Essays on Cognitive Physical Science
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Understanding Mind

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Preface

The preceding Essay 3 about "A Physicist's Model of Mind" of October 2015 (hdl.handle.net/2236/50310) has been read by test readers with different academic backgrounds, such as physicists, engineers, philosophers, psychologists, sociologists, ethologists, and science journalists. It turns out that the comments received fall into three categories, viz. test readers with a background in physical science and engineering, who in general respond positively or even enthusiastically, test readers with a background in the cognitive sciences (i.e. the human sciences relating to mind), who respond reservedly and sometimes defensively, and those of philosophers and science journalists, who take a non-committal stand.

The responses from test readers with an academic background in the cognitive sciences are such as to suggest that their reservation stems not only from a defiant reaction to criticism levelled at certain aspects of these sciences, but primarily from differences between the methodologies [2] of the cognitive sciences and that of physical science. The methods of philosophy, in comparison, differ significantly from the former two. Science journalists, in

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[1] Honorary Professor

[2] The term methodology is used whenever the term 'method' can be misunderstood as 'method of measurement' rather than 'method of typical approach to a problem'.

contrast and obviously, cannot be expected to favour a particular view; they simply report about what comes along as they understand it, regardless of methodology.

The different methodologies pose a serious problem for anyone who, like me, tries to apply a physical-science perspective to mind-related findings coming from the cognitive sciences. Cognitive scientists feel violated, while physicists and engineers are confronted with an unusual, because non-mathematical, treatment of a phenomenon, here the human mind.

While I realise that the reservation of cognitive scientists can be overcome only by those scientists willing to familiarise themselves with the physical science method of treating a phenomenon, I must do my best to further my original intention of explaining the phenomenon of mind to my physical science colleagues and to engineers, who commonly expect a solution to a physical science problem to be crowned by a mathematical formula. Only those of my colleagues who have an inclination towards philosophy are happy also without a mathematical formulation. They realise that an enigma like the mind needs lots of explanatory and speculative text before the stage is set for a mathematical treatment (if that should ever be possible for complex dynamic systems like brain and mind).

Cognitive scientists have, very understandably, a problem with a model of mind like mine (in the following referred to simply as the Model), which not only differs from their concept of model [3], but which, in the main, seems to merely confirm, in a highly theoretical way, their own empirical research findings. "Of what use is this to psychology and sociology?", say might ask. My answer: A physical-science-type model provides a structure for a unified vision of empirical research findings, which helps to put these findings into an ordered relationship based on the underlying laws of physical science. Such a structure certainly helps physicists to understand the phenomenon of mind, but it may also appeal to some cognitive scientists as an alternative to the existing, rather vague, visions of mind.

These and further advantages of the Model may not have come to the fore sufficiently clear in my Essay 3, as evidenced by the aforementioned reactions of test readers. These may simply have been too overwhelmed by the many unconventional aspects of the Model as well as by the density of arguments. It is for this reason that I have decided to rewrite Essay 3 in a more reader-friendly style which tries to avoid too much interlacing between key points and elaborations. In other words, the current Essay 3.1 is focussed on a summarising

[3] In psychology, "modelling" stands for a procedure whereby a subject observes a model object, for the purpose of learning to imitate the behaviour of the latter.

sequence of key points (presented as a core text) , followed by separate presentations of the underlying arguments (either below the core text, or in additional essays to follow).

Another reason for writing this new Essay 3.1 is that a new important aspect of consciousness has to be added to the Model of Essay 3. This aspect derives from the idea that the conscious emergence of thought does result from the underlying subconscious mental activity exceeding a certain threshold value of intensity [4]. This idea has become another hypothesis of the Model, the Threshold Hypothesis of Consciousness. The new vision of consciousness has necessitated the introduction of yet another hypothesis, the Direct Access Storage hypothesis. Both hypotheses are elaborated below.

To clarify what is meant by the terms conscious and subconscious: My 'subconscious' is identical to one of three meanings of the psychological 'unconscious', viz. "lack of awareness of internal processes" (*Penguin Dictionary of Psychology*). The psychoanalytical meaning, retraceable to Sigmund Freud, is excluded as irrelevant. In conformity with the Threshold Hypothesis of Consciousness, the term 'conscious' refers to 'partial awareness of internal processes'.

Yet another reason for writing this Essay 3.1 is the introduction of an earlier overlooked feature of the Least Effort Principle, named Knowledge Priming, which makes an important contribution to the understanding of learning and mind.

A physicist's search for an understanding of mind is somewhat similar to the search for an understanding of why a chameleon changes its skin colour. The argument that the animal is so clever as to change skin colour for camouflage purposes misses the point. The animal is not that clever. Naturalists will argue that the phenomenon is a result of evolution, not subject to the will of the chameleon, and they would be interested in how well the animal's skin colour matches the colours in the environment under a variety of circumstances. The physicist will want to know what exactly evolution has done to cause the phenomenon.

The answer is that natural selection has favoured the chameleon's survival after a per-chance change of DNA of its precursor has led to the inclusion of pressure-sensitive nano-crystals in its skin. To be specific, every nano-crystal reflects a

[4] The concept of threshold values is widely used in physical science. It has been introduced into psychology in the 1860s, as a means of studying psychological reactions to external stimuli (referred to as psychophysics). My use of the concept differs from its use in psychophysics.

certain wavelength of incident sunlight (i.e. it reflects a certain colour) dependent on the crystal's instantaneous "density". Therefore, a change of pressure on the nano-crystal leads to a change of its "density" and, hence, to a change of its colour. The change of pressure is brought about by a change of environmental colour serving as chameleon-internal stimulus. Those chameleons whose internal signal processing achieved a matching of skin colours to that of the environment survived in the long run. A marvel of evolution, but no longer a mystery.

This is the type of answer which a physicist aims for also when investigating mind.

