# Mind and matter as asymptotically disjoint, inequivalent representations with broken time-reversal symmetry

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## Abstract

Many philosophical and scientific discussions of topics of mind-matter research make implicit assumptions, in various guises, about the distinction between mind and matter. Currently predominant positions are based on either reduction or emergence, providing either monistic or dualistic scenarios. A more-involved framework of thinking, which can be traced back to Spinoza and Leibniz, combines the two scenarios, dualistic (with mind and matter separated) and monistic (with mind and matter unseparated), in one single picture. Based on such a picture, the transition from a domain with mind and matter unseparated to separate mental and material domains can be viewed as a result of a general kind of symmetry breaking, which can be described formally in terms of inequivalent representations. The possibility of whether this symmetry breaking might be connected to the emergence of temporal directions from temporally non-directed or even non-temporal levels of reality will be discussed. Correlations between mental and material aspects of reality could then be imagined as remnants of such primordial levels. Different conceivable types of inequivalent representations would lead to correlations with different characteristics.

## 1 Introduction

The central topic addressed in this paper is the mind-matter distinction in a general conceptual sense, not in the more specific sense of a distinction between mind and brain or between mind and body. While the latter areas are discussed mainly in fields such as the philosophy of mind, cognitive science, neuroscience, physiology, and psychology, the problem of how a distinction between mind and matter in general terms can possibly be conceived is discussed primarily by philosophers of physics and philosophically interested physicists. Given that physics itself has been developed and has to be understood as a science of the material world, some philosophers and physicists have always been fascinated by the question of how this material world is related to anything that appears as non-material, say mental, to us – our concepts, ideas, thoughts, feelings, and so on.

The article begins with some general remarks about different philosophical conceptions concerning the relationship between mind and matter (section 2.1). Subsequently, some selected positions by physicists concerning the same issue are outlined briefly (section 2.2). They emphasize the emergence of a distinction between mind and matter from an underlying distinction-free domain of description rather than relationships between mind and matter directly. Section 3 offers speculative suggestions about possible features of the emergence of a mind-matter distinction. More specifically, a scenario is proposed that provides nonlocal correlations between mental and material states. These correlations are not permanent but decay, leading to asymptotically disjoint states with no remaining correlations (section 3.1). Moreover, the breaking of time-reversal symmetry is proposed as a key feature characterizing the emergence of distinguished mental and material states (section 3.2). Section 4 concludes the paper.

# 2 Mind and Matter

## 2.1 Monism versus Dualism

The question of relationships between the material world with its facts or data and its apparently non-material counterpart or complement, that is the domain of models and theories, belongs to the oldest, most puzzling, and most controversial questions in the long history of philosophy and the history of science. One of the main reasons for its controversial nature is that the question itself is understood in different ways depending on basic assumptions concerning our conceptions of reality. What makes all approaches toward this question as well as the discussions about those approaches so difficult is the fact that those assumptions are often implicit rather than clarified explicitly.

For many good reasons, any related inquiry has to take into account the corpus of knowledge we have acquired so far. The contemporary status of the sciences is the result of centuries of history, built upon various lines of empiricist tradition and upon the Cartesian distinction of res cogitans and res extensa. At present, there are many scientific topics touching this distinction itself as more and more aspects of mind-matter research become timely and sensible research topics.

From the viewpoint of a philosophically informed contemporary physicist (who typically disregards any kind of "mind-over-matter" idealism), there are two general frameworks within which reality can be conceived.[1] One of them is denoted usually as *physicalism* (or *materialism*) and expresses the *monistic* idea that the basis of reality consists of the material world alone; anything like qualia, consciousness, psyche, mind, or spirit is anchored in the material elements and fundamental laws of physics. For physicalists, the way in which these apparently non-material higher-level properties can be explained is a follow-up question, again answered differently within different ways of thinking, using conceptual schemes such as, e.g., emergence, supervenience, or reduction. These concepts are tightly related to each other.

In general, it is helpful to keep in mind that emergence is an extremely colorful, but often not well-defined concept that has to be discussed together with supervenience and reduction.[2] All these topics have to do with instabilities (of different kinds) and have been addressed in various fields such as morphogenetics, synergetics, complex systems, non-equilibrium thermodynamics, catastrophe theory, and others. It can be argued that emergence or supervenience are connected with a weak type of reduction insofar as emergent properties must not contradict fundamental laws at a basic level of description, but also neither are determined uniquely nor can be derived uniquely from that level without further (contextual or contingent) conditions. For instance, physical processes in the human brain must not violate any applicable physical laws, but by no means are these laws sufficient to understand any of the higher-level properties and functions the brain has and performs. Nevertheless, the fundamental laws of physics can be assumed to be exhaustive at the basic level, and the existence of higher-level properties does not necessarily force us to add further "fundamental laws".

