory [Baas 1994; Baas & Emmeche 1997; Helvik 2005], and also neurology, as is illustrated by leading neurologist Antonio Damasio in [Damasio 1999, 337], where he mentions that: "The term mind […] encompasses both conscious and non-conscious operations. It refers to a *process*, not a thing. What we know as mind, with the help of consciousness, is a continuous flow of mental patterns, many of which turn out to be logically interrelated."

Treasuring this line of reasoning, in the following sections, I will investigate how underlying dynamics and higher-order patterns develop and relate to one another. However, before going into greater detail concerning our brain's neurocognitive mechanisms, first I'd like to shed some more light on the abovementioned connection between (anti)realisms and cognitive neuroscience.

1.2 REALISM, ANTIREALISM, AND OBJECT-ORIENTATION

Although many different forms of realism can be distinguished, two general aspects are commonly considered essential: *existence* and *independence*. Realists typically claim the objective existence of reality (or any particular subject matter in question), independently[6] of the ways we think about it or describe it. A typical account of scientific realism is put forward by Robert Nola [Nola 2002, 1]:

> "Metaphysical, or ontological, realism with respect to the observables of science is the view that unobservable objects, properties of objects, events and processes exist independently of what we believe, receive or see there is in the world, or what linguistic framework, we used to talk about world. […] under this heading can be found the scientific entity realism advocated by Ellis, Devitt, Hacking, Cartwright and Hellman, amongst many others. … Such a [robust scientific] realism stands opposed to varieties of anti-realism ranging from constructive empiricism (which remains sceptical, not only about the truth or verisimilitude of our theories even though the theories do have truth values, but also claims about what exists), to the constructivism of many sociologists of science."

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[6] "Although there is a clear sense in which a table's being square is dependent on us (it was designed and constructed by human beings after all), this is not the type of dependence that the realist wishes to deny. The realist wishes to claim that apart from the mundane sort of empirical dependence of objects and their properties familiar to us from everyday life, there is no *further* sense in which everyday objects and their properties can be said to be dependent on anyone's linguistic practices, conceptual schemes, or whatever." [Miller 2005]

When trying to take into account the way we perceive and analyse reality – as Wolfram suggested – it's quite striking that apparently the notion of 'object-like entities' or 'individuals' is entirely taken for granted within definitions of realism, and antirealism. However, given the risk of impredicativity, it seems to me that taking any premature position on the physical or mental status of 'objects' goes beyond the scope of any (anti)realism definition.

That is, distinguishing object-oriented entities *first* requires a definite outcome concerning the (anti)realism issue, since drawing the border between the physical and the mental *already* involves distinguishing reality in an object-oriented sense. Explicitly judging physical and mental structures as separable effectively entails treating them as if they were stand-alone 'objects'. Here, I'd like to mention Jean Piaget's argument that the later-arriving acts of 'object recognition' performed by nurslings – this only starts from the second week of life – do *not* imply, prove or even suggest that the universe is really cut up into objects, that is, into things conceived as permanent, substantial, external to the self, and firm in existence [Piaget 1954, 5].

This line of reasoning clearly urges us *not* to draw any premature conclusions on the existence of 'objects' as actual stand-alone structures within physical reality. Eventually, distinguishing between *the natural world* and *experience of the natural world* on the one hand, and between 'objects' within either *the natural world* or *(phenomenal) experience of the natural world* on the other hand, is ultimately based upon the same neurocognitive mechanism of (pre)conscious discrimination. In this way, the implementation of 'objects' in a definition of realism or antirealism, is unwarrantedly presuming 'objects' to be prior to the neurocognitive mechanisms yielding 'object-experience', thus putting together impredicative definitions of realism or antirealism.

Although distinguishing between observable and unobservable parts of reality is already a dubious thing to do – for it facilitates the application of ambiguous concepts[7] – incorporating separate entities within the (anti)realism definitions is *certainly* unwarranted. To avoid such undesirable a priori assumptions, for the time being, until an appropriate alternative has been identified, I'd like to propose to preferably use the following straightforward (instead of exhaustive) definitions of realism and antirealism:

Realism: *doctrine stating that the natural world exists independently of (perceptual) experience.* [8]

Antirealism: *doctrine stating that the existence of the natural world cannot be verified beyond experience.*

A supplementary overview of scientific realism will complete the picture. And although many accounts of scientific realism can be found in the philosophical literature [e.g., Leplin 1984; Psillos 1999; Nola 2002] I prefer to use Samir Okasha's quite clear and compact summary [Okasha 2002, 59]:

"Realists hold that the aim of science is to provide a true description of the world … [whereas] anti-realists hold that the aim of science is to provide a true description of a certain *part* of the world – the 'observable' part. As far as the unobservable part of the world goes, it makes no odds whether what science says is true or not, according to the anti-realists. ... [T]he realist thesis that science aims to truly describe the world and the anti-realist thesis that science aims to truly describe the observable world obviously coincide, as far as the study of [concrete objects, events and processes] is concerned."

In order to withstand historical examples of empirically successful theories that later turn out to be false, a branch of realism developed, which claimed that scientific theories should be considered to *approximately* describe what is *actually* going on. Whether or not 'an approximately true theory' can be considered an acceptable concept, a necessary condition is surely that the entities the theory

[7] As mentioned above, concepts like consciousness, mind, and neural-mental patterns involve an overlap of definiendum and defining system. This brings about a mutual interdependence of the natural world and perceptual experience that is not adequately covered by conventional (anti)realism definitions.

[8] See footnote 6.

talks about really do exist [Okasha 2002, 65]. And although the realism-antirealism dichotomy has long been considered to be essential when it comes to scientific truth, it leaves a somewhat twofold secondary question still unanswered. That is, the question if **(a)** when realism has it right, are there also actual 'objects' out there in the natural world to which our thoughts refer (i.e., the '*objects of thought*'), or **(b)** when antirealism is the way to go, can we legitimately consider '*thoughts of objects*' (in an anti-realistic sense) to be actual autonomously existing 'objects' within mental reality?

Given the abovementioned findings concerning impredicative definitions and the inseparable interconnectedness of defeniendum and defining system, we cannot make any premature claims on the physical or mental status of 'objects'. So, the very discriminatory experiential cognitive system, which is considered fundamental to the (anti)realism issue, acts as the ultimate judge concerning its own independent actual existence with respect to the outer natural world. This is similar to a map depicting itself as a simplified object upon itself (in this way indicating: 'this is the location of the map'), thus suggesting or even predetermining that the simplification is correct.

Besides – although largely overlooked within traditional philosophy – it's already been recognised throughout various fields of science that the notion of 'object' should not be taken for granted. As indicated by the following quotations, it's not unusual to be explicitly sceptical regarding the concept of 'object':

" … the elements in the visual field are typically referred to in the psychological literature as 'objects', where the exact referent of this term is deliberately left ambiguous. In particular, it is left open whether what is being referred to are enduring physical objects, proximal [viewer centered] visual patterns, or other spatially local properties. … In every case considered here, 'object' is understood in terms of whether something is perceived as an individual. … Moreover, I confine my usage to visual objects, not to real physical objects, although … the two are closely linked." [Pylyshyn 2003, 173-174]

"Quantum theory … starts from the division of the world into the "object" and the rest of the world, and from the fact that at least for the rest of the world we use the classical concepts in our description. This division is arbitrary and historically a direct consequence of our scientific method; the use of the classical concepts is finally a consequence of the general human way of thinking." [Heisenberg 1958, 54-55]

"The point is that we do not know what an atom is 'really'; we cannot ever know what an atom is 'really'. We can only know what an atom is like. By probing it in certain ways, we find that, under certain circumstances, it is 'like' a billiard ball. Probe it in another way and we find it is 'like' the Solar System. Ask a third set of questions, and the answer we get is it is like a positively charged nucleus surrounded by a cloud of electrons. These are all images that we carry over from the everyday world to build up a picture of what an atom 'is'. We construct a model, or an image; but then, all too often, we forget what we have done, and confuse the image with reality." [Gribbin 1995, 186]

"It is Piaget's observational discovery that the concept of separate, localized objects is a construct. … This shows that the principles on which philosophical atomism is built are mere assumptions, which have a priori no greater likelihood than any other ones. … But, above all, the fact that the notion of localized objects is but a construct, liberates us from the so-called common sense view (which was also that of Aristotle) according to which individual macroscopic objects obviously – and therefore *necessarily* – exist as individuals independently of ourselves …" [d'Espagnat 1976, xx].

All these quotations clearly indicate that the notion of 'object' should be handled with great caution, and that an uncritical attitude regarding the actual existence of 'objects' is definitely undesirable. That's why any theory that puts forward some form of object-oriented entities as fundamental, should be distrusted. In practice, this means that atomism, Aristotelian substance philosophy, multitudinism[9], mechanistic worldviews, and similar folk psychology perspectives on reality should all be considered inadequate and obsolete.

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[9] Multitudinism: " […] any world view in which the universe is considered as being ultimately composed of a great number of very simple parts, all of which have properties attached locally to them." [d'Espagnat 1976, xx]

However, avoiding the use of the concept ‘object’ when *only* applying the straightforward definitions of realism and antirealism does not pay full respect to our obvious everyday experience of ‘objects’. Therefore, the additional concept of ‘object-orientation’ will suitably fit this state of affairs:

Object-orientation: *the manifestation as a distinct totality.*

Here, ‘manifestation’ can be taken to mean *existence*, *occurrence*, *perception* and/or *behaviour* as a distinct totality. It could even be interpreted in a Whiteheadian sense of ‘becoming actual’ (cf., the concept of ‘actuation’, see for instance, [Christensen 1986]) [10]. Because of this multi-applicability of the concept of ‘object-orientation’, no premature choice is being made in favour of any realistic or anti-realistic interpretation, thus making it possible to give a more unbiased interpretation of the ‘existence’ and ‘independence’ aspects of the available realism and antirealism definitions.

2 OBJECT-ORIENTED NEURAL DYNAMICS

In his well-received multidisciplinary book ‘Conceptual Spaces’, Peter Gärdenfors presents a framework for cognitive representations forming a bridge between the symbolic and connectionist approaches within cognitive science and computational studies [Gärdenfors 2000]. For explanatory purposes he compares neural networks with a dense jungle. First, on a myopic scale, the mobility of travellers is confined by environmental and bodily constraints – body size and free space between vegetation determine freedom of movement. Together, these constraints determine a class of possible trajectories through the jungle, where the most effective trajectories can only be chosen by judging local conditions, since a global overlook is not feasible. At this stage, chosen trajectories can only be described on a very low and detailed level, since dense jungles do not provide a conveniently arranged supply of freely accessible landmarks which can shorten the list of required directions. Therefore, travelling instructions would require step-by-step descriptions of the local environment, in this way exhibiting susceptibility for the frame problem[11]. That is, travelling through the dense jungle effectively *changes* local conditions. Consequently this would require instructions for future travellers to be *on-the-go adaptable*. Given the continuously changing local conditions, the chosen trajectories are determined by localized dynamical traveller-environment interactions, thus making preconceived overall travelling instructions impossible.

When deprived from any possibility to navigate on a nonlocal scale[12], from a global bird's eye view, initially, the followed trajectories can be conceived to be very similar to ‘random walks’ (see, for instance: [Feller 1968; Hughes 1995]). Introducing two additional opposing dynamics – the constructive creation of life-sustaining trajectories, and the destructive overgrowth of trajectories by jungle vegetation – can explain how non-randomness can emerge from this initially random traveller behaviour. A reasonably critical proportionate relation between these two opposing dynamics is required to acquire a sufficiently stable evolution of life-sustaining trajectories.[13]

After a while – when enough travellers have paved the way - the weighted sum of local conditions yields optimized global trajectories, thus establishing pathways that make travelling more efficient. At this level of forest (cf., neuronal) development, the possibility to find directions and

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[10] In fact, David Bohm’s concepts of implicate and explicate order convey a quite analogous picture [Bohm 1980].

[11] Biological organism perspective of the frame problem: According to Daniel Dennett, the frame problem involves how cognitive organisms can maintain faithful *beliefs about the world* throughout the organism’s *world-changing belief-induced acts* [Dennett 1978, 125]. Artificial organism perspective: “How … does the machine's program determine which beliefs the robot ought to re-evaluate given that it has embarked upon some or other course of action?” [Fodor 1983, 114].

[12] E.g., through using a compass or Global Positioning System.

[13] N.B.: This last paragraph is my addition, and does not exclusively follow Gärdenfors’s original jungle analogy.

plan further ahead is introduced. In the 'neuronal jungle of the brain' more long-range signalling will thus spontaneously manifest itself (because traffic flows are more economic), in this way providing *anticipation*, that is, the spontaneous selection of available alternative routes, based on traffic efficiency. In effect, faster travelling signals simply 'outrun' the signals that are following slower trajectories, causing the latter to become obsolete and fade away.

Eventually, as the travellers proceed and expand their jungle explorations, more and more pathways will cross each other forming an extensive network of interrelations. Due to distinctive features of various possible forest (cf., neuronal) locations, crossings and other places can be recognized and given names, so that travel instructions can be spelled out on a symbolic level of description. And although on all three levels, it's always the movements of travellers that are being represented, low-level descriptions typically require a lot of unnecessary detail information, whereas higher level maps can be much more economical (by referring to the associated distinctive location features which then become emblematic for the followed trajectory). In actual brains this emblematic marking procedure is performed through neural-mental mapping of the body's physiological responses [Damasio 1994, 1999]. This 'embodiment' gives bodily meaning to the signalling of neurons (see also: [Lakoff & Johnson 1999]).