A model of mind resulting from such investigation is only as good as its explaining power of human reasoning and behaviour. If this is satisfactory for the reasoning and behaviour normally encountered, then - and only then - does it make sense to extend the model to states of mind which deviate from normal. These states, ranging from emotional (agitation of mind) to aberrational (psychopathic, suicidal, neurotic, etc.) are not under consideration in this Essay 3.1.

Introduction

The core text about the Model is found below in a box intended to make the core text stand out. This core text is to serve as a backbone for further essays which are to provide the elaborations missing here.

Below the box are additional texts. The first pertaining directly to the core text. A further one about the main differences of methodologies typical of the approach to problems in physical science, in the cognitive sciences, and in philosophy. And a final one is an appendix, in which mind is viewed as an analogy of a private library (as an introduction for readers unfamiliar with any of the direct approaches).

Readers who are unfamiliar with the model approach typical of physical science are advised to first read the text titled Comparison of Methodologies (pp. 20) before turning to the Core Text.

Core Text

The Modular Mental Structure Model (the Model for short)

The Model is an artificial representation of mind which has been developed (invented if you wish) by a physicist using a physical-science-typical approach. Selected findings from the evolutionary theory, neuroscience, other cognitive sciences, and physical science are used in the construction of the Model.

Hierarchic architecture of nature

Basic to the Model is a vision of nature as being of hierarchic architecture as detailed in Essay 2. In short, the material world (inorganic and organic) consists of components, which consist of components, which again consist of components, etc., down to the most fundamental entities, referred to as fundamental "particles". In other words, every component is constituted of an assembly of components from a next-lower hierarchy level. Every such assembly of components brings forth new properties, referred to as an emergent properties, which are not possessed by the non-assembled lower-level components. For instance, a network of neurons in a brain exhibits emergent properties not possessed by individual neurons, and an assembly of neuronal networks brings forth new emergent properties not possessed by individual networks. The implication of this vision is that an emergent property can be *understood* only by a study of the structure of the assembly of lower-level components.

In the Model, the emergent property of particular interest in a neuronal network is its capability for information storage, and the emergent property of interest in the assembly of all neuronal networks in the brain is the mind.

Post-humanistic complexity

In order to distinguish the Model from unscientific misconceptions nurtured by the philosophical position of humanism, the Model sets off by viewing the entity Man as a complex dynamic system of cooperating anatomical components, where every anatomical component is a system on its own.

Physiology

The anatomical system believed to house the mind and consciousness is the brain. Decades of brain research have shown the brain to consist of networks of neurons (i.e. nerve cells). The neuronal linkages forming the network are not separate "wires", but are neuron-own tentacles joining one another at a linkage point called synapse. Signal transmission from one neuron to another can be controlled (on, off, and regulated) at the synapse.

Every neuron can be interlinked with many other neurons by many of such

tentacles (upstream of the synapse referred to as axons, downstream as dendrites) via an equal number of synapses. Control at each of these synapses determines to which other neurons signals are transmitted to and with which intensity.

The number of interlinking tentacles has been found to increase with the learned contents of the mind, suggesting that new growth of tentacles and their synaptic joining is induced by new information intake at the sensory organs.

It appears to be consentient among a large number of neuroscientists that the mental content of a given neuronal network (sometimes referred to as neuronal circuit) is encoded in the "active" configuration of this network, i.e. in the configuration of the networked neurons which are interlinked via synapses in the "on" mode.

Core hypothesis of the Model

It is here where the Model cuts in, viz. by means of the hypothesis that there is a one-to-one relationship between the physical structure of the learning-related parts of the brain and its mental contents. This is the **Core Hypothesis** of the Model.

The idea behind the core hypothesis is that, of necessity, the mind must be a consequence of a physiological, and hence physical, configuration of the brain, and that any such physical configuration must be subject to the laws and principles of physics.

(A message to physicists: From this viewpoint it is plausible to regard the physical storage of sensory information in form of a neuronal network as a conversion of the kinetic energy conveyed by sensory signals into a signal-specific potential energy in the brain.)

An implication of the core hypothesis is that any new mental information necessitates either a new neuronal network to be physically configured or an existing neuronal network to be physically reconfigured, both requiring available material and energy resources to be consumed (where consumption means the conversion of both material and energy into other forms).

Least Effort Principle and knowledge priming

This process is subject to evolutionary constraints, viz. that the development of those brains has been favoured which were able to maximise the economics of realising a learning goal. A detailed analysis shows this evolutionary dictate to

give rise to a Principle of Least Effort which can be expressed as an "evolutionary predisposition for minimising the consumption of physical resources (materials and energy) for the physical processes behind essential learning", where 'essential learning' can be further specified as survival-furthering learning, embracing both the physical configuration of new neuronal networks and the physical reconfiguration of existing neuronal networks. This is a principle of highest significance for the understanding of mind.

Part of the Least Effort Principle is a feature referred to as knowledge priming, able to explain the often underestimated importance of mental priming in reasoning and behaviour.

By similar argument, evolution has also favoured fastest possible transmission of signals within neuronal networks as well as between those neuronal networks which encode related information. Therefore, the Least Effort Principle implies that information pertaining to a single object (such as mother) is assembled in closely spaced clusters of dedicated neuronal networks, in the Model referred to as modules.

Modular structure

In consequence of the Core Hypothesis, the term 'module' can be applied both to a physical entity (a physical module) and its mental content (a mental module). In other words, the postulated modular *physical* structure of the learning-related part of the brain gives rise also to a modular *mental* structure of this part of the brain. Hence, the name of the Model, viz. Modular Mental Structure Model.

The Model distinguishes between two types of modules, viz. information modules and knowledge modules. A module which records sensory information is referred to as information module. This information does not suffice for an integrated world view, i.e. one which is suitable for mental analysis of the past and prediction of the future. For this purpose, Man needs knowledge modules, in which information from a number of information modules is combined (by brain-internal processing) into self-consistent visions of things (object, quality, state, event, etc.) and their interrelation. For instance, different sensory information about the thing 'mother', stored in different information modules, are combined in a knowledge module containing knowledge about mother and her interrelations with the child and with the thing 'father'.