Although this analogy is not perfect, it shows that there is no unique way of mapping the world, and that effective neural-mental mapping can occur quite easily due to local-global interactions. Following this, Gärdenfors mentions that, from the lowest, most fine-grained level of signal processing, *pattern recognition*[14] is central to the processing of raw sense-data [Gärdenfors 2000, 253] – although Thomas Metzinger points out (by referring to Raffman) that pattern recognition is actually preceded by pattern *comparison* [Metzinger 2003, 70]. [15]

Anyhow, in computational studies, pattern recognition requires comparison with known patterns to determine a match or mismatch [Gärdenfors 2000]. Usually some pre-available comparison-objects or stored 'primitives' are being used for that purpose [Ibid., 252], but in order to get actual higher-order learning capabilities and to be consistent with evolutionary, neural selectionism (to account for higher-order brain activity) self-referential neural dynamics[16] are needed (see section 2.5).

Through matching novel somatosensory input with stored memory representations, our brain's neurocognitive mechanisms (such as pattern recognition, categorization, concept formation, and focal attention) generate neural and mental patterns that ultimately *pose as* singular, object-oriented units. Several (brain) researchers point out that this 'matchmaking' is governed by underlying self-referential neural processes [Damasio 1999; Edelman & Tononi 2000; Gärdenfors 2000]. These self-referential neural dynamics yield object-oriented patterns, in this way spontaneously accomplishing the preconscious and conscious categorization of novel somatosensory input. Without this neural self-reference, there can be no emergent mental experience to single out any recognizable structure or 'objects' from 'bare' neural patterns. All that would remain is William James's 'big blooming buzzing confusion', without any emergent, object-oriented structures that can be distinguished [William James 1911].

Following this line of thought, mental objects should preferably be regarded as *relatively stable*, *emergent* structures (i.e., mental patterns) brought along by a dynamical, self-referential substrate (i.e., neural patterns). Consequently, as Edelman and Tononi point out, neural self-referential selectionism (which brings forth neural-mental mapping) is prior to neural-mental object formation [Edelman & Tononi 2000, 214], and all its object-oriented descendants (pattern recognition, perceptual categorization, binocular fusion, etcetera).

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[14] Pattern recognition: " … the act of taking in raw data and taking an action based on the category of the data." [Duda et al. 1973, 2000]

[15] "In a context of pairwise comparison, healthy individuals can distinguish upon two just noticeably different shades of a certain colour, although they cannot recognize and memorize these shades as particular shades of this colour." [Raffman 1995, 294*ff*].

[16] As will become clear later on, self-referential dynamics can also be described as circular, reciprocal, iterative, reentrant or reflexive dynamics. It usually depends on the context which term is preferred.

In our conscious experience, the bound-in-one, collective 'whole' of these object-oriented neural-mental patterns is so convincing as a realistic image of reality, that it usually makes us firmly believe, or even claim (as many physicists do), that reality *is* ultimately object-based. This has often seduced researchers to model the brain accordingly, although this brings along various problems, like the earlier mentioned body/mind problem (see section 1), the binding problem[17], the frame problem, and so forth. Further along in this paper, I will argue for a *process-oriented*, selectionist model for brain patterning, to properly address these problems. For now, I will suffice by quoting Antonio Damasio and Thomas Metzinger, two influential brain theorists who approach the concept of 'objects' with healthy scepticism:

"I do not have any idea about how faithful neural patterns and mental images are, relative to the objects to which they refer. Moreover, whatever the fidelity may be, neural patterns and the corresponding mental images are as much creations of the brain as they are products of the external reality that prompts their creation. […] Whatever it [the experienced 'object'] is like, in absolute terms, we do not know. The image we see is based on changes which occurred in our organisms – including the part of the organism called brain – when the physical structure of the object interacts with the body. The signalling devices located throughout our body structure – in the skin, in the muscles, in the retina, and so on – help construct neural patterns which map the organism's *interaction* with the object." [Damasio 1999, 320]

Damasio's quotation shows how difficult it is to avoid object-oriented distinctions (which – of course – implicitly involve the premature separation of 'the natural world' and 'conscious experience'). Even though he is sceptical towards 'object-depicting brain patterns', he still seems to believe in an object-based reality. In comparison, Metzinger's account of object cognition sounds more explicitly sceptical:

"In this elementary process of object-formation [i.e. the activation of a coherent phenomenal object through an underlying neuronal process], as many empirical data show, a large portion of the fundamental processuality on the physical level is being, as it were, "swallowed up" by the system. In other words, what you subjectively experience as an integrated object, possessing a transtemporal identity … is being constituted by an ongoing process, which constitutes a stable, coherent content and, in doing so, systematically deletes its own temporality. The illusion of substantiality arises only from the first-person perspective. It is the persistent activity of an *object emulator*, which leads to the phenomenal experience of a robust object." [Metzinger 2003, 23]

Thus, the abovementioned 'processuality on the physical level' yields *dynamical* patterns that – through emulation – act as a *static* pattern. In consecutive order, the different time slices within the neural process of 'object-construction' [Ibid., 22] exhibit not enough variety to actually tell them apart in mutual comparison – let alone to be *recognized* as different individuals through 'memorial matching' (cf. footnote 15).

2.1 DUALISM AND REDUCTIONISM DUE TO OBJECT-ORIENTATION

So, although there seems to be more than enough scepticism in the scientific community towards the actual existence of objects, this still hasn't stopped the concept of 'object' to slip into typical definitions of realism and antirealism (see Robert Nola's quotation in section 1.2). As already stated, the collective whole of object-oriented mental patterns is apparently so convincing as a realistic image of reality, that our conscious experience usually considers it too natural to reject. Therefore, we tend to hang on to the concept of 'object', and are not easily persuaded to expel it from our theories and definitions.

[17] "The binding problem is, basically, the problem of how the unity of conscious perception is brought about by the distributed activities of the central nervous system." [Revonsuo & Newman 1999]

Accordingly, dualist interactionism is appealing since bodies and brains *seem* very different from minds and consciousness, so it seems quite plausible to claim that they effectively *are* very different. But rather, the visual system, the body and the mind, etcetera, only *subjectively appear to be* distinct and different totalities, capable of interaction of some kind.[18] On closer scrutiny, dualism leaves much to explain. For instance, how should we conceive of a *substance that thinks*, and how could a causally closed physical world (as proclaimed by dualism) ever be affected by consciousness?

In his instant classic book 'Consciousness Explained', Daniel Dennett underlines that dualism – despite its bothersome problems – spreads its wings even further [Dennett 1991, 33-39]. He points out that dualism is very hard to avoid, even when one is explicitly and deliberately intending to elude it. A suitable example can be found in the refusal of reductive[19] materialists to make any reference to the concept of 'mind' (since this could lead them into all kinds of difficulties associated with body-mind dualism), whereas they're simultaneously presuming the existence of several distinct functional subsystems of the brain (e.g., short-term memory, long-term memory, perceptual processing). Concerning this 'modular brain point-of-view', Dennett mentions that:

" … the exclusive attention to specific subsystems of the mind/brain often causes a sort of theoretical myopia that prevents theorists from seeing that their models still presuppose that somewhere, conveniently hidden in the obscure "center" of the mind/brain, there is a Cartesian Theatre, a place where "it all comes together" and consciousness happens." [Dennett 1991, 39]

And: " … while materialism of one sort or another is now a received opinion approaching unanimity, even the most sophisticated materialists today often forget that once Descartes's ghostly *res cogitans* is discarded, there is no longer a role for a centralized gateway, or indeed for any *functional* center to the brain. … The brain is Headquarters, the place where the ultimate observer is, but there is no reason to believe that the brain itself has any deeper headquarters, any inner sanctum, arrival at which is the necessary or sufficient condition for conscious experience." [Dennett 1991, 106]

So, reductive materialists simply deny that consciousness would be anything other than neural processing. However, for consciousness to be nothing more than a brain state, Velmans mentions, it must be *ontologically identical* to a brain state [Velmans 2000, 36]. And since *correlation* and *causation* do not establish ontological identity[20], this denial doesn't seem to be very promising.

In reference to this problematic state of affairs, Velmans points out that "some ideas about the nature of consciousness and its relationship to the material world are so deeply ingrained in our culture that they *are taken for granted by dualists and materialists alike*, thereby providing the point of departure for their 2,500-year-old debate" [Velmans 2000, 103]. Subsequently, he argues that the artificial 'gap' between conscious experience and the physical world is actually prompted by a mere *subjective* effect that he calls 'perceptual projection'.[21] In his view, neglecting the *subjectivity* of this perceptual projection, causes us to unwarrantedly look upon conscious experience and the physical world in an object-oriented way – as if the body-mind gap were *objective reality*.

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[18] There's extensive evidence of the body and brain affecting mind and consciousness, and vice versa (e.g., the visual system affects visual experience, and visual experiences influence subsequent actions). Within dualism the ontological status of such interaction is quite problematic, since it's difficult to see how the physical can interact with something non-physical (see, for instance: [Velmans 2000, Dennett 1991]).

[19] Reductionism asserts that complex things can always be reduced to simpler or more fundamental things. This can be said of objects, phenomena, explanations, theories and meanings. "Reductionists commonly argue that if one could find the neural *causes* or *correlates* of consciousness in the brain, then this would establish consciousness *itself* to be a brain state." [Velmans 2000, 35]

[20] "Ontological identity is *symmetrical*; that is, if A is identical to B, then B is identical to A. Ontological identity also obeys *Leibniz's law*: if A is identical to B, all the properties of A are also properties of B, and vice versa." [Velmans 2000, 36]. Correlation is symmetrical, but doesn't obey Leibniz's law. Causation is asymmetrical (if A causes B, the reverse doesn't automatically follow) *and* doesn't obey Leibniz's law. Like Velmans, Searle has also argued that causality should not be confused with ontological identity [Searle 1987].

[21] The effect that the world *appears* to be *outside* the brain, although information about the world is encoded *inside* the brain [Velmans 2003]

In avoidance of a never-ending dispute on this, another option would be to state that we cannot possibly make any claims beyond experience. But this anti-realistic viewpoint has fallen from grace, because there definitely seems to be a correlation between unobservable physical reality and the direct empirical experience of reality, since science has been so successful in producing its many useful applications.

2.2 EMERGENTISM

Although it might look as if we're running out of options – dualism and reductionism are inherently problematic, and antirealism is unsatisfactory – there's still the alternative of *emergentism*. In its most established use, emergentism states that emergent properties are distinct from, and additional to, their base properties, and arise unpredictably from them. In the form of property dualism [Velmans 2000, 39], emergentism retains the view that consciousness and physical matter are simply different kinds of property of the brain.

Although closely related to the concept of 'supervenience'[22] [Davidson 1970; Kim 1993], emergentism permits emergent mental phenomena to have an inherently unpredictable relation with any underlying microphysical characteristics, whereas supervenience suggests that a more strict relation between higher and lower-order phenomena should be present:

"Mental characteristics are in some sense dependent, or supervenient, on physical characteristics. Such supervenience might be taken to mean that there cannot be two events exactly alike in all physical respects but differing in some mental respects, or that an object cannot alter in some mental respects without altering in some physical respects." [Davidson 1970, 214]

Put short, according to the supervenience hypothesis you cannot change the arrangement of higher-order phenomena without changing their underlying microphysical properties. Within the context of the body-mind problem, this means that mental patterns should be considered supervenient on their microphysical properties. Emergentism on the other hand, usually allows for changes of higher-order phenomena that need not possess a one-on-one, direct linkage with changes at any underlying lower-order levels. However, both emergentism and the supervenience hypothesis, consider consciousness to be *irreducible* to, yet somehow *dependent* on the physical constitution of the brain, thus avoiding the abovementioned problems (i.e., correlation and causation not establishing ontological identity) of reductionism.

To comprehend how this could be possible, it is helpful to consider how properties that are not present in the individual can emerge from large ensembles of individuals. For instance: although in individual water molecules the property of liquidity is not present, very large ensembles of water molecules – due to the combined effect of the molecular movements – clearly possess the property of liquidity. Similarly, consciousness could simply be just a physical macroproperty of the brain [Searle 1987].

In accord with this line of thought, Nils Baas, a leading emergentist and complexity theorist, mentions: "Consciousness is not a property of individual neurons, it is a natural emergent property of the interactions of the neurons in the nervous system of the body in an environment" [Baas 1996].[23] Although at first sight, Baas's argument might seem quite plausible, there's a rather nasty catch to emergentism when used in the context of consciousness. First of all, Searle has come to realize that macroproperties like liquidity (and solidity, etc.) *are* reducible to molecular behaviour,

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[22] In philosophy, supervenience is a well-defined relation between "higher-level" (e.g. mental) and "lower-level" (e.g. physical) properties. Jaegwon Kim's 'strong supervenience' – which he considers equal to 'global supervenience' – is stated as: *A strongly supervenes on B just in case, necessarily, for each x and each property F in A, if x has F, then there is a property G in B such that x has G, and necessarily if any y has G, it has F.*

[23] For other literature on brain dynamics and emergence, see, for instance: [Chialvo 2004; Fingelkurts & Fingelkurts 2005; Fischer & Bidell 2006; Linkenkaer-Hansen 2002].

whereas consciousness *cannot* similarly be reduced to mere neuronal behaviour [Searle 1997, 211]. This irreducibility exists in the fact that 'consciousness' and the 'experience of consciousness' cannot be seen separately. That is, whenever considering *reducible* features, it's possible to distinguish between the *experience* of the feature and the feature *itself*. Successively, this possibility facilitates the reduction of the higher-order macroproperties (the experiential features) to the physical origins of the feature. But, since "consciousness and the experience of consciousness are the same thing" [Searle 1997, 213], this reduction cannot be made.