The physical and mental structures of knowledge modules are exactly analogue to those of information modules. The only difference is that the input to the knowledge modules comes from information modules rather than from direct

sensory input.

Self

Obviously, knowledge modules are not only laid on for external entities (mother, boss, enemy), but also about the self. This becomes possible by the sense of self-awareness, or consciousness, in all situations in which one is involved (observed by the sensory organs or by brain-internal self-monitoring). The Model distinguishes between two knowledge modules of the self, one pertaining to the self-as-perceived, and another pertaining to the self-as-envisaged.

Consciousness

The function of consciousness as just described, is postulated to be its only function. This function is the identification of self in anything in which a person is involved in. This is a drastic (some would say 'heretical') departure from the general assumption (or rather conviction) that the function of consciousness is to manage a person's reasoning and behaviour. The consequence of this new vision of consciousness is that all brain processes have to be subconscious, and that only relatively few outcomes of these processes become conscious in what is vaguely described as "thinking".

I am now adding two new hypotheses to the Model of Essay 3 which help to give more substance to the new vision of consciousness. One is the Threshold Hypothesis of Consciousness, which states that there exists a threshold value for the intensity of a subconscious mental activity in a set of related modules beyond which (threshold) the outcome of this activity becomes conscious. Mental activities of an intensity below this threshold value remain subconscious. The other one is the Direct-Access-Storage hypothesis, which postulates the existence of temporary information storage modules having a function similar to a Direct Access Storage Device in computers. Both hypotheses are explained in some detail at the bottom of this core text.

Private paradigms

A key aspect of the Model is that knowledge modules within a set covering a particular knowledge area are usually not of equal importance, but are importance-ranked. In consequence, one of these modules rises to a status of dominance within the set, called 'private paradigm module', or 'private paradigm' for short. Examples of private paradigms are dogmas about an Almighty in the religious field, but also the key precondition "No supernatural interference" in the field of physical science. Most widespread and conflict-

prone of all is the private paradigm of the I-am-right-and-you-are-wrong type.

The significance of a private paradigm rests in its gatekeeper function: It bars or allows signal admission to the area of knowledge which it belongs to. In this sense, the private paradigm contributes in a significant way to satisfying the Least Effort Principle.

At this stage it must be added that private paradigms do not necessarily have the last say in human behaviour. Rather, if genetically inherited human needs require to be satisfied, than it is the output of "hard-wired" needs modules who dominate reasoning and behaviour, regardless of what ("flexible-wired") private paradigm modules may propose.

Mind

From the foregoing, it is clear that the Model allocates all mental activity to the modules described above, whence the definition of mind can now be formulated as "Totality of mental contents and mental activities of all physical modules".

Least Mental Stress Principle and Collateral Learning Principle

The Model features a total of three principles, of which the Least Effort Principle is one. The other two are the Least Mental Stress Principle, and the Collateral Learning Principle.

The Least Mental Stress Principle acknowledges the fact that new sensory information, coming in at every moment during the wake state, does not necessarily fit into the existing knowledge modules. In fact, some of this new information is likely to obstruct the fast processing of later incoming challenges. Therefore, evolution has favoured the development of mechanisms for prompt removal of the obstruction without loosing the information. Physical stress is the driver for such prompt removal.

The two ways open are either a separation of the new information from the existing knowledge modules for starting a new, quite different, set of knowledge modules or a modification of existing knowledge until the new information fits.

The former is both an evolutionary predisposition (in early life) and a consequence of the Least Effort Principle (throughout life) and is referred to as the Collateral Learning Principle. (An example is a set of knowledge modules pertaining to physical science in parallel to a set of modules centred on a spiritual belief.)

The alternative to collateral learning, viz. modification of existing knowledge until the new information fits, involves individual modules as well as sets of modules. Modification of an individual module is aimed at re-optimising *self-consistency*, and modification of a set is aimed at re-optimising *mutual compatibility*.

From a physical science point of view, the obstruction caused by non-fitting information is a physical resistance to the processing of further sensory information, thereby delaying a rapid decision for action to be arrived at in a critical situation. I am positing that the physical resistance is a cause of physical stress within the system, which in turn activates activities for prompt elimination of this resistance.

According to the Core Hypothesis, this physical stress has a mental equivalent which I am calling 'mental stress', whence the duress to eliminate the physical stress is also a duress to eliminate mental stress. In short, the Least Mental Stress Principle is an "evolutionary predisposition for eliminating the incompatibility of new information with existing knowledge"

Complex dynamic systems brain and mind

As mentioned at the beginning, the Model acknowledges the complex dynamic nature of the biological system Man. The study of non-biological complex dynamic systems has shown that such systems are inherently deterministic despite the fact that their behaviour is essentially unpredictable to the point of being seemingly chaotic (whence they are also referred to as chaotic systems). The lifetime of such a system depends on the continuous import of energy from the environment of the system. This given, such a system is self-organising and self-maintaining. In the case of a biological complex dynamic system, the system is also self-reproducing, but also self-destroying after a while (usually after reproducing).

In the Model, the biological system 'healthy adult Man' is regarded as the analogue of a non-biological complex dynamic system, featuring the same properties as the latter. More specifically, Man is regarded as consisting of two mutually interdependent subsystems 'body' and 'brain', which in combination behave analogous to a non-biological complex dynamic system, and which for analytical purposes can be individually treated as complex dynamic subsystems. The Model is, obviously, focussed on the subsystem 'brain'. The Core Hypothesis implies that the status 'complex dynamic subsystem' applies not only to the physical entity brain, but also to the entity mind.

Can learning be undone?