Secondly, considering an individual neuron, water molecule, or any other phenomenon as an objectively existing distinct totality, should basically be regarded as improper employ of object-oriented thought. Eventually, the 'individual' cannot be seen separately from its environment; the dynamical or relatively stable collective totality of physical, mental, or even intermediate 'psycho-physical' patterns.

In fact, the above-mentioned first and second argument are intimately related. Providing the possibility to distinguish between the 'experience of a feature' and the 'feature itself', effectively entails considering the 'observed system' as being isolated from the 'observer' in an object-oriented way. Whenever there is a concrete and obvious overlap between the artificially and improperly separated 'halves' of the inseparable totality of 'observer' and 'observed system' (as is the case with the observing 'experience of consciousness' and the observed 'consciousness itself') , the deficiencies of object-oriented methods of description become particularly apparent. So, object-oriented methods of description will – although usually in a quite covert way – definitely and universally lead to definition difficulties (impredicativity; as mentioned in section 1.1). However, these difficulties really become exposed in the open when the observer cannot be reasoned away – as is the usual mode of operation within traditional and even contemporary science.

For these same reasons, Jaegwon Kim's 'strong supervenience' [Kim 1993] should also be considered to be an inadequate concept for explaining the mind/brain – as it presupposes distinct 'objects' (e.g., A and B; see note 22) where this distinction shouldn't be made in the first place.

At the end of the day, dealing with such object-oriented terminology of distinct and absolute individuality will inevitably bring along body-mind dualism in the sense Daniel Dennett has mentioned in section 2.1. As long as this object-oriented separateness is being applied – although the higher order patterns, phenomena, or properties in question may *seem* to have been reduced to their substrata – the object-oriented (modular) portrayal of brain architecture will eventually always *reintroduce* dualism by implicitly assuming that somewhere in the brain its physical machinery should interact with its elusive 'ghost'[24] (see [Dennett 1991, 106]).

2.3 MUTUAL ENTRAINMENT

Trying to find his way around this dualist booby trap, Roger Sperry regards consciousness to be a holistic property of the brain that **(a)** emerges from brain activity and **(b)** concurrently regulates the substrate neural activity from which it emerges [Sperry 1969, 1970]. Although Sperry himself does not give an account of how emergence and regulation could actually occur together, Edmond Dewan suggests that if the process of 'mutual entrainment' would happen in the brain, this could facilitate the parallel occurrence of emergence and regulation [Dewan 1976]. Entrainment – a term coined by the 17th century physicist Christaan Huygens – is the spontaneous synchronization of multiple oscillating subsystems by 'locking into' one another, resulting in synchronized interdependent activity on a global system scale (e.g., generators in a power grid). Dewan points out that:

[24] Although object-oriented reductionism inevitably involves implicit dualism, the reverse doesn't hold, since usually strict dualism entails the absolute distinctness of the physical and the mental (see for instance [Koestler 1967]).

“This mutual entrainment is a splendid example of *self-organization*, and it is obvious that such a system can be regarded as a *single unit* so far as its function is concerned. Out of mutual entrainment has emerged what Wiener [Wiener 1961] terms a ‘virtual governor’ which controls the entire system in a manner which uses feedback. This virtual governor is not located in any one spot in the system, but rather it pervades the system as a whole, so that it does not have a ‘physical existence’ in the usual sense. It is an *emergent property of the entire system* which goes far beyond what any single unit can accomplish in accuracy and power.” [Dewan 1976, 185]

Dewan suggests that the ‘virtual governor’ of a power grid relates to the individual generators like consciousness and mind relate to the activity of the (modular) neuronal units of the brain [Ibid., 185], and over the years, this idea has been adopted by several researchers in the field of mind/brain studies [Gärdenfors 1993; Corning 1997, 382]. Particularly interesting in this respect, is how local excitatory and inhibitory neurotransmitter signalling can govern global synaptic synchronization [Butkus 2006, 37-38].

2.4 BRAIN PLASTICITY

Because of the structural and functional correspondence between synaptic and power generator networks, synaptic synchronisation could very well occur through mechanisms similar to mutual entrainment. However, the big difference between networks of power generators and synapses, is the ‘plasticity’ occurring in neural systems [Diamond et al. 1985; Cotman et al. 1988; Buonomano & Merzenich 1998; Butefisch et al. 2000]. Plasticity occurs particularly and most dynamically within the cerebral cortex and entails, roughly speaking, that active synapses persist and inactive synapses perish. In fact, rapid formation of synapse structures depends proportionally upon prior (somato)sensory information [Stern et al. 2001], in this way determining the prompt dynamics of synaptic circuits accompanying (somato)sensory experience, and – amongst others – enabling sensory maps to be developed [Maletic-Savatic 1999]. So, synaptic activity helps to enable the cerebral cortex to evolve through the interaction between intrinsic growth-decay dynamics and environmentally derived activity [Quartz & Sejnowski 1997; Rail et al. 2000].

At the molecular level, synaptic plasticity involves modification of existing synaptic proteins [Shi et al. 1999] and the regulation of gene transcription and the concentration of key proteins at synapses. Among the influences that play a part in the dynamical organisation of synaptic architecture – determining the strength of synapses and establishing learning and memory capabilities – are neurotransmitters, protein kinases, ion channels, and gene transcription factors [Bailey et al. 1996; Kandel 2004]. These influences *all involve self-referential dynamics*, as the concentration of neurotransmitter, the quantity of ion channels, level of target protein modification by protein kinases, etcetera, can mutually intensify (or inhibit) one another. Such unidirectional mutual reinforcement will form a positive feedback loop, eventually generating a very static synaptic configuration, which is too stable to demonstrate any actual learning capabilities. Two negative feedback mechanisms – synaptic ‘scaling’[25] and ‘metaplasticity’[26] – provide some counterbalancing means for diminishing synaptic strength [Pérez-Otaño & Ehlers 2005], thus preventing this problematic scenario of ‘overstaticness’ to unfold.

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[25] Synaptic scaling serves to maintain the strengths of synapses relative to each other, lowering amplitudes of small excitatory postsynaptic potentials in response to continual excitation and raising them after prolonged blockage or inhibition [Pérez-Otaño and Ehlers 2005]. This effect occurs gradually over hours or days, by changing the numbers of NMDA receptors at the synapse [Ibid.].

[26] Metaplasticity, another form of negative feedback, reduces the effects of plasticity over time Thus, if a cell has been affected by a lot of plasticity in the past, metaplasticity makes future plasticity less effective [Pérez-Otaño and Ehlers 2005].

2.5 REENTRY AS 'NEURAL MUTUAL ENTRAINMENT'

To account for the abovementioned adaptability and dynamic stability of developing neuronal networks, Gerald Edelman developed his 'Theory of Neuronal Group Selection', which he has been expanding and fine-tuning for almost three decades now [Edelman & Mountcastle 1978; Edelman 1987; Edelman & Tononi 2000]. The theory of neuronal group selection holds that the mind must have arisen from two processes of selection: Darwinistic natural selection and somatic selection. The mechanisms of the first process are widely acknowledged within the scientific community, whilst the second process provides the mind/brain with structure and functional performance through developmental and experiential dynamics. Somatic selection has three main tenets [Edelman & Tononi 2000, 83-85]:
1. Developmental selection. Although genes and inheritance for the most part determine the initial anatomy of the brain, starting from the early stages of embryonic development, somatic selection largely establishes the connectivity at the level of synapses. The growing embryo's neurons develop countless multidirectional interconnections facilitating an immensely diverse repertoire of neural circuits, with a built-in potential for variability.
2. Experiential selection. Overlapping this developmental somatic selection of synaptic growth and interconnection in the embryonic stage, behavioural experience directs the process of synaptic selection within neuronal groups through plasticity dynamics: "neurons strengthen and weaken their connections according to their individual patterns of electrical activity: Neurons that fire together, wire together" [Ibid., 83], see also [Hebb 1949; Sporns et al. 2004; Butkus 2006, 25]. Put straight, populations of neurons that are actively involved in behavioural experience develop more interconnections, while inactive populations become isolated and eventually perish. In this way, on a myopic scale, the firing of neurons is constrained by their own level of neuronal interconnectivity (i.e., with their direct and indirect neuronal environment) and with the height of their activation threshold. Together, these constraints initiate self-organizing neuronal trajectories that are most 'fit' to yield ongoing neuronal firing. In this way, the synaptic growth of the self-organizing trajectories fine-tune the genetically predetermined initial anatomy of the brain's neuronal 'jungle' to form clear-cut neural pathways – as has been demonstrated in section 2 (see also: [Gärdenfors 2000, 33-35]).
3. Reentry. In order to achieve proper somatosensory and sensorimotor maps, the neural pathways in question have to be mutually correlated through some effective means. Edelman and his associate Tononi stress that 'reentry' is the pre-eminent mechanism: "... reentry is a process of ongoing parallel and recursive signalling between separate brain maps along massively parallel anatomical connections, most of which are reciprocal. It alters and is altered by the activity of the target areas it interconnects" [Edelman & Tononi 2000, 105-106].

Because of the all-pervading multilevel occurrence of reentry, synaptic configurations will not develop towards relatively static, constrained states – as would happen due to singular fixed feedback loops (cf., the concept of 'overstaticness' in section 2.4) – but remain adaptable, thus facilitating the possibility of variation and selection. In this way it provides the dynamic core[27] with a high level of neural-mental integration *and* differentiation to establish connective flexibility and learning capabilities. This available neuronal variability – which Edelman and associates call 'degeneracy'[28] and which is achieved through developmental selection – allows conscious organisms

[27] According to Edelman and his associates, reentry occurs within the dynamic core: the highly complex, distributed functional cluster of neurons, located mainly within the thalamocortical system, serving as a dynamic coordinating infrastructure for the integration of neural traffic originating from widely dispersed brain regions [see, for instance, Edelman & Tononi 2000, 143-145].

[28] Degeneracy closely matches the concept of 'multiple realizability'. In the philosophy of mind, the multiple realizability thesis contends that a single mental kind (property, state, event) can be realized by many distinct physical kinds

to distinguish things in the otherwise 'big blooming buzzing confusion' mentioned by William James [James 1911]. That is, similarly to mutual entrainment, reentry accomplishes synchronization of the activity of neuronal groups in different brain maps, thus more or less 'shaping' the organism's diverse cognitive and motor capabilities into distinguishable totalities. In this way, synchronized reentrant firing can initiate various neural pathways of perception, proprioception and interoception to bring forth an integrated-differentiated collective totality of sensorimotor and somatosensory patterns which will yield coordinated behaviour (see, for instance: [Edelman and Tononi 2000, 48-50 and 87]).

3 INTEGRATING BODY, MIND, AND UNIVERSE

Whether or not mutual entrainment or reentry explicitly coordinate spatially separated nerve impulse traffic to merge into a bound-in-one, unified totality of conscious patterns, there is little doubt that an integration-mechanism for the distributed activities of the central nervous system actually exists (see, for instance: [Revonsuo & Newman 1999; Velmans 2000, 42; Edelman & Tononi 2000, 14]). Conformingly, Edelman and Tononi point out that reentry governs how the brain's diverse, multi-dimensional and functionally segregated maps cohere *without* a higher-order controller to guide the process from a pinnacle position [Ibid., 106].[29] This does *not* clarify, however, how such a mechanism – which in our previous examples solely functioned as a regulation mechanism – could bring along *conscious* patterns.

To account for the emergence of subjective conscious experience, in his second book 'The Feeling of What Happens', Antonio Damasio states that brain patterns have to convey the higher-order narrative of '*the organism caught in the act of representing its own changing state as it goes about representing something else*' [Damasio 1999, 170]. And astonishingly, within the process of conveying this self-representing narrative, the knowing and knowable entity of the 'self' gets to be created. In line with this, Thomas Metzinger boldly challenges the traditional notion of 'conscious self' by stating that:

> " … no such things as selves exist in the world: Nobody ever *was* or *had* a self. All that ever existed were conscious self-models that could not be recognized *as* models. The phenomenal self is not a thing, but a process – and the subjective experience of *being someone* emerges if a conscious information-processing system operates under a transparent self-model. You are such a system right now, as you read these sentences. Because you cannot recognize your self-model *as* a model, it is transparent: you look right through it. You don't see it. But you see *with* it. In other, more metaphorical words, the central claim […] is that as you read these lines you constantly *confuse* yourself with the content of the self-model currently activated by your brain." [Metzinger 2003, 1]

Metzinger explains the dynamics of the Phenomenal Self-Model by referring to the simultaneous occurrence of proprioceptive feedback with self-referential cognitive processing. The mechanism of proprioception represents the 'bodily self' just as a physical object, by internally representing ongoing musculoskeletal information through neural patterns. Simultaneously, through cognitive processing the underlying neuro-selectional dynamics of the self-model are emulated, so that it can be implemented within the self-model to create the *impression* of unfolding subjective experience [Metzinger 2003, 301]. "This is what 'embodiment' means, and what at the same time generates the intuitive roots of the mind-body problem: the human self-model treats the target system [i.e., pro-

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[Bickle 1998; see also Putnam 1988; Fodor 1988]. Here, different neuronal configurations can provide very similar mental effects.