Key aspects of the Model are that, during one's lifetime, mental activity never ceases (also not during sleep or coma), and that brain-deposited and brain-processed information can never be "unlearned" by reverting any part or all of the brain to the original virgin state. What can and does happen regularly is that a module is re-configured, viz. by the growth of additional neuronal tentacles, as well as by deactivating selected synapses. What can also happen is that certain synaptic linkages in a module "wither" over time due to disuse. Neuroscience expresses this fact in a brief rule stating "Use it, or loose it", where "it" refers to the affected part of a neuronal network. The fate of "withering" may affect a complete knowledge module only if its governing private paradigm module condemns this module to disuse over a long period of time. This does not mean, though, that this module will revert to its original virgin state (i.e. a state when the virgin structure of a module emerges within a sea of neurons with relatively few synaptic linkages).

(The analogy to a configured module is a brick house, which can also not be reconverted into the original bricks and binding materials. In other words, a configured module can be disabled, but not be returned to its virgin state.)

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Model supplements (not in Essay 3)

The Threshold Hypothesis of Consciousness

The new vision of consciousness introduced with the Model appears to be its most difficult aspect to accept for almost everyone, because this vision seems to contradict all experiences with the apparently free-willed recalling of bits of memory into consciousness. Not all memories emerging in consciousness are of this type. Instead these memories emerge spontaneously in consciousness, apparently uncalled for. The Model has to provide explanations for both types, of course.

Basic to the vision put forward in the Model is that information taken in by the human brain is not lying dormant, but that the majority of stored information is subject to subconscious processing whenever required (i.e. when information is assembled into knowledge, and when knowledge has to be adapted to new information). Throughout the wake state, it happens that the outcome of such subconscious processing becomes conscious. My interpretation of this phenomenon is that an outcome becomes conscious if the causative mental activity is of so high an intensity that it exceeds a brain typical threshold value.

This is when "uncalled for" memories emerge spontaneously.

The apparently willed recalling of memories is explained in a similar way, except that memories do not pop up into consciousness out of the blue, but as a consequence of a stimulation (name, picture, sound). Assuming that one sees a picture of Table Mountain in Cape Town, then the subconscious mental processing thereof stimulates all memories related to Table Mountain. Of the stimulated mental activities only those release details into consciousness whose intensities exceed the threshold value.

(It is obvious that the brain, being unaware of the Threshold Hypothesis of Consciousness, interprets conscious memorising as resulting from willed recalling of memory.)

Of particular significance is that the Threshold Hypothesis of Consciousness unifies the hitherto disparate concepts of conscious and unconscious states into a single phenomenon. This is a complete departure from the widespread popular view which regards the unconscious to be an opposite of the conscious.

The Direct-Access-Storage hypothesis

The foregoing vision of consciousness is incomplete without answers to questions such as "What is the purpose of rendering the outcome of subconscious high-intensity mental activity conscious?" and "What enables one to speak and write fluently in a learned language about a subject which has been brain-processed in 'brain language'?" Answers to questions of this type require another supplementary feature of the Model to be postulated, viz. a features which explains how knowledge released from a module in 'brain language' form (i.e. by electro-chemical signalling optimised for communication between neurons) is converted into specific forms dictated by the languages spoken and written by a person.

The basic assumption here is that 'brain language' is common for all humans. And it is posited that knowledge translated for a lecture in English, say, is stored (in English-compatible form) in a temporary information storage module which has a function similar to that of a Direct Access Storage Device in computers (which is "a storage device that can directly read or write to a specific place"). Likewise, knowledge translated for a lecture in Japanese is stored (in Japanese-compatible form) in another temporary information storage module. Storage in speech-compatible and text-compatible form ensures that verbal expressions and blackboard writing are fluently enabled out of these modules (in the following referred to as Direct Access Storage modules). This answers the question re. fluency of speech and writing posed earlier.

It is now posited that the outcome of subconscious high-intensity mental activity exceeding the aforementioned threshold is (temporarily) stored in such modules, and that it is out of these modules that items become conscious, viz. either in English or in Japanese, or in any other language for which a module exists. Again, "What is the advantage of these items becoming conscious?"

The answer is simple if one returns to the alleged function of consciousness, viz. the identification of self in anything in which a person is involved in. On the one hand, this is the identification of self in the sensory intake of information, e.g. in the sensory intake of a verbal exchange between two disputants (when the auditory reception of one's own uttering would be processed in the exact same way as that of the opponent). On the other hand, consciousness should then also identify the self in anything which the brain contemplates on the basis of what it has learned. This implies that an idea generated by a person's brain should be marked as self-generated by becoming conscious. Once, the idea has become conscious, it can immediately and directly be fed into the normal intake stream of sensory information (i.e. without a detour via voice and ear or via writing and eye) for fast-track participation in further mental processing.

In other words, one's becoming aware of a new emergent item in a Direct Access Storage module is an indication of that, firstly, the brain has identified the self as the originator of this item, and that, secondly, the item is ready for immediate and direct acceptance into the regular learning process.

Hence, consciousness has an important informative functions in brain and mind, but it does neither cause nor manages anything.

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Consequences of the Model

The Model has a number of consequences which challenges Man's vision about himself/herself to the extreme. Key among these are (1) the Core Hypothesis which links mind to the physics and chemistry of neuronal "clustering" in the brain, (2) the relegation of consciousness from the function of managing human reasoning and behaviour to a function focused on the identification of self in all mental information processing, (3) the exclusively subconscious nature of mental information processing, (4) the virtually complete recording of sensory intake in the virgin brain, (5) the essentially collateral recording of sensory intake in the virgin brain, (6) the subconscious self-organisation of recorded information into knowledge, (7) the limited "conscious" access to both,

information and knowledge in one's brain, (8) the incessant compatibility-optimising subconscious processing of new and old information, and the sporadic conscious revealing of the outcome of such processing (according to the Threshold Hypothesis of Consciousness and the Direct Access Storage hypothesis), (9) the physical irreversibility of a learning-modified brain to a virgin state, (10) the evolutionary predisposition for minimising the consumption of physical resources (materials and energy) for the physical processes behind mental activities (the Least Effort Principle), (11) the definition of mind as "Totality of mental contents and mental activities of all physical modules", (12) the inherently physical nature of mind, (13) the brain-internal physical stress deriving from external challenges to the mind, (14) the inherently severe reaction to such challenges, (15) the negation of a free will in the conventional sense, (16) the negation of the existence of a free-will-related motivation (as assumed in the administration of law and elsewhere), and (17) the strong dependence of human reasoning and behaviour on the Least Effort Principle.