[29] This also involves the binding problem (see footnote 17): How to get an integrated, coherent totality of widely dispersed, segregated brain maps without introducing the homunculus-problem. That is, if there is such a homunculic supervisor directing brain activity, how is this supervisor's activity being guided?

prioceptive system, cognitive processing system, etcetera] generating it as subject and object *at the same time*." [Ibid., 301].

Taking the *embodied mind thesis* [30] to its extreme, one might justifiably state that physical and mental structures cannot be seen separately. This is exactly what Max Velmans tries to put across, when he mentions that " … the nature of mind is not *either* physical *or* conscious experience, it is at once physical *and* conscious experience. For lack of a better term we may describe this nature as psychophysical" [Velmans 2000, 250]. This psychophysical functionality of the brain is also mentioned by Roger Shepard [Shepard 1987, 1319], and accordingly, Velmans claims the nature of mind is best described by the 'reflexive model', which, according to Max Velmans, "suggests that in terms of phenomenology there is no actual separation between the perceived body and experiences *of* the body or between the perceived external world and experiences *of* that world. It goes without saying that when one has a conscious thought, there isn't some additional experience *of* a thought 'in the mind'." [Velmans 2000, 111]

Summarizing, the reflexive model involves the coordinated interplay of the *outer-brain* physical dynamics on the one hand, with *inner-brain* perceptual, proprioceptive, and interoceptive patterns on the other hand. Although it is *inner-brain encoding and processing* that generates a faithful phenomenological experience of the physical world, this world is definitely experienced to be *outside the brain*. Thus, the perceiving mind subjectively 'places' its phenomenological experiences 'in the physical world', so that from the perspective of subjective phenomenal experience, there's no clear separation between the 'physical world', the 'phenomenal world' and the 'world as perceived' [Velmans 2000, 125-126]. Hence, what we normally perceive to be the 'physical world' is *part of* what we experience. It is *not apart from* it. Thus, the 'physical world' just *is* what we experience and there is *no additional* experience of the world 'in the mind or brain' [Ibid., 126]. Following this line of thought, physical objects as perceived should *not* be considered distinct from our percepts *of* those 'objects' [Ibid., 139].

3.1 NON-REPRESENTATIONAL MEMORY

Corresponding to this reflexive model of the mind/brain, Edelman and Tononi advocate the existence of non-representational memory [Edelman & Tononi 2000, 93-95] (see also: [Damasio 1999, 320-321] for a similar account). Non-representational memory does *not* involve the 'mental duplication' of the natural world, but rather considers thalamocortical circuitry within ongoing selectional development (including synaptic growth and decay, changing constraints, biochemical and behavioural dynamics, etcetera), yielding beneficial[31] psychophysical performances, acts, and/or behaviour.

Although I'd like to distinguish this view from the controversial behaviourist position that referring to any internal mental states is undesirable, the mechanisms associated with non-representational memory, can be considered quite similar to the 'neo-behaviourist' interpretations of 'positive and negative reinforcement' mentioned by James Dinsmoor [Dinsmoor 2004]. The *standard* notion of 'behavioural reinforcement' has often been criticized to be circular, for it seems to argue that response strength is increased by reinforcement while simultaneously pointing at reinforcement as increasing response strength. However, neuronal selection is *biologically grounded* through the self-organizing evolutionary dynamics of random neurocellular growth and decay (determined by many underlying and higher-level system-wide influences, constraints, and effectiveness of emerged neural pathways). This means that, within selectional systems, behaviour can be said to be intimately interconnected with the underlying self-organizing selectional dynamics, which are in turn 'reinforced' (positively or negatively) by the generated effects of the behaviour in

[30] The embodied mind thesis holds that human cognition and consciousness can only be understood in terms of the enactive structures (i.e., the body and the environment) in which they arise [Lakoff & Johnson 1999].
[31] That is, fulfilling (or suppressing) a desire, necessity, stimulus or natural impulse of the organism in question.

question. So, instead of identifying a circular argument, rather this arrangement *illustrates the biologically grounded*, *selectional potential of neural self-reference*. Mentioning 'circularity' is only appropriate when concepts like 'reinforcement' and 'response strength' can be considered axiomatic or 'primitive' concepts, instead of emergent features within a truly complex[32] selectional system.

Thus through *reentrant* dynamics, the resulting selectional psychophysical activity will eventually yield coordinated behaviour, typically resembling the goal-directive activity of the immune system [Edelman & Tononi 2000, 94-95]. In immune systems an antibody is not an exact representation of a foreign antigen, yet through the mechanism of immunological memory antibodies can identify this antigen (and its relatives). Similarly, non-representational memory can be described as a totality of dynamical psychophysical patterns behaving as 'environment interdependent imprints' of organism-related neural-mental patterns. That is, although the mind/brain is inseparably connected with the organism and the environment, for explanatory purposes, we imagine the mind/brain to be a (relatively separate and stable) complementary sub arrangement within the entire dynamical open system of 'organism-universe'.

Viewed like this, consciousness is an embedded facet of the greater universe, actuated by reflexive psychophysical dynamics [Velmans 2000, 233], see also [Cahill 2005]. This implies that – in order to give rise to an embedded, reflexive, psychophysical mind/brain – our universe should also be reflexive. Accordingly, Velmans argues we should adopt ontological monism together with epistemological pluralism. This dual-aspect theory, which he calls 'reflexive monism', basically means that the information displayed in experiences and their physical correlates can be thought of as two manifestations of reflexive processing. That is, for those who embody them, mind/brains become manifest through conscious patterns (experiences), whereas mind/brains that are viewed from the outside, concretise as physical patterns (material structures).

So-called 'physical' and 'mental reality' are inseparably connected and both individually as well as communally exhibit reflexive dynamics. That is, within 'physical reality' relatively stable physical structures are inseparably interconnected within their material environment, behaving *according to* the environmental influences while at the same time *reflexively affecting* the state of their physical environment (see also: [Heisenberg 1958, 89-90; Stapp 1971, iv; Smolin 1996; Wolfram 2002; Cahill 2005]). Similarly, mental structures cannot be seen separate from their mental environment, since their local behaviour is governed by global reentrant signalling (cf. mutual entrainment dynamics). This is illustrated by the process of 'individual' mental patterns or thoughts triggering subsequent patterns or thoughts, in a continuous flow [Damasio 1999, 318-319].

Finally and most importantly, however, reflexive dynamics also manifest themselves on the non-existent edge of what we usually consider to be *physical* and *mental* patterns – on the virtual 'body-mind boundary'. When body states are being captured through proprioception and interoception, and the physical state of the natural world is encapsulated through perception, the bound-in-one collective whole of proprioceptive, interoceptive and perceptual patterns can bring along an emulated experience of a *self within the natural world* – as the organism's cognitive processing conveys the reflexive neural-mental narrative of body-mind interplay [Damasio 1999, 170; Metzinger 2003, 301; Velmans 2000, 228-231].

[32] In algorithmic information theory [Chaitin 1998; Li & Vitanyi 1993], the 'Kolmogorov- Chaitin complexity' of a string (or a sequential object or process) is defined by the size of the smallest program for calculating it. In a higher-dimensional non-sequential system, complexity involves the level of potential compression into a smaller description. That is, when no smaller description can produce the same output, the system can be said to be complex. Complexity is thought to be essential to brain functioning [Tononi et al. 1998; Linkenkaer-Hansen 2000; Fingelkurts & Fingelkurts 2004].

3.2 HIGHER-ORDER PATTERNING THROUGH SELF-ORGANIZATION

Although the mechanisms of reentry and mutual entrainment may satisfactorily clarify how integration of different perceptual, proprioceptive, and interoceptive patterns can be achieved, it is still unclear *how* patterns at a neural level can self-organize to eventually bring along *conscious* patterns. That is, how can truly complex higher-order patterns emerge from previously emerged lower-order patterns, and how can system-wide self-representation (which is needed to facilitate global attentional availability of local patterns, a necessary condition for consciousness [Metzinger 2003, 75]) emerge merely through interaction of lower-order patterns?

In order to shed some light on these matters, it's convenient to focus on the simplest conceivable dynamics that yield similar results. Therefore, I'd like to introduce a very simplified model of collective evolutionary development: the 'threshold voter model', a model of evolving group opinion within societies [Ehrlich & Levin 2005].

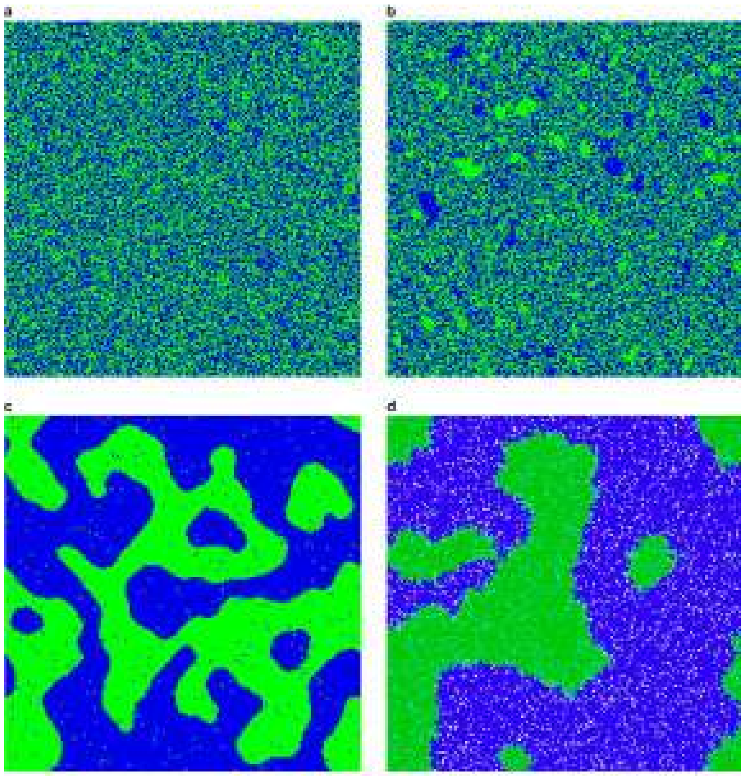

Figure 1: The threshold voter model [Ehrlich & Levin 2005] **(a)** Long-term patterning in the dynamics of two opinions for the threshold voter model with a low threshold; **(b)** Long-term patterning in the dynamics of two opinions for the threshold voter model with a high threshold. Note the existence of small, frozen clusters; **(c)** Long-term patterning in the dynamics of two opinions for the threshold voter model with an intermediate threshold. Note the clear emergence of group structure; **(d)** Long-term patterning in a model of social group formation, in which individuals imitate the opinions of others in their (two) groups, and others of similar opinions, and may switch groups when their views deviate from group

Although this model deals with the evolutionary change of social norms[33], its initial set-up displays remarkable similarities with the tenets of Edelman's Theory of Neuronal Group Selection and Gärdenfors's jungle analogy, because of the role of thresholds and the system's local behaviour, actuating dynamic global patterning. In this example agent-based modelling is being applied: although this may imply object-oriented foundations, the elementary individuals are themselves considered to form a complex totality of interconnected and interdependent systems. Moreover, agent-based modelling particularly focuses on the resulting collective dynamical patterns, rather than on any would-be foundational level.

Let's first consider the starting conditions of the threshold voter model, then expand it to clarify the emergence of higher-order patterns, and finally discuss the similarities with other self-organizing threshold systems like, for instance, an organism's neural-mental system. In the threshold voter model (figure 1; original data by R. Dunnett and S.A. Levin),

1. … a society of individuals is represented through pixels within a two-dimensional grid, where every pixel embodies a single individual;

[33] Social norms: representative or typical patterns and rules of behaviour in a human group [Sumner 1911; Ehrlich & Levin 2005].

2. … possible opinions are represented in green and blue;
3. … the individuals within the grid can adopt one of the two possible opposing opinions indicated by the distinct colours;
4. … an individual's change in opinion occurs if the proportion of neighbours with a different opinion exceeds a specified threshold[34].

Now, when the thresholds are low and individuals will continuously change their opinions, no group patterns will form (figure 1a). In contrast, where high thresholds determine the rate of change in opinion, the 'stickiness' is high and the model shows a rigidly static grid. So once again clear-cut group patterns will not develop (figure 1b). In between these extremes, however, relatively stable group patterns form at intermediate thresholds (figure 1c). In this *simplified* two-dimensional model of change in opinion within societies, eventually one opinion will prevail and cover the entire grid, due to the singular unidirectional feedback mechanism (cf., 'overstaticness'; section 2.4). This only happens over much longer time periods than those of group pattern formation, so relevant patterns are sufficiently apparent and perceivable. Finally, when modifying the model to consider linkages among traits and group labels, additional patterning can develop. That is, introducing the possibility of innovation (through random mutation) of traits, gives birth to multiple (sub)opinions and multiple persisting (sub)groups (figure 1d).

In this multiple opinion model, robust reflexive interdependence between lower and higher-order patterns can be achieved by introducing *motion of the individuals* which will both physically *change* the grid and is *affected by* the grid. Such reflexive interdependence can *potentially* comprise psychophysical dynamics, since opinions trigger behaviour and behaviour triggers opinions in an inseparably interconnected way, although the *simulated* opinions are of course without any (bodily or somatic) content and are constituted by predetermined instructions, *not* selection.

Such reflexive dynamics can be accomplished by equipping the individuals with (i) a *similarity seeking capability* to identify and follow similar neighbours, and (ii) a matching *similarity signalling mechanism* to allow an individual's trail to be recognized and followed by group members that are nearby. Additionally, to allow for movement of individuals to occur, some 'elbow space' should be created by expanding the grid, so that not every pixel is occupied with an opinionated individual. In this way, the possibility of memory trails is introduced (similar to the memorial functions of traveller trajectories; see section 2).

A similar system, which displays built-in *recognition* and *signalling* mechanisms (and provides an easier to model situation than verbal communication), is discussed within a paper by Erik Rauch et al. on pattern formation of simulated insect swarms [Rauch et al. 1995]. Their paper describes how *randomness* is intimately connected with 'osmotropotaxic sensitivity' – the proportion in which an individual follows a trail of evaporating pheromones (marker fluids). In real-world situations 'osmotropotaxic sensitivity' – just like a synapse's sensitivity to neurotransmitters – is influenced by myriad interconnected and underlying aspects. These aspects are most effectively modelled through introducing a *noise factor* proportioning the individual's marker fluid sensitivity. [35] Rauch et al. suppose this noise factor is somehow hardwired into the sensory apparatus of the simulated organism – which is basically another way of saying that the noise-related randomness is an *intrinsic feature* of the organism-environment system. In this way, the system's intrinsic underly-

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[34] Although, within computer models the neighbour's influence on an individual's change in opinion is usually pre-specified, in real-world situations this depends on system-wide (lower- *and* higher-order) dynamics (for instance, local and global neurotransmitter levels).

[35] These aspects – e.g., pattern density, marker fluid concentration, marker fluid sensitivity, marker fluid saturation and evaporation, rate of pattern modification, and the underlying factors of the preceding aspects – are difficult to represent explicitly within a simulation, because (a) there's a high level of interconnectedness, i.e., such complex systems can be considered to be their own smallest model, so necessarily, only the system 'itself' would give comparable output (cf. [Casti 1997; Chaitin 1998]) and (b) although the grain size of the *original* 'individual events' can be smaller than the grain size of their *simulation*, they may eventually still bring along large scale effects, which cannot be 'captured' by the simulation in question. This also holds for 'self-simulation', which is pivotal to the occurrence of consciousness (cf. [Metzinger 2003, 70]).

ing noisy aspects facilitate the ongoing semi-stable variability of patterns, which helps pattern formation to persist, makes memory functioning[36] and consolidation appear [Chialvo et al. 1995; Chialvo et al. 2000; Linkenkaer-Hansen 2002, 10-11], and prevents the system to eventually develop towards non-patterned unanimity [Ehrlich & Levin 2005] due to 'overstaticness'. Several neuroscientists have also mentioned the occurrence of similar 'metastability' in the brain, that is, the tendency of 'separate' brain structures to function *autonomously* at the same time as they exhibit tendencies for persistent *coordinated* activity, thus providing adaptive behaviour within changing, and not fully predictable environments [Bressler & Kelso 2001; Fingelkurts & Fingelkurts 2001, 2004].

In order to realistically implement this feature in an expanded threshold voter model, the marker fluid sensitivity is expressed by β, and the noise factor by its inverse: $1/\beta$. Bringing down the mean value of β below a certain level will undermine the system's internal coherence and degree of correlation, as the noise becomes more influential and group patterns start to chaotically disintegrate on a system-wide scale. On the other hand, too much increase of the mean value of β will yield strict and rigid marker fluid tracking, reducing the systems capability of renewal, thus limiting its dynamical adaptability (e.g., without random trait mutations, patterns will eventually perish [Ehrlich & Levin 2005]). When set at an appropriate level, however, the average marker fluid sensitivity of all the system's individuals (a) brings along effective interconnectedness within the system, (b) provides for a prolonging memory effect to unfold, and (c) offers built-in adaptability and variability (which are both associated with learning skills; see, for instance, [Fischer 2006; Fischer & Bidell 2006; Butkus 2006, 35]).

Since higher-order 'macroscopic' information (in the form of collectively coordinated movements of the system's 'microscopic' individuals) only emerges in a confined set of complex system states associated with an appropriate 'opinion changing threshold' and proper β-value [Ehrlich & Levin 2005], the system can be considered very similar to systems exhibiting Self-Organized Criticality [Bak et al. 1987, 1989]. Although the *instructionally* fine-tuned threshold levels and β-values facilitate the higher-order collective patterning to persist over time, the expanded threshold voter model will not spontaneously *self*-organize towards complexity. That is, complex systems should necessarily exhibit *selectional* (instead of instructional) underpinnings, otherwise spontaneous emergence would not be possible. However, given the possibility of truly *selectional* substrate dynamics, such self-organized higher-order patterning may very well occur in real-world situations. So, in this way, this section's first question – i.e., how truly complex patterns, like reflexive consciousness, could occur from lower-order dynamics – seems to be properly addressed.

Additionally, the second requirement – acquiring system-wide reflexive self-representation – is also suitably met. That is, a sense of system-wide reflexive self-representation is acquired through the *system-changing* influence of the collective whole of marker fluid sensitivities, while at the same time this very collective whole itself is inevitably *affected by* the system. Nevertheless, this does not mean that the possibility of actual psychophysical dynamics has been validated without a shadow of a doubt. The presence of instructional (instead of selectional) foundations, and the absence of a truly complex and reflexive 're-representation mechanism'[37], still prevent this from happening.

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[36] In [Chialvo et al. 2000] Dante Chialvo and his accomplices describe "a robust form of noise-induced memory which appears naturally as a direct consequence of including distributed nonlinearities in the formulation of a neuron's input region." Such noise-induced memory is also confirmed to occur by Povinelli and collaborators [Povinelli et al. 1999]. According to Chialvo and his accomplices, such "memories are believed to be written as a stronger coupling among individual, or groups of neurons. These couplings are strengthened by neural co-activity much in the same way that the pheromonal field is preserved or strengthened by coherent frequent … traffic [of individuals]." [Chialvo et al. 1995]

[37] 'Consciousness, as we shall see, only arises when the object, the organism, and their relation, can be re-represented.' [Damasio 1999, 160]; ' ... one might say that the swift second-order nonverbal account narrates a story: *that of the organism caught in the act of representing its own changing state as it goes about representing something else*. But the astonishing fact is that the knowable entity of the catcher has just been created in the narrative of the catching process.' [Damasio 1999, 170]

However, a persistently recurring mechanism can be identified from the discussed threshold systems. In the jungle as well as in insect swarms, enduring trajectories embody a robust dynamical memory of successful activity. As the system's collective activity marks its trails through leaving behind a distinctive duplicate of itself (e.g., a beaten track or pheromone trail) it literally constitutes a 're-collection' of its own past behaviour. As the process of evolving, collective, and interdependent activity goes on for longer periods of time, the global, system-wide patterning of these 're-collection trails' becomes highly correlated until every 'single' locality of the system depends on past activity of every other 'single' locality of the system. In this way, truly complex spatial and temporal structures emerge hand-in-hand as a natural consequence of the growing correlations via emerging structures that in turn bias the path of the temporal dynamics until the system is fully correlated in a statistical sense [Linkenkaer-Hansen 2002, 15], thus establishing a physically embedded memory.

Klaus Linkenkaer-Hansen also mentions in his doctoral thesis that the brain is a pre-eminent system for exhibiting Self-Organized Criticality [Ibid., 15], making it plausible that memory dynamics as mentioned above, can actually develop through self-organizing natural and somatic selection:

"The ideal SOC [Self-Organized Criticality] system is spatially extended with locally interacting units. These features are clearly met by the brain with its typical density of neurons reaching approximately a 10^5 neurons pr. mm^2 of cortical tissue and on the order of 10^3–10^4 synaptic connections pr. neuron [Nunez 1995]. Although many neurons project to distant brain regions, most synaptic connections are made within the macrocolumn of approximately 3 mm in radius [Nunez 1995]. The prerequisite of being spatially extended (i.e., having many units) has to do with the need of the system to generate spatial structures that can hold a memory of past activity." [Linkenkaer-Hansen 2002, 15]

In cognitive science, memories are usually conceived of as a neuronal representation of a previous event that is accessible to consciousness. However, such a conception implicitly presumes dualism by treating the neuronal representation and consciousness as separate entities. Considering that the brain is an outstanding example of a complex threshold system[38] it is more likely that neuronal patterning, memory formation, and conscious mental activity should be seen as a 'many-in-one', as suggested by reflexive monism [Velmans 2000, 233].

3.3 PROCESS-ORIENTED FOUNDATION OF HIGHER-ORDER SYNTAXES

Previously in this paper I have argued that from the most basic subconceptual level, the brain's neurocognitive processes inevitably bring along object-oriented portrayal of reality. That is, through self-referential (i.e., reentrant) dynamics neural patterns organize themselves into distinguishable *units* ('neural-mental objects'). Synchronized reentrant firing can initiate various neural pathways of perception, proprioception and interoception to bring forth an integrated-differentiated collective totality of sensorimotor and somatosensory patterns which will yield coordinated behaviour [Edelman and Tononi 2000, 48-50 and 87]. Concurrently, successful behaviour will strengthen the associated neuronal trajectories, thus providing the appropriate conditions for relatively stable higher-order patterning to emerge through 'somatic selection' [Edelman & Tononi 2000, 83-85] (see also section 2.5). This neural self-referential selectionism (active throughout the brain, on a local and global level) facilitates neural-mental object formation [Edelman & Tononi 2000, 214]. In this way, preconscious and conscious categorization of novel somatosensory input is enabled, which is essential to higher-order neurocognitive processes (such as concept formation and pattern recognition)

[38] With (1) thresholds for synaptic excitation, (2) excitation recovery times (forming short-term memory trails), and (3) highly complex reentrant neuronal interconnection facilitating system-wide local-global correlation (as needed for an embedded-embodied long-range memory) the brain clearly exhibits complex threshold dynamics.

and which provides the emergent syntactical 'objects' of conscious experience. Put short, the integrated-differentiated collective totality of sensorimotor and somatosensory patterns yields coordinated behaviour, strengthening the associated neural pathways through 'neuroplasticity', in this way 'actuating' preconscious and conscious object-oriented patterning.

When considering consciousness as a 'self-simulating' process[39], the grain size of the simulated patterns (e.g., non-conscious somatosensory maps) can be smaller than the grain size of their *simulation* (i.e., the higher-order conscious amalgam of perceptual, proprioceptive, and interoceptive patterns), so the simulation's resolving power will not be sensitive enough to obtain a 100% complete duplication. This is further explained in the quotation below (see also section 2):

"What Raffman has shown [see note 15] is the existence of a shallow level in subjective experience that is so subtle and fine-grained that – although we can *attend* to informational content presented on this level – it is neither available for memory, nor for cognitive access in general. […] We cannot – this seems to be a central insight – achieve any epistemic progress with regard to this most subtle level of phenomenal nuances, by persistently extending the classic strategy of analytical philosophy into the domain of mental states, stubbornly claiming that basically there must be some form of linguistic content as well, and even analyzing phenomenal content *itself* as if it were a type of conceptual or syntactically structured content […] " [Metzinger 2003, 70].

Reflecting on these findings, we must conclude that *preconscious processing* cannot be 'captured' by *conscious experience*. That is, a conscious organism cannot be sentient of certain synaptic and/or neuronal events that are too small-grained, even though these events inevitably give rise to the organism's experiential patterns. And although this conclusion may seem inescapable, it still doesn't clarify *why* this is so.

However, when considering the situation from a process-oriented, selectional, and self-organisational point-of-view, things might get more clear and understandable. First of all – as mentioned earlier – seen from a process-oriented context it is simply inappropriate to label preconscious processing and conscious experience as separate object-oriented mechanisms. That is, an emergent (mental) syntax is not applicable onto its own substrate, because – similarly to overlapping definiendum and defining system – the *instrument* and *target* of syntactical portrayal overlap. Moreover, 'consciousness' is *not* the common denominator of the mechanisms in scope; rather, 'patterning' is the common feature. Accordingly, I'd prefer some alternative terminology – if possible – that is not exclusively focussed on the term 'consciousness'.

Taking into account these annotations, as a working hypothesis, it seems more appropriate to refer to 'preconscious processing' as 'reflexive syntax-actuating patterning', and to 'conscious experience' as 'experiential syntactical patterning'[40]. This would take into account the impossibility for an experiential system to capture its own complex underlying dynamics by using a reflexively emergent object-oriented syntax. Attempts to nonetheless express complex pre-syntactical dynamics through mere object-oriented syntactical units (neural-mental 'objects') would inevitably bring along impredicativity, since the applied object-oriented syntactical units depend on the very substrate medium which is supposed to be syntactically expressed.[41]

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[39] Thomas Metzinger describes several kinds of neural-mental self-simulation (e.g., mental, motor, and autobiographical self-simulation) exemplified in quite a representative way by phenomenal self-simulation [Metzinger 2003, 340-344] which – he argues – is essential to the emergence of consciousness, and which he affiliates with Damasio's concept of 'core self' [Damasio, 1999, 134-143].