Additions and elaborations

The above core text can do with a few additions and elaborations, as follows:

Prerequisites

The first and foremost prerequisite of the Model is the key precondition of physical science "No supernatural interference".

Post-humanism

A further prerequisite (touched upon in the core text) is the rejection of the prejudices of the philosophical view of humanism. These prejudices derive from the basically non-religious stand of humanists, which led to an overrating of Man as "an autonomous being capable of self-determination", such that "an individual's choices can make a real difference to a society, or to the course of history" (*Penguin Dictionary of Philosophy*). To be more specific, humanism presupposes that Man has an individual free will and a moral compass "founded upon reason". In particular, humanists "deny that humans should be viewed as simply part of the natural world", whence humanists "reject a purely biological analysis which reduces humans to the same level as animals" (*Palgrave Key Concepts of Philosophy*). All of these are prejudices which have no place in the Model.

Hierarchic architecture of nature and levels of logic

Yet another prerequisite is the adoption of a vision of a hierarchic architecture of nature (sometimes referred to as reductionism). As explained earlier, the hierarchy rests upon a basic level of smallest constituents of nature, followed by a next-higher level occupied by clusters of the constituents from the basic level. The next-plus-one-higher level, in turn, is occupied by clusters of the clustered constituents from the preceding level, and so on, until an upper level is reached which is occupied by the objects (biological or non-biological) which are part of Man's environment. Characteristic of this hierarchy is that every clustering of constituents from a preceding level gives rise to new properties of the new cluster not found on lower levels, referred to as emergent properties. These properties are a direct consequence of this clustering, and of this particular clustering only. Whence emergent properties can be influenced by influencing the clustering process. This is, for instance, the basis of engineering of materials.

For instance, the clustering of atoms into a metal such as steel gives rise to the emergent property of rigidity of steel, and this rigidity can be influenced by suitable engineering of this clustering process. In analogy, the "clustering" of neurons into neuronal networks in a virgin brain gives rise to the emergent property of memory in these networks, and this memory can be influenced by suitable "engineering" of this "clustering" process. The "clustering " of neuronal networks, in turn, gives rise to the emergent property of mind in the brain, which is more than a mere collection of memories.

The hierarchic-architecture vision of nature is a prerequisite for the understanding (in a physicist's sense) of anyone of the many successive clustering states of constituents of Man's world. For instance, the rigidity of steel cannot be understood by a measurement of its rigidity, but only by investigating the relationship between the clustering of its atoms and the resulting rigidity. In analogy, the mind of a brain cannot be understood by a measurement of the mental activity, but only by investigating the relationship between mental activity and the "clustering" of neurons into neuronal networks and also of the "clustering" of neuronal networks into a brain. This approach has been followed in the Model in order to secure an understanding of mind in a physicist's sense.

The hierarchic vision of the architecture of nature and the occurrence of emergent properties has important implications for the understanding of physical phenomena. For instance, returning to the example of the rigidity of steel, an understanding can be arrived at only by the study of certain assemblies of atoms which form architectural components of steel (such as crystallites and dislocations), but not by studying the architecture of the atoms themselves. In other words, the rigidity of steel can be understood only by studying the components of steel on the next-lower hierarchy level below the assembled-steel

level. If these two levels are referred to as levels of logic, then one can formulate a rule stating that for an understanding of a phenomenon one should argue on two adjacent levels of logic, viz. a level exhibiting the phenomenon and n next-lower one pertaining to the components who when assembled give rise to the phenomenon.

Core Hypothesis

The idea behind the core hypothesis (i.e. the one-to-one relationship between the physical structure of the learning-related parts of the brain and its mental contents) is that, of necessity, the mind must be a consequence of a physiological, and hence physical, configuration of the brain, and that any such physical configuration must be subject to the laws and principles of physics.

This idea was seeded by the fact that engineers have, since the invention of the phonograph by Edison, succeeded in devising so many different ways of converting speech and music into mechanical, magnetic, electronic, and other input-sensitive physical types of recording, that it seems natural for evolution to have created an equivalent input-sensitive bio-physical means of recording.

From this idea it was a simple step to posit the mental structure of the brain to be linked in one-to-one correspondence to a configurable modular physiological structure of the brain [5]. More precisely, sensory input is posited to cause a number of neurons to interlink into a network which serves as a recording of the sensory information. This neuronal network (referred to as an information module) is of physical existence (like the wax imprints in Edison's phonograph), but it represents a recording of sensory information, which is referred to as the mental content of the module. The implication is that any modification of the mental content requires also a physical modification of the module, in accordance with the laws and principles of physical science.

Knowledge modules

The conversion of information into knowledge is an ongoing physical and mental process. Are there structural features in the brain which could help in this process? Yes, there are! Viz. in form of a cortex-wide network, discovered in 2001 [6], reported to be "preferentially active when individuals are not focussed

[5] A similar idea is implied in the 'identity theory of mind', which argues that "all aspects of mental life [can] be identified with physical brain processes" (Paddy McQueen and Hilary McQueen, Key Concepts in Philosophy, Palgrave Macmillan, 2010). This theory lacks the specificity of the Model in that it speaks vaguely of brain states being equivalent to patterns of neurological activities.

[6] Marcus E. Raichle, *The brain's dark energy*, Scientific American, Febr. 17, 2010.

on the external environment", but when "your mind is at rest - when you are daydreaming in a chair, say, asleep in a bed or anesthetized for surgery". The activity in this network is known as "default mode activity".

In the Model, this default-mode activity of the brain is regarded as generating knowledge from information, viz. by starting new knowledge modules, by rendering new modules compatible with existing knowledge modules, by fitting new information into existing knowledge modules, and by rendering everyone of these modules as self-consistent as possible. All knowledge generation is, of course, governed by both, the Least Effort Principle and the Least Mental Stress Principle.