[40] 'Experiential syntactical patterning' occurs when the emergent syntax is 'rich' enough for the reflexive dynamics to bring along 'experiential self-simulation'.

[41] The only instruments ready-available for *analysing* the underlying neural substrate ('syntax-actuating patterning') are the higher-order mental concepts that are emergent from the neural substrate *itself*. Obviously, these mental concepts cannot satisfactorily represent something *beyond* their own syntactical domain – just as uttered words cannot adequately embody all the characteristics of the uttering vocal system (e.g., aspecific speech sounds, in-between-words salivation sounds, etcetera). Moreover, the vocal system cannot be seen separately of it complex 'grand environment', e.g., the entire organism with its lungs, tongue, abdominal muscles, speech related brain functionality, but also the external envi-

When committing ourselves to these inescapable findings, we'll have to accept that our current object-oriented syntax for experiencing and describing reality is just an idealisation. As a result, we'll have to look for an alternative for conventional object-oriented accounts of reality, which (a) would have to be reflexive, not linearly hierarchical (i.e., would have no consecutively piled up levels of object-oriented entities); (b) exhibits self-referential dynamics; (c) spontaneously grows emergent, higher-order structures; (d) is selectional, not instructional.

In comparison to the conventional object-oriented way of thinking, these characteristics call for a rather different approach for portraying reality. According to conventional present-day physics reality basically consists of individual, unitary entities that are able to interact with one another within a geometrical space which functions as a 'container of entities'. Accordingly, the universe is widely considered to be founded on fundamental starting entities, serving as the 'building bricks' of physical reality.[42] How then, should we conceive of process-oriented foundations? That is, how can a *process* be a fundamental building brick?

For this purpose, I think 'autopoiesis' can be a very useful concept. Autopoiesis – literally meaning 'self-creation' – was introduced by Chilean biologists Humberto Maturana and Fransisco Varela in the 1970s as an attempt to characterize the nature of living systems (e.g., biological cells):

"An autopoietic machine is a machine organized (defined as a unity) as a network of processes of production (transformation and destruction) of components which: (i) through their interactions and transformations continuously regenerate and realize the network of processes (relations) that produced them; and (ii) constitute it (the machine) as a concrete unity in space in which they (the components) exist by specifying the topological domain of its realization as such a network." [Maturana and Varela 1980, 78]

In biological autopoiesis, the naturally evolved organelles of a living organism's cells – through external distributed inflow of 'nourishing' molecules and energy – manufacture the biochemical substances (such as nucleic acids and proteins) which reflexively maintain the organized bounded totality of cellular structure that, yet again, *produces* these substances. From an object-oriented point of view this explanation can be considered impredicative. However, autopoiesis should preferably be applied in the process-oriented context of non-linear dynamics; that is, biological or natural structures should *not* be considered to be invariable axiomatic or primitive objects, but rather relatively stable emergent dissipative structures brought along by a dynamical inflow which is relatively small compared to the distinguishable structures in scope (e.g., organelles, gas particle systems, etcetera) [Nicolis & Prigogine 1977]. Although regularly referred to as '*substrate* inflow', actually this inflow – is not hierarchically *underlying* the emergent stable structures. To be more precise, there is a reflexive, selectional interdependence between lower-order and higher-order patterning. This implies that there is no actual separation between the 'two', other than a virtual, merely experiential separation (due to our object-oriented neurocognitive mechanisms). Moreover, this indicates that object-oriented foundations of natural systems (such as biological cells, or the universe) are simply fictional.

Consequently, in the context of autopoiesis, the concept of '*lower-order underlying substrate*' is only acceptable for instructive purposes (as a figure of speech), merely functioning as an approximate, instrumental notion. In fact, such object-oriented terminology would be more appropriate for so-called allopoietic systems, such as a toy factory whose final product is distinct from the factory itself. Moreover, its end product can be fully accounted for by putting together all the required elementary components according to well-definable procedures. That is, these allopoietic systems are characterized by the occurrence of elements and totalities in an object-oriented syntax similar to the hierarchical syntax of formal set-theory or algebra. More specifically, they rely on raw materials (cf., elementary components) to manufacture toys (cf., organized totalities) by executing a fixed set of operational tasks or working instructions (cf., algorithms). All in all, this implies

ronment providing acoustic characteristics, air, speech responsive peers, etcetera. Words cannot render an exact and complete conceptual copy of this complex totality.

[42] Please notice that this belief already (prematurely) involves dualist materialism.

that object-oriented systems are not suitable for spontaneous self-reproduction, whereas they excel at processing input units to produce any preconceivable final product (that is, a product for which it suffices to sum up all the elementary components and the matching working instructions to get a perfectly fine specimen).

In contrast, substrate dynamics of *complex autopoietic* systems cannot be adequately 'captured' by such an instructional object-oriented syntax. That is, no truly elementary components can be identified that, together, will produce all the emergent characteristics of a self-organising complex system. There is no blueprint ready-available, or even *conceivable* for any supposed end result of self-organizing evolutionary development. So, without the possibility of an object-oriented blueprint it will not be possible for axioms, primitives, postulates, or any other object-oriented foundation to provide a solid basis for such systems. Instead of having object-oriented foundations, an autopoietic system might 'bootstrap' itself into existence [cf. Cahill & Klinger 2005] through autopoiesis-like self-creation. Quite recently, Christopher Langan has suggested how the occurrence of such self-creation can be accounted for. In the following passage he focuses on the universe as an intrinsic self-simulation[43]:

"The laws that govern a system may be reposed in the space that contains its objects, or in the objects themselves. Classical physics reposes everything in space, applying spatial concepts like vectors and tensors to fields outside the objects. However, it is possible to apply a logical transformation which inverts this picture, turning it "outside-in". This results in a "distributed subjectivization" in which everything occurs inside the objects; the objects are simply defined to consistently internalize their interactions, effectively putting every object "inside" every other one in a generalized way and thereby placing the contents of space on the same footing as that formerly occupied by the containing space itself. Vectors and tensors then become descriptors of the internal syntactic properties and states of objects. In effect, the universe becomes a "self-simulation" running inside its own contents." [Langan 2002, 41-42]

Instead of presupposing space as a 'container of physical entities' Langan suggests the universe itself to be self-determining and therefore to exhibit self-containment:

"Self-determinacy is like a circuitous boundary separating the poles of the above dichotomy [of determinacy and indeterminacy] … a reflexive and therefore closed boundary, the formation of which involves neither preexisting laws nor external structure. Thus, it is the type of causal attribution suitable for a perfectly self-contained system. Self-determinacy is a deep but subtle concept, owing largely to the fact that unlike either determinacy or randomness, it is a source of bona fide meaning. Where a system determines its own composition, properties and evolution independently of external laws or structures, it can determine its *own* meaning, and ensure by its self-configuration that its inhabitants are crucially implicated therein." [Langan 2002, 5]

Additionally, his ideas convey "a meta-Darwinian message: the universe evolves by hological self-replication and self-selection. Furthermore, because the universe is natural, its self-selection amounts to a cosmic form of *natural* selection. But by the nature of this selection process, it also bears description as *intelligent self-design* " [Langan 2002, 50]. That is: " […] by its self-generative, self-selective nature, which follows directly from the analytic requirement of self-containment, reality is its own 'designer'." [Ibid., 52]

Although I'd like to mention that, in the first stages of development, such a self-simulating universe cannot be considered intelligent in the everyday sense that it would behave according to a carefully thought-through scheme. Rather, to avoid misunderstanding I prefer to use the term 'reflexive'. That is, in a human being intelligence is usually thought to emerge during ongoing foetal and childhood development, not to be promptly present within the newly conceived embryo. On the other hand, it would be quite acceptable to state that intelligence is *implicitly* present in reflexive dynamics. Moreover, I very much value the attempt to reconcile the two opposing groups of evolu-

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[43] Earlier in this section (3.3) self-simulation has also been mentioned by Thomas Metzinger within the context of conscious experience [Metzinger 2003, 70 and 340-344].

tionists (supporting natural selection) and creationists (supporting Intelligent Design), so I can certainly understand why Langan would use the term 'intelligent self-design', although no intelligence seems to be involved in the initial self-creation.

Additionally, the notion of 'object' – as used by Langan in the abovementioned quotation – could use a similar nuance. That is, when he mentions that every object exists in every other one, these objects should not be considered objects in a conventional sense. Rather, 'they' should be seen as reciprocally entangled autopoietic machines [Maturana and Varela 1980, 78], i.e., self-creating processes, or dissipative structures [Nicolis & Prigogine 1977] that are relatively stable and – although *conceivable* as distinct objects – should be regarded as processual in a Heraclitean sense[44]. Therefore, collectively, these 'pseudo-objects' – that are actually process-oriented patterns – should be considered *one* universal totality in self-containment.

Although it might be tempting to ask *how* self-creation can *precisely* bring about this universal totality, an answer can *only* be given in terms of higher-order concepts that ultimately cannot fully and adequately cover the all-inclusive universal totality of which they themselves are part. That is to say, any attempt to *conceptually* portray the primal beginnings of the universe will yield conceptual impredicativity. When requested to nonetheless give it a shot, I would definitely fall back on Christopher Langan's 'syndiffeonesis' [Langan 2002, 15-16]: "Syndiffeonesis implies that any assertion to the effect that two things are different implies that they are reductively the same; if their difference is real, then they both reduce to a common reality and are to that extent similar. Syndiffeonesis, the most general of all reductive principles, forms the basis of a new view of the relational structure of reality."

Following this logic, the 'existence of non-existence' can form a syndiffeonic relation which perhaps can be suitably described as a pre-syntactical, pre-geometric omnipresent singularity[45] that bootstraps its *intrinsic environment* into existence [cf., Langan 2002]. In that case, in order to maintain universal identity[46], systemwide intrinsic self-footaging[47] would have to occur, yielding ongoing self-referential heterarchical activity. Necessarily, such universal self-referential activity should be stochastic, since the universally occurring local 'footaging' of the global status involves ever-increasing interconnected patterning, which is very similar to the myriad underlying interconnections denoted by the intrinsic noise of osmotropotaxic systems in section 3.2. That is, the footaging process changes the 'local-global' status, which simultaneously needs to be 'footaged' throughout the system again, and so on, in this way yielding ongoing self-organizing, noisy, self-similar, truly complex patterning of topological relations[48].

On balance, these ideas of the universe as a reflexive stochastic self-organising system are very much compatible with the Process Physics train-of-thought [Cahill 2005]. Starting out with a 'close-to-no-structure' non-linear noisy iterative matrix grid, it shows a remarkably correspondence with the early conditions of the reflexive self-organizing self-containing universe mentioned

[44] Heraclites of Ephesus was a pre-Socratic Greek philosopher whose most famous statement is "panta rei" [all is flux], i.e., everything flows (and nothing stands still).

[45] Cf. the notion of 'pregeometry' mentioned by Reg Cahill and Christopher Klinger [Cahill & Klinger 1996]. Additionally, I'd like to mention that a pregeometrical singularity cannot denote an infinitely small phenomenon, since there is no geometrical scale with respect to which it could be infinitely small. However, a singularity's *intrinsic environment* can be considered to supply an ever-evolving internal complexity.

[46] A singularity cannot be seen separately of itself (since 'all is one'), thus requires to exhibit universality (i.e., the quality or condition of being universal; 'being the same all over'). Accordingly, universal self-containing identity (= syndiffeonesis) involves everything to incorporate everything (cf. quantum non-locality and quantum entanglement). Another appropriate motto would be: "all is in all." (cf. [David Bohm 1980])

[47] I.e., reflexive read-write functionality, as mentioned by Christopher Langan [Langan 2002, 1]. Please note the resemblance with the 'similarity seeking and signalling capability' mentioned in section 3.2, and the intrinsic noisiness associated with this.

[48] Initially, space is nonexistent, because the system starts out pregeometrically. Therefore, we can only refer to the topological relations from which space eventually emerges (together with unidirectional process-time and later-arising physical structures) [Cahill & Klinger 1996 and 2000; Cahill 2005].

above[49]. Established by founding father Reg Cahill, the recently developed Process Physics uses the notions of Self-Referential Noise and Self-Organised Criticality to create a new type of modelling of the universe. In this way it brings along not only the conventional formalisms of Relativity and Quantum Mechanics, but also some new intrinsic features such as unidirectional time, the present moment effect and quantum state entanglement (including EPR effects, nonlocality and contextuality). Moreover, an alternative theory of gravity as a superposition inflow effect has also emerged [Ibid.].

In conclusion, reflexive Self-Organized Criticality seems to be a universal mechanism for establishing dissipative structures: not only in the mind/brain (neural-mental patterns), but throughout the natural universe. In this way, higher-order structures reflexively evolve through natural selection bringing along an emergent object-oriented syntax (i.e., object-orientation; see section 1.2) from autopoietic noisy processual foundations.