Least Effort Principle and the Knowledge Priming feature

Learning was and is key to the success of humans. Evolution has given them learning-eager brains, and natural selection has favoured the survival of those making the most of learning for the least consumption of physical resources for the learning and thinking processes. The obvious contradiction between learning and saving of resources has given rise to compromise strategies of the brain which have ensured Man's survival in exchange for certain boundary conditions. These boundary conditions require to be known for the Least Effort Principle to be understood.

To start from scratch: The large brain of modern homo sapiens is a consequence of an original per-chance change of DNA of its precursor, as well as of the fact that the new-size brain was fully made use of from the start. The latter follows from an economising property of evolutionary biology, which brings about that an underused or disused part of a biological entity is starved of material and energy resources until it shrinks to a size corresponding to usage or until it "withers" to a state of uselessness. This is expressed by the rule "Use it, or loose it". The loss of a disused feature can become inheritable by a process known as gene switching.

On basis of the use-it-or-loose-it rule, it can be argued that the modern human brain is, on average, fully active within its physical limits.

(In terms of the Model of Essay 3.1) these physical limits are set by the highest possible delivery rate at which physical resources (material and energy) for the construction work of configuration or reconfiguration of physical modules can be made available at the construction sites, as well as by the highest possible rate at which the construction work can be done. Fast delivery is secured by a continuous flow of blood to every part of the brain, which, however, does not necessarily imply an unlimited availability of resources at the construction sites.

I do speculate, though, that it is the construction work which is responsible for most of the activity of the brain. After all, it takes two decades for a virgin brain to reach an autonomous adult state.

Early in life, the construction activity of the brain consists almost entirely of configurations of new knowledge modules, and little of reconfigurations of existing knowledge modules (there just are not that many). This changes with age, until eventually reconfiguration work dominates. The aforementioned compromise with the saving-of-resources dictate of a Stone Age life, was in operation at all times. Viz. in that in the (first) *configuration* of a knowledge module that information was and is favoured which is the most resources-saving for a particular self-consistent piece of knowledge (i.e. the physical basis for Ockham's razor). And, in that the *reconfigurations* of existing knowledge modules were and are reduced. Both together constitute the essence of the Least Effort Principle.

In other words, in the case of a *configuration* of new knowledge modules, the Least Effort Principle favours the "cheapest" self-consistent configuration possible from the in-brain available information. And, in the case of a *reconfiguration* of an existing knowledge module, the Least Effort Principle favours its avoidance or delay, or the option of configuration of an independent new knowledge module for collateral learning (if the collateral configuration is "cheaper" than the reconfiguration of an existing module).

The Least Effort Principle is not the only incentive for avoiding a reconfiguration, but also the being-out-of-service of existing knowledge modules if the reconfiguration is more than minor. This aspect may leave the mind disoriented in critical times.

On basis of the foregoing, the Least Effort Principle can be defined, for instance, as an "evolutionary predisposition for minimising the consumption of physical resources (materials and energy) for the physical processes behind essential learning", where 'essential learning' can be further specified as survival-furthering learning, embracing both the physical configuration of new knowledge modules and the physical reconfiguration of existing knowledge modules.

Now to a point of considerable importance: The concept of private paradigms introduced in the Model, suggests that the Least Effort Principle would favour the configuration of a new knowledge module even more (i.e. more than by favouring the "cheapest" self-consistent configuration possible) if such a paradigm would act as a condensation point for information which can contribute to the new knowledge. Why? Because this priming by paradigm

would save resources by short-cutting the search for compatibly information. In fact, it would provide a flying start for the new knowledge module. I like to introduce the term Knowledge Priming for this even "cheaper" type of learning.

The overall conclusion is that in combination with the mind's reluctance to reconfigure existing knowledge modules, knowledge priming leads to a scenario in which an established set of knowledge primers will govern a mind's reasoning for a long time.

Because physical science is swamped with well established knowledge primers (such as wave/particle duality, Heisenberg uncertainty, Big Bang singularity, and many more), it is evident that physical science requires a critical re-evaluation of the validity of these primers.

Collateral Learning Principle

The principle of collateral learning is of particular significance because without it, Man would not be able to learn anything. In fact, the newborn is confronted with bits and pieces of information which he/she it unable to piece together into knowledge. At that stage, all learning consists of collecting information into many elementary information modules which later on serve as sources for the assembly of knowledge modules.

The real learning starts with the first development of a knowledge module (perhaps about the mother). As more knowledge modules become assembled by the clustering of seemingly related information, collateral learning becomes the rule, because the majority of knowledge modules are not sufficiently developed for becoming linked into sets.

As the mind expands further, sets of knowledge modules assemble into centres of knowledge. Also these develop in parallel because a relationship between these centres is not yet apparent. At adulthood most of these centres have been rendered mutually compatible, thus providing a unified world view (e.g. a scientific world view). Centres which remain incompatible with this world view (e.g. a religious world view), keep on being developed collaterally.

Least Mental Stress Principle

The idea behind the least mental stress principle is that evolutionary success of Man depends on an efficient processing of sensory information in that part of the brain which has been configured into an autonomously acting entity during two decades of pre-adult learning, and that this configuration has been the result of three processes: Firstly, an increase of the number of information modules,

due to the daily intake of new sensory information. Secondly, an increase in the number of knowledge modules, due to a combination of information from the new information modules into a self-consistent vision of things. Thirdly, a reconfiguration of those old and new knowledge modules which have become mutually incompatible by the intake of new sensory information.

It is the latter process which the least mental stress principle relates to by way of the hypothesis that the incompatibility of two or more knowledge modules generates a physical obstruction (call it resistance) to the processing of sensory information. In other words, the incompatibility disallows an unequivocal decision for action to be arrived at in a critical situation; bad for survival and, hence, not favoured by the evolutionary process. The physical obstruction associated with the incompatibility constitutes a physical stress. The one-to-one correspondence between physical and mental structures generates an equivalent mental stress.

Natural selection has favoured the development of brains capable of reducing obstructions due to incompatibilities, and thereby reducing both physical and mental stress. In short, information processing in brains is governed not only by the Least Effort Principle, but also by a Least Mental Stress Principle, aiming at a reduction of mental stress by way of reducing the physical stress.

Comparison of Methodologies

Recently, I read a text by a protestant theologian which he himself rated as rather critical of certain aspects of the consentient interpretation of some passages in the New Testament. The theologian complained about the reluctance of those theological publishers whom he had been in contact with, to publish his manuscript. This is an experience not uncommon in other disciplines of academic research, and was not surprising. Surprising to me was the extend to which I failed initially to understand the theologian's text and to identify his key argument.

This falls squarely into my experiences with readers of my Essay 3 described in the opening paragraph of the Preface above. Common to these difficulties of understanding a text from a different area of academic study is obviously the use of a different terminology, but not only that. Just as much, if not more, is contributed by the different methodology of approach to a problem. This is what the following text is focussed on.

Let me start with a word of warning, viz. although there is some clarity of what the main methodology of physical science is, it is by no means clear what the methodologies of the cognitive sciences and of philosophy are.

Nevertheless, I believe to have identified one fundamental difference between the methodology of physical science and other methodologies, viz. that described above as the hierarchic-architecture-of-nature vision, which ties an understanding of nature to a scientific description of the emergent properties between two adjacent levels of this hierarchy. This vision of nature is not evident in any of the methodologies of the cognitive sciences and of philosophy.

But there are also other differences. Let me start with philosophy, because philosophers have also attempted to find the essential differences between the 'philosophical method' (if it then exists) and the so-called 'scientific method' (which is assumed by philosophers to be established in physical science).

The majority opinion among philosophers appears to be that there is not a single method of solving philosophical problems, but as many as it takes to find a solution. But common to all (according to Wikipedia) is that the truth of any assumption made by anyone is questioned (called the 'doubt stage') on the basis of counter arguments from which a solution is put forward for discussion among philosophers (called the 'dialectic stage'). In other words, philosophers are educated to disagree with any existing assumption, and to keep the discussion going forever. This particular feature is held out as the key characteristic of any philosophical method, distinguishing it from the methods used by "other disciplines, in which the experts can agree about most of the fundamentals" (Wikipedia). This short-form description of the philosophers' approach to a philosophical problem shall, in the following, be referred to as *the* philosophical method.

It is certainly true that the physical science approach to a phenomenon is not aimed at an ongoing discussion, but at a consentient solution. In other words, findings are unlikely to be accepted if these are not in total compliance with the mainstream teaching of physical science, unless empirical testing proves something else. Hence, from a philosophical perspective, the physical science method is one which is inherently tied to starting with a hypothesis and ending with empirical testing, whereupon findings are cemented into a consentient (not necessarily lasting) form (such as laws of physical science, falsely declared as laws of nature).

The philosophical method does not require its findings to be empirically tested. Rather, philosophical findings are not supposed to be cemented into lasting form. They must remain open for further critical analysis.

One critical comment of mine concerns the philosophers' attempt at comparing the physical science method and the philosophical method as if they were competitors. In my view, they are anything but. In fact, they are complementary; they belong together. Why? Firstly, because arguments for the philosophical method don't fall out of the blue. For many issues, these arguments have to be based on scientific findings derived by the physical science method. Secondly, since scientific findings tend to be cemented into lasting forms, the philosophical method should be a second stage of a combined method (the scientific-philosophical method, say) for the purpose of critically evaluating the findings of the physical science method. This combination is, indeed, what is sorely missing for most findings of quantum physics and of cosmology.

How successful is the philosophical method on its own? Not very, if one looks at the various philosophers' visions of mind, at least if one reads the recent introductory text by philosopher Albert Newen about the philosophy of mind (*Philosophie des Geistes*, C. H. Beck, 2013). From this text, I deduce that the conventional identification of mind with the phenomenon of consciousness remains the key stumbling block, and that there is no evidence whatsoever of any attempt to approach the problem in a way similar to that of the Model. The latter is not surprising, of course, if one considers what has been said above about the philosophical method.

Looking now at the methodologies of the cognitive sciences, let me quote an experience which hints at what these methodologies may be like: In a recent French TV documentary about human intelligence, the apparent importance of a particular type of brain cell, the astrocytes (a type of glia cell) was deduced from the fact that Albert Einstein's brain was found to have had an above average concentration of these cells. This and other evidence left me wondering about the wide gap apparently existing between the methodologies of the cognitive sciences and physical science.

Problems start already with a simple term such as "modelling", which in physical science stands for "act of constructing a model". Not so in psychology, where "modelling" stands for "procedure whereby a subject observes a model, for the purpose of learning to imitate the behaviour of the latter" (Penguin Dictionary of Psychology). Small wonder that physicists and psychologists misunderstand one another.

This given, are there common features of methodologies used in the cognitive sciences (psychology, sociology, ethology, psychiatry anthropology), and what are they? After some enquiry, it seems to me that their methodologies resemble an engineering approach in the study of materials. This engineering method essentially consists of the study of so-called engineering properties of materials prior to and during application in engineering projects. The study of the atomic features underlying these properties is not part of the engineering method.

The cognitive sciences method is analogue thereto. Also here, the human mind (the analogue of the engineering material) is not studied in terms of neuronal features as done by way of the Model, but by way of empirical observations and measurements which are statistically evaluated and ranked.

The cognitive sciences method has its origin in the age-old medical diagnosis practice, from which it was imported into psychiatry (most psychiatrists have a basic education in medicine) and thence into other cognitive sciences. In this practice, empirical evidence of aberrant departure from "normal" health is assembled and linked to standard descriptions of illnesses and of hypothesised biological mechanisms (e.g. the Meridian Theory of Chinese medicine).