4 CONCLUSION

Throughout this paper, we've gone to far lengths in fulfilling Steven Wolfram's suggestion to also focus on the mechanisms *through which we become aware* of reality's phenomena. Remarkably, the inescapable 'object-basedness' of concepts turned out to originate from these very mechanisms, instead of exclusively representing the foundational structure of physical reality. That is, the self-referential nature of our neurocognitive mechanisms causes neural signals to self-organize into object-oriented neural-mental patterns, which simultaneously unify *and* 'feed' our conscious phenomenal experience, short-term and long-term memory, and information processing mechanisms.[50] Although within the threshold system models, no actual self-conscious patterns occur, this is not surprising, because this can only happen in truly complex systems that can convey the higher-order narrative of the system '*caught in the act of representing its own changing state as it goes about representing something else*' [Damasio 1999, 170]. However, the fact that *higher-order global* patterning emerges through introducing *random local* activity, indicates that such dynamics could very well be possible in actual mind/brains, thus facilitating the integration of the supposedly separate mechanisms of conscious experience, memory, information processing, and probably also imagination.

In our conscious experience, the bound-in-one, collective whole of these object-oriented phenomenal, memorial, and information processing patterns is extremely convincing as a realistic image of reality. However, ultimately reality *is not* object-oriented [Cahill 2005; Corbeil 2004], for a true *uni*verse would comprise an inseparable unity, facilitating intrinsic interaction with and within itself (which can thus be suitably called 'self-referential' or 'reflexive'), hereby yielding relatively stable, but fundamentally dynamic, psychophysical structures. In Velmans's words [Velmans 2000, 233]: "In this vision, there is *one* universe … with relatively differentiated parts in the form of conscious beings like ourselves, each with a unique, conscious view of the larger universe, of

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[49] Please note that an Process Physics – in contrast with Christopher Langan's CTMU (Cognitive-Theoretic Model of the Universe)

[50] In this way the frame problem disappears within the wink of an eye. For the frame problem suggests that beliefs are being stored and *then* processed to yield coordinated behaviour, whereas in fact phenomenal experience, memory functioning and information processing cannot be seen separately – 'they' are simply self-organizing, integrated-differentiated neural-mental patterning. Edelman and Tononi have presented a similar solution in [Edelman & Tononi 2000, 108], where they emphasize that value-category memory, perceptual categorization and primary consciousness are very closely connected through reentrant linkage. It must be stressed though, that several types of memories (such as, working memory, autobiographical memory, proprioceptive memory) might be identified, which thank their different functionality to the differences in global availability, robustness, degree of reentrant interconnectedness, etcetera.

which it is a part. In so far as we are parts of the universe that, in turn, experience the larger universe, we participate in a reflexive process whereby the universe experiences itself."[51]

This unconventional statement is comprehensively brought home by Reg Cahill's daring efforts of presenting a self-organizing process-oriented threshold model of the universe, which is driven by self-referential noise [Cahill 2005]. The notion of 'universal singularity' can facilitate processual noisy foundations of the natural universe, without the need for any external, pre-available, absolute and eternal laws[52]. Accordingly, rather than the static four-dimensional modelling of present day (non-process) physics, Cahill's Process Physics provides a dynamic model where space- and matter-like structures emerge from a fundamentally random, but self-organising substrate, so that physical matter should be conceived of as a relatively stable whole of dissipative structures [Cahill 2005]. Subsequently – following similar selectional dynamics as mentioned by Gärdenfors (section 2) and Edelman (section 2.5), and as shown through the self-organising threshold systems in section 3.2 – higher-order mental patterns could be actuated from a dynamical, self-referential neural substrate. Hence, physical and mental patterns can be considered to naturally evolve from one and the same reflexive process (see also section 3.1), in this way comprising psycho-physical patterns .

Since (in section 3.3) the spontaneous self-simulational nature of *reflexive* processes is found to be essential for the occasion of both the natural universe and experiential consciousness, conventional axiomatic object-oriented mathematics should no longer be considered absolute and eternal. That is, it should not be considered to have existed 'beyond' the beginning of the universe, because reflexive selectional self-simulational patterning does not call for additional *external* and *instructional* rules or laws to determine behaviour. In effect, reflexive self-organizing patterning is a calculator (i.e., calculating structure), 'calculated structure', and 'structure to be calculated on' at the same time[53]. This is closest reflected by the still fairly youthful branch of mathematics called Algorithmic Information Theory [Chaitin 1998]. Algorithmic Information Theory identifies the presence of intrinsic randomness in (mathematical) systems that are sufficiently rich to exhibit self-referencing.

So, while Algorithmic Information Theory shows that ordered mathematical structures convey intrinsic randomness, conversely, in sections 2 and 3.2 (in the jungle analogy and the expanded threshold voter model) it is demonstrated that initial random behaviour can spontaneously give birth to ordered structures. That is, complementary to confirming randomness to be intrinsic to ordered (mathematical) systems, it is shown that – given an appropriate ratio of constructive/destructive[54] dynamics – from randomness eventually ordered patterning can arise. Moreover, endogenous randomness in the form of Intrinsic Stochastic Resonance is believed to play an essential role in synchronized brain oscillations[55]. This indicates that structure and randomness are two sides of the same coin: reflexive processuality.

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[51] "This reflexive monism combines ontological monism and epistemological pluralism (there is one thing that can be known in many ways) with the added suggestion that knowledge is, ultimately reflexive." [Velmans 2000, 235]

[52] From a conventional object-oriented point-of-view it's quite disturbing that such pre-existent absolute and eternal laws are formulated by using an object-oriented syntax, whereas 'beyond' the beginning of the universe the concepts of 'object', 'space' and 'time' should be considered meaningless.

[53] In this way, an axiom-less system is attained (cf., the axiom-less Heraclitean Process System of Process Physics [Cahill & Klinger 2000]).

[54] I.e., construction/destruction of orderly syntactical patterns, constituting order-disorder dynamics.

[55] In his doctoral thesis, Klaus Linkenkaer-Hansen mentions: "The possibility that the endogenous activity of physiological systems may play the role of noise for stochasticresonance-based processing of neuronal signals has been suggested by several investigators [Balázsi, Kish & Moss 2001; Braun, Wissing, Schäfer & Hirsch 1994; Chialvo, Longtin & Müller-Gerking 1997; Collins, Chow & Imhoff 1995; Douglas, Wilkens, Pantazelou & Moss 1993; Glanz 1997; Kelso 1995; Nozaki, Collins & Yamamoto 1999; Stacey & Durand 2000; Traynelis & Jaramillo 1998] but evidence for this so-called intrinsic stochastic resonance has only been obtained from simulation studies [Chik, Wang & Wang 2001; Rudolph & Destexhe 2001; Stacey & Durand 2000; Stocks 2001; Stocks & Manella 2001]." [Linkenkaer-Hansen 2002, 17] This is not surprising, since earlier in this paper we've already seen that (noisy) substrate dynamics cannot be properly expressed by using the object-oriented syntax of higher-order structures (e.g., brain-scanning equipment).

Hence, as Heraclitean processuality turns out to be pivotal to physics and metaphysics, the presupposition of distinct, object-oriented totalities within the definitions of realism and antirealism (i.e., physical reality being distinct of mental reality) should be considered quite inappropriate. For the built-in 'object-basedness' of realism and antirealism originates from our brain's neurocognitive reflexive mechanisms, instead of exclusively representing the foundational structure of physical reality. And although we tend to describe reality in an object-oriented fashion by using discriminate terminology (which indicates Velmans's epistemological pluralism), in fact reality *cannot* be cognitively or theoretically captured in an adequate way through holding the separate existence of physical and mental entities. In this way, Velmans's ontological monism is endorsed, since it advocates the inseparable unity of the universe. Therefore, process-oriented reflexive monism should be considered the only suitable foothold for further scientific endeavour.

REFERENCES:

Baas, N.A.
1994, Emergence, hierarchies and hyperstructures, in C.G. Langton, ed., *Artificial Life III, Santa Fe Studies in the Sciences of Complexity, Proc. Volume XVII*, 515–537, Addison-Wesley, Reading, MA.
1996, A framework for higher order cognition and consciousness, 633-648 in S. Hameroff, A. Kaszniak & A. Scott, eds., *Towards a science of consciousness*, MIT Press/Bradford Books.

Baas, N A. & Emmeche, C.
1997, On emergence and explanation, *Intellectica*, 2(25): 67–83.

Bailey, C.H., Bartsch, D., & Kandel, E.R.
1996, Toward a molecular definition of long-term memory storage, *Proc. Natl. Acad. Sci.*, 93(24): 13445-52.

Bak, P., Tang, C., & Weisenfeld, K.
1987, Self-organized criticality: an explanation of $1/f$ noise, *Physical Review Letters*, 59: 381–384.

Bak, P., Chen, K., & M. Creutz, M.
1989, Self-organized criticality in the 'game of life', *Nature*, 342: 780-782.

Balázsi, G., Kish, L.B. & Moss, F.E.
2001, Spatiotemporal stochastic resonance and its consequences in neural model systems, in *Chaos* 11:563−569.

Bickle, John
1998, Multiple Realizability, in E.N. Zalta, ed., *The Stanford Encyclopedia of Philosophy (Fall 2006 Edition)*, URL = < http://plato.stanford.edu/archives/fall2006/entries/multiple-realizability/ >.

Bohm, D.
1980 *Wholeness and the Implicate Order*, London, Boston: Routledge & Kegan Paul.

Boolos, G.
1998, *Logic, Logic & Logic*, London: Harvard University Press.

Braun, H.A., Wissing, H., Schäfer, K, & Hirsch, M.C.
1994, Oscillation and noise determine signal transduction in shark multimodal sensory cells, in *Nature* 367:270−273.

Bressler, S.L., & Kelso, J.A.S.
2001, Cortical coordination dynamics and cognition, *Trends in Cognitive Sciences*, 5: 26-36.

Buonomano, D. V., & Merzenich, M. M.
1998, Cortical plasticity from synapses to maps, *Annu. Rev. Neurosci*, 21: 149-186.

Butefisch, C., Davis, B., Classen, J., Wise, S., Sawaki, L., Kopylev, L., & Cohen, L.G.
2000, Mechanisms of use-dependent plasticity in human motor cortex, *Proc. Nat. Acad. Sci.,* 97: 3661-5.

Butkus, M.A.
2006, *Depression, volition, and death: The effects of depressive disorders on the autonomous choice to forgo medical treatment*, PhD Dissertation, Pittsburgh, PA: Duquesne University.

Cahill, R.T.
2005, *Process Physics: From Information Theory to Quantum Space and Matter*, NewYork: Nova Science. (Many Process Physics papers can be found on: www.scieng.flinders.edu.au/cpes/people/cahill_r/processphysics.html)

Cahill, R.T., & Klinger, C.M.
1996, Pregeometric Modelling of the Spacetime Phenomenology, in *Physics Letters* ***A*223**, 313-319.
2000, Self-Referential Noise and the Synthesis of Three-Dimensional Space, in *General Relativity and Gravitation* **32**, 529.
2005, Bootstrap Universe from Self-Referential Noise, *Progress in Physics***,** 2, 108-112.

Cahill, R.T., Klinger, C.M., & Kitto, K.
2000, Process Physics: Modelling Reality as Self-Organising Information, in: *The Physicist*, **37**(6), 191-195.

Casti, J.L.
1997 *Would-Be Worlds: How Simulation is Changing the Frontiers of Science*, New York: Wiley.

Chaitin, G.J.
1998 *The Limits of Mathematics: A Course on Information Theory and the Limits of Formal Reasoning*, Singapore: Springer-Verlag.

Chialvo, D.R.
2004, Critical Brain Networks, *Physica A,* 340(4): 756.

Chialvo, D.R., & Millonas, M.M.
1995, How swarms build cognitive maps, in L. Steels, ed., *The biology and technology of intelligent autonomous agents*, NATO ASI Series, (144): 439-450.

Chialvo, D.R., Cecchi, G.A., & Magnasco, M.O.
2000, Noise-induced memory in extended excitable systems, *Physical Review E*, Vol. 61, Nr. 5: 5654-5657

Chialvo, D.R., Longtin, A., & Müller-Gerking, J.
1997, Stochastic resonance in models of neuronal ensembles, in *Phys Rev E* 55:1798−1808.

Chik, D.T.W., Wang, Y., & Wang, Z.D.
2001, Stochastic resonance in a Hodgkin-Huxley neuron in the absence of external noise, in *Phys Rev E* 64:021913.

Christensen, D.E.
1986 *The Search for Concreteness: Reflections on Hegel and Whitehead, a Treatise on Self-Evidence and Critical Method in Philosophy*, Cranbury, London, Mississauga: Associated Press.

Corbeil, M.J.V.
2004, Process-Information Metaphysics and Environmental Philosophy, *Concrescence AJPT*, Volume 5.

Collins, J.J., Chow, C.C., & Imhoff, T.T.
1995, Stochastic resonance without tuning, in *Nature* 376:236−238.

Corning, A.
1997, Holistic Darwinism: 'Synergistic Selection' and the Evolutionary Process, *Journal of Social and Evolutionary Systems*, 20: 363-400.

Cotman, C.W., Monaghan, D.T., & Ganong, A.H.
1988, Excitatory amino acid neurotransmission, *Annu. Rev. Neurosci.*, 11: 61-80.

Damasio, A.R.
1994, *Descartes' Error: Emotion, Reason, and the Human Brain*, New York: G.P. Putnam.
1999, *The Feeling of What Happens: Body and Emotion in the Making of Consciousness*, New York: Harcourt Brace.

Davidson, D.
1970 Mental Events, reprinted in D. Davidson, ed., 1980, *Essays on Actions and Events*, 207-225, Oxford: Clarendon Press.