How do the foregoing contemplations reflect on the Model, in which findings of the cognitive sciences and of physical science are subjected to reasoning typical of physical science?: As is typical of the physical science method, the Model starts off with a hypothesis, untypical of the cognitive sciences method. Then the Model is developed according to the Ansatz approach, also typical of the physical science method.

The Ansatz approach consists of "the establishment of starting assumptions and/or propositions into an educated guess about a problem and its solution that is verified later by its results". The starting assumptions and/or propositions were chosen from both, rules of physical science and findings of the cognitive sciences. These were selectively combined until overarching characteristics (such as the Least Effort Principle and the Collateral Learning Principle) emerged, which were verified by a large number of empirical manifestations of the mind (such as, for instance, religious beliefs and the coexistence of belief and science in the same brain).

This Ansatz approach has little resemblance to any cognitive sciences method, and is something which cognitive scientists, unfortunately, have to familiarise themselves with in order to derive benefit from the Model.

Concluding remarks

A key message of the Model is that the (similar) methodologies of the cognitive sciences are not the only ways towards getting to grips with the mystery of mind. The very different physical-science-typical approach of the Model is a very promising alternative. In fact, it is the first definitive proposal of what mind may, in fact, be, and how it relates to the physical science vision of nature.

Any vision of mind resembling that of the Model has enormous consequences for humanism and the human sciences. It confirms Man's place to be at the tip of a branch of the biological evolution on earth; nothing more, nothing less. A tip which has seen an advance of knowledge over many thousands of years, but no advance of the physiological design which would justify the nosiness of some cultures towards others, in particular that of the Western culture towards that of the last remaining Stone Age cultures.

Every culture has succeeded in developing a vision of its world which enabled it to survive in a stable environment, regardless of whether this vision was purely speculative, as long as it concerned things not essential for survival (such as spiritual belief). Unfortunately, it is the speculative vision of things not essential for survival which often poses the greatest threat to survival, because the physical-science-based least effort principle causes the mind to be intolerant towards other dissenting minds. This is nothing which Man can control by way of a (non-existent) free will, but something which Man has to live with. This is another key message of the Model.

Yet another key message is that Man may have fooled himself for ages about the function and importance of consciousness as well as about the existence of a free will, This free will would seem to be that of a biological construct featuring the characteristics of the Model combined with the capability of generating species-typical replicas. The self-delusion about a free will has severe consequences also for the reigning concept of motivation for human actions, much used in the administration of law.

The relegation of consciousness from it earlier position of importance in and for the human mind puts also an end to the eight decades old metaphysical speculation of quantum physicists about the consciousness of an experimentalist having an influence on the outcome of a measurement of a quantum object.

Finally, the Model explains why the wisdom (the combined knowledge) of one mind just cannot be also the wisdom of another, and why it is futile to insist that the general validity of one's own wisdom should be obvious to all. This self-delusion is forever bound to remain a reason for conflict.

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Appendix: The library analogy of the human mind

Feedback from test readers of my Essay 3 ("A Physicist's Model of Mind") taught me that my physicist's vision of the human mind cannot be as easily understood by non-physicists as I would wish, and that the use of analogies would be helpful. One of these analogies is that of a private reference library.

Let me start with a few general facts:

The system Man is said to be at an adult state when it functions autonomously in the environment in which it developed to this state, i.e. the environment in which Man grew up to adulthood over about 20 years.

The adult state is characterised by the system's ability to identify challenges of most types occurring in this environment, and to respond appropriately, i.e. to respond decisive, fast and challenge-neutralising.

In order for these adult characteristics to develop, the system must have been primed with a wide variety of challenge-vs.-response combinations to fall back onto for reference. These combinations stem from various sources: From own experience, from the narrated experience of others, from tales, legends, novels, film scripts, theatre scripts, from intelligent speculations, and from other sources. All of these are held at the ready in a brain repository, commonly referred to as memory.

This brain repository has a number of similarities to a private reference library. For instance, that both, the repository and the reference library, develop from a very basic stock, and that it is the nature of this basic stock together with further first acquisitions which give the library its initial focus. It is not that this focus remains fixed, but it is something of lasting importance. This lasting importance is evidenced by the fact that, as a rule, the first acquisitions of a private reference library are kept for a lifetime.

According to the Model, also the initial focus of a brain's repository will remain of lasting importance, although one may, later on, not be able to recall all aspects of this focus into consciousness. This is taken account of in the Model by positing that no entry in the brain repository can ever be eliminated therefrom. It can be modified or disused, but never eliminated. It is there, even if unable to be recalled into consciousness.

As the stock of a private reference library is developed, it becomes imperative for all acquisitions to be catalogued and cross-referenced for easy access. This is imperative also for all entries into the brain repository. The development of a mechanism for the cataloguing and cross-referencing of these entries has been favoured by the evolutionary process. The mechanism itself has not yet been identified, but must be governed by the laws of physical science. This mechanism is part of the process of learning, which is a self-organised process.

It is a shortcoming of this process that adulthood overtakes learning in order for a new generation of the species Man to be raised before the optimal time for re-production has gone by. In other words, the brain repository is far from being fully developed by the time that Man regards himself/herself as ready for an autonomous life as an adult. The consequence is that the young adult makes many sub-optimal decisions based on a deficient world view (deriving from an under-developed brain repository). In terms of the private-reference-library analogy, this is equivalent to the library being under-stocked.

Of highest priority for the brain repository is an incessant maintenance of its topicality, as well as the application of means to get as fast as possible to topical results without detours and delays; detours via outdated knowledge modules, and delays due to contradictory information. The evolutionary process has devised two strategies for bringing this about: Detours via outdated knowledge modules are avoided by a continuous process of updating these in response to the intake of new information. And delays due to fundamentally contradictory information are avoided by the strategy of collateral learning (explained in the main text above). The private-reference-library analogy to collateral learning is the acquisition of and separate shelving of books with contradictory contents. The private-reference-library analogy of updating of knowledge modules would be the partial rewriting of shelved books. This is not done in a private reference library, whence the analogy ends here.

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