Dennett, D.C.
1978, *Brainstorms*, Cambridge, MA: MIT Press.
1991, *Consciousness Explained*, New York: Little, Brown & Co. (cited from: *Consciousness Explained*, London, New York, Victoria, Toronto, Auckland: Penguin Books, 1993).

Dewan, E.M.
1976, Consciousness as an Emergent Causal Agent in the Context of Control System Theory, in G.G. Globus, G. Maxwell & I. Savodnik, eds., *Consciousness and the Brain: A Scientific and Philosophical Inquiry*, 181-198, New York: Plenum Press.

Diamond, M.C., Scheibel, A.B., Murphy, G.M. Jr., & Harvey, T.
1985, On the brain of a scientist: Albert Einstein, *Exp. Neurol.*, 88: 198-204.

Dinsmoor, J.A.
2004, The etymology of basic concepts in the experimental analysis of behavior, *Journal of the Experimental Analysis of Behavior*, 82(3): 311–316.

Dixon, N.F.
1981 *Preconscoius Processing*, New York: Wiley.

Douglas, J.K., Wilkens, L., Pantazelou, E., & Moss, F.
1993, Noise enhancement of information transfer in crayfish mechanoreceptors by stochastic resonance, in *Nature* 365:337−340.

Duda, R.O., Hart, P.E., & Stork, D.G.
1973 *Pattern Classification*, New York: Wiley (cited from: 2000 *Pattern* Classification, New York: Wiley).

Edelman, G.M., & Mountcastle, V.B.
1978 *The Mindful Brain: Cortical Organization and the Group-Selective Theory of Higher Brain Function*, Cambridge, MA: MIT Press.

Edelman, G.M.
1987 *Neural Darwinism The Theory of Neuronal Group Selection*, New York: Basic Books.

Edelman, G.M., & Tononi, G.
2000 *Consciousness: How Matter Becomes Imagination*, London: Allen Lane, The Penguin Press.

Ehrlich, P.R., & Levin, S.A.
2005, The evolution of norms. *PLoS Biol* 3(6): 194.

d'Espagnat, B.
1971, *Conceptual Foundations of Quantum Mechanics*, New York: Benjamin (cited from: 1976 *Conceptual Foundations of Quantum Mechanics*, New York: Benjamin).

Feller, W.
1968, *An Introduction to Probability Theory and Its Applications, Volume 1*, New York: Wiley

Fingelkurts, An.A., & Fingelkurts, Al.A.
2001, Operational architectonics of the human brain biopotential field: towards solving the mind-brain problem, *Brain and Mind*, 2: 261-296.
2004, Making Complexity Simpler: Multivariability and Metastability in the Brain, *The Int. J. of NeuroSci.*, 114(7): 843-862.
2005, Mapping of brain operational architectonics, in F.J. Chen, ed., *Focus on brain mapping research*, New York: Nova Science.

Fischer, K.W.
2006, Dynamic Cycles of Cognitive and Brain Development: Measuring Growth in Mind, Brain, and Education, in A.M. Battro, & K.W. Fischer, eds., *The educated brain*, Cambridge, U.K.: Cambridge University Press.

Fischer, K.W., & Bidell, T.R.
2006, Dynamic development of action, thought, and emotion, in W. Damon & R.M. Lerner, eds., *Theoretical models of human development. Handbook of child psychology* (6^{th} ed., Vol. 1, 313-399), New York: Wiley

Fodor, J.A.
1983 *The Modularity of Mind*, Cambridge, MA: MIT Press.
1988 *The Language of Thought*, New York: Thomas Cromwell.

Fumerton, R.
2000, Foundationalist Theories of Epistemic Justification, in E.N. Zalta, ed., *The Stanford Encyclopedia of Philosophy (Spring 2006 Edition)*, URL = <http://plato.stanford.edu/archives/spr2006/entries/justep-foundational/>.

Gärdenfors, P.
1993, The Emergence of Meaning, *Linguistics and Philosophy*, vol.16, nr.3, June 1993.
2000, *Conceptual Spaces, The Geometry of Thought*, Cambridge, MA: MIT Press.

Glanz, J.
1997, Mastering the nonlinear brain, in *Science* 277:1758−1760.

Gribbin, J.
1995 *Schrödinger's Kittens and the Search for Reality: Solving the Quantum Mysteries*, New York: Little, Brown.

Heisenberg, W.
1958 *Physics and Philosophy, The Revolution in Modern Science*, New York, Harper and Row

Helvik, T.
2005 *Dynamical Systems of Interacting Units: Information Transport and Higher Order Structures*, PhD-thesis, Trondheim: Norwegian University of Science and Technology (NTNU).

Hughes B.
1995, *Random Walks and Random Environments*. Oxford: Clarendon Press

James, W.
1911, Percept and Concept: The Import of Concepts, in: *Some Problems of Philosophy: A Beginning of an Introduction to Philosophy*, New York: Longmans Green, 1911

Kandel, E.R.
2004, The molecular biology of memory storage: a dialog between genes and synapses, Biosci. Re., 24(4-5): 475-522.

Kelso, J.A.S.
1995, *Dynamic patterns: the self-organization of brain and behavior*, London: MIT Press.

Kihlstrom, J.F.
1987, The cognitive unconscious, *Science*, 237: 1445-1452.

Kim, J.
1993, *Supervenience and the Mind: Selected philosophical essays*, Cambridge: Cambridge University Press.

Koestler, A.
1967, *The Ghost in the Machine*, London: Hutchinson

Lakoff, G., & Johnson, M.
1999, *Philosophy in the Flesh*, New York: Basic Books.

Langan, C.M.
2002, The Cognitive-Theoretic Model of the Universe, in *Progress in Complexity, Information, and Design*, Vol. 1.2 and 1.3 (double issue), April-December 2002.

Leplin, J. (ed.)
1984, *Scientific Realism*, Berkeley: University of California Press.

Li, M., and Vitanyi, P.
1993, *An Introduction to Kolmogorov Complexity and Its Applications*, New York: Springer.

Linkenkaer-Hansen, K.
2002, *Self-Organized Criticality and Stochastic Resonance in the Human Brain*, PhD-thesis, Helsinki: Helsinki University of Technology.

Maletic-Savatic, M., Malinow, R., & Svoboda, K.
1999, Rapid Dendritic Morphogenesis in CA1 Hippocampal Dendrites Induced by Synaptic Activity, *Science*, Vol. 283, 19 March 1999.

Metzinger, T.
2003, *Being No One, The Self-Model Theory of Subjectivity*, Cambridge, MA: MIT Press.

Nicolis, G., & Prigogine, I.
1977, *Self-Organization in Non-Equilibrium Systems: From Dissipative Structures to Order Through Fluctuations*, New York: J. Wiley & Sons

Nola, R.
2002, Realism through manipulation, and by hypothesis, in T.D. Lyons & S. Clarke (eds.), *Recent Themes in the Philosophy of Science: Scientific Realism and Commonsense*, Dordrecht: Kluwer Academic Publishers.

Nozaki, D., Collins, J.J., & Yamamoto, Y.
1999, Mechanism of stochastic resonance enhancement in neuronal models driven by 1/*f* noise, in *Phys Rev E* 60:4637–4644.

Nunez, P.L.
1995, *Neocortical dynamics and human EEG rhythms*, Oxford: Oxford University Press.

Okasha, S.
2002, *Philosophy of Science, A Very Short Introduction*, Oxford: Oxford University Press..

Pérez-Otaño, I. & Ehlers, M.D.
2005, Homeostatic plasticity and NMDA receptor trafficking, *Trends in Neuroscience*, 28(5): 229-238.

Piaget, J.
1954 *The Construction of Reality in the Child*, Basic Books, New York (original version: Jean Piaget, *La Construction du Réel chez l'Enfant*, Delachaux et Nietle, Lausanne & Geneva, 1937; cited from *The Construction of Reality in the Child*, Basic Books, New York, 1974).

Povinelli, M.L., Coppersmith, S.N., Kadanoff, L.P., Nagel, S.R., & Venkataramani, S.C.
1999, Noise stabilization of self-organized memories, *Physical Review E*, 59(5-A): 4970-4982.

Psillos, S.
1999, *Scientific realism: How Science Tracks Truth*, London: Routledge.

Putnam, H.
1988 *Representation and Reality*, Cambridge, MA: MIT Press.

Pylyshyn, Z. W.
2003 *Seeing and Visualising: It's not what you think*, Cambridge, MA: Bradford Books/MIT Press.

Quartz, S.R., & Sejnowski, T.J.
1997, The neural basis of development: A constructivist manifesto, *Behavioral and Brain Sciences*, 20: 537-596.

Raffman, D.
1995, On the persistence of phenomenology, in T. Metzinger, ed., *Conscious Experience*. Thorverton, UK: Imprint Academic.

Rail, D.L., Henry, B.I., & Wearne, S.D.

2000, *Self-organized criticality models of neural development*, Applied Mathematics Report AMR00/3, Sydney: University of New South Wales.

Rauch, E.M., Millonas, M.M., & Chialvo, D.R.
1995, Pattern formation and functionality in swarm models, Phys. Lett. A, 207: 185-193.

Revonsuo, A., & Newman, J.
1999, Binding and Consciousness, *Consciousness and Cognition*, 8: 123-127.

Rudolph, M. & Destexhe, A
2001, Correlation detection and resonance in neural systems with distributed noise sources, in *Phys Rev Lett* 86:3662−3665.

Searle, J.
1987, Minds and brains without programs, in C. Blakemore & S. Greenfield, eds., *Mindwaves*, Oxford: Blackwell.
1997 *The Mystery of Consciousness*, London: Granta Books.

Shepard, R.N.
1987, Toward a universal law of generalization for psychological science, *Science*, 237: 1317-1323.

Shi S.H., Hayashi Y., Petralia R.S., Zaman S.H., Wenthold R., Svoboda K., & Malinow R.
1999, Rapid spine delivery and redistribution of AMPA receptors after synaptic NMDA receptor activation, *Science*, 284(5421): 1811-1816.

Shope, R.K.
2004, The Analysis of Knowing, in I. Niiniluoto, M. Sintonen, J. Wolenski, eds., *Handbook of Epistemology*, 283-329 Dordrecht: Kluwer Academic Publishers.

Smolin, L.
1996, A Theory of the Whole Universe, in John Brockman, *The Third Culture: Beyond The Scientific Revolution*, New York: Touchstone.

Sperry, R.W.
1969, A modified concept of consciousness, *Psychological Review*, 76(6): 532-536.
1970, An objective approach to subjective experience, *Psychological Review*, 77(6): 585-590.

Sporns, O., Chialvo, D.R., Kaiser M., & Hilgetag, C.C
2004, Organization, development and function of complex brain networks, *Trends in Cognitive Sciences*, 8(9): 418-425.

Spuzic, S. & Nouwens, F.
2004, A Contribution to Defining the Term 'Definition', in Proceedings of the 2004 Informing Science & Information Technology Education Joint Conference (Santa Rosa, CA, USA): 645-662.

Stapp, H.
1970, S-Matrix Interpretation of Quantum Theory, *Physical Review*, D3: 1303-1320 (cited from the preprint of the Lawrence Berkeley Laboratory, 22 June 1970).

Stern, E.A., Maravall, M., & Svoboda, K.
2001, Rapid development and plasticity of layer 2/3 maps in rat barrel cortex in vivo, *Neuron*, 31: 305-315.

Steup, M.
2005, Epistemology, in E.N. Zalta, ed., *The Stanford Encyclopedia of Philosophy (Fall 2006 Edition)*, URL = < http://plato.stanford.edu/archives/fall/2006/entries/epistemology/>.

Stocks, N.G.
2001, Information transmission in parallel threshold arrays: suprathreshold stochastic resonance, in *Phys Rev E* 63:041114(9).

Stocks, N.G., & Manella, R.
2001, Generic noise-enhanced coding in neuronal arrays, in *Phys Rev E* 64:030902(4).

Stacey, W.C. & Durand, D.M.
2000, Stochastic resonance improves signal detection in hippocampal CA1 neurons, in: *Journal of Neurophysiology* 83:1394−1402.

Sumner, W.G.
1911 *Folkways: A study of the social importance of usages, manners, customs, mores, and morals*, Boston (Massachusetts): Ginn & Co.

Tononi, G., Edelman, G.M. & Sporns, O.
1998, Complexity and coherency: integrating information in the brain, *Trends in Cognitive Sciences*, 2: 474-484.

Traynelis, S.F., & Jaramillo, F.
1998, Getting the most out of noise in the central nervous system, in *Trends Neurosci* 21:137−145.

Velmans, M.
1991, Is Human Information Processing Conscious?, *Behavioral and Brain Sciences*, 14: 651-726.
1995, The Relation of Consciousness to the Material World, *Journal of Consciousness Studies*, 2(3): 255-265.
1996, An introduction to the Science of consciousness, in M. Velmans, ed., *The Science of Consciousness: Psychological, Neuropsychological, and Clinical Research*, London: Routledge.
2000, *Understanding Consciousness*, London: Routledge.
2003, Is the brain in the world, or the world in the brain?, *Behavioral and Brain Sciences*, 26: 427-429.

Wiener, N.
1961, *Cybernetics*, Cambridge, MA: MIT Press.

Wolfram, S.
2002, *A New Kind of Science*, Champlain, Ill.: Wolfram Media