The other general framework is characterized as *dualism*, ranging from ontological to epistemological and methodological versions. Briefly speaking, ontological dualism maintains that the world *consists* of mind and matter (or other, corresponding concepts) as ultimately separate "substances". Epistemological dualism refers to mind and matter as fundamentally different domains with respect to our modes of gathering and processing knowledge of the world, irrespective of what this world "as such" ("in itself") may or may not be. Methodological dualism reflects an attitude that is neutral with respect to the claims made by the other two variants. It utilizes the mind-matter distinction as a basic, but maybe not the only possible methodological tool to inquire into the structure of the world.

In its weakest (methodological) form, dualism is a prerequisite of any physicalist approach insofar as the latter presupposes a distinction between matter and something that appears to be non-material and – in one way or another – has to be related to, explained by, or even derived from the elements and laws of the material world. Within such a kind of minimal dualism, which is hard to avoid, we may use distinctions such as that of models and data, theories and facts, and so forth (compare Atmanspacher 1994). In the present article, any dualistic kind of argument is meant in a non-ontological manner.

For a physicalist approach, the concepts of emergence, supervenience, or reduction seem to refer explicitly to the world of material facts; they refer to a reality addressed by a certain type of realism. However, keeping in mind that this reference presupposes the (possibly nonunique) selection of a viewpoint, we may also argue that emergence, supervenience, or reduction primarily refer to our

[1] For more details about these topics the reader is referred to the relevant literature, e.g., Chalmers (1996).

[2] Some useful sources are Silberstein (1998), Primas (1998), Scheibe (1997), Chalmers (1996), Crutchfield (1994), Kim (1984).

(non-material) descriptions of the material world rather than to elements of that world itself. The interpretations of those descriptions populate the entire spectrum between a naive *realism*, an unreflected belief in an external reality, and a radical *relativism*, typically unattractive to working scientists who are used to dealing with or relying on the regulative power of events that "really" happen in the material world.

## 2.2 Tentative Ideas about Mind-Matter Relationships from the Viewpoints of Some Physicists

In recent years some fairly popular speculative accounts of mind-matter issues have been developed by physicists such as Penrose or Stapp. Their ideas and concepts, for instance outlined in Penrose (1994) and Stapp (1993), still lack both a satisfying formal framework and empirical confirmation and are, therefore, not easy to criticize fairly. Very roughly speaking, Penrose expects that a comprehensive understanding of consciousness as a feature of the mental world depends on the development of a more comprehensive quantum theory, including non-algorithmic elements of measurement, certain aspects of quantum coherence, and ultimately even quantum gravity. In Stapp's approach, contemporary quantum theory does (more or less) already represent a sufficient formal framework for describing the properties and laws of the mental world. For him, understanding consciousness as a feature of the mental world amounts to a more comprehensive interpretation of quantum theory as it exists, including elements of the philosophy of Whitehead and James. A discussion of additional positions concerning mind and matter from the viewpoint of physicists has been given by Butterfield (1995).

From a more general perspective, the various positions about mind and matter can be grouped according to two main categories. First, there is the majority of those who argue in favor of a thesis like "(basically) it's all physics", implicitly assuming different types of materialist perspectives in the sense that anything mental can be (more or less strictly) deduced from the properties and laws of the material world. A liberal subgroup within this category is the group of those who would admit that higher-level properties and laws emerge from (and cannot be strictly reduced to) lower-level properties and laws in some sense to be defined. On this view, advocated, e.g., by Searle (1992, 1997), consciousness would be conceived as an emergent property of the material brain.

The second category treats mind and matter as two domains of description with equal importance in a dualistic fashion. But, as mentioned above, this dualism can have many variations. The epistemological version of dualism is the focus of this paper. It says that mind and matter are distinct for the purpose of our modes of knowledge acquisition; they are not considered to be distinct a priori. Corresponding approaches typically assume an ontological level of description without any split of mental and material domains, which is more fundamental than the descriptive level with split domains. If the transition from the fundamental level to that with mind and matter separated is to be addressed in terms of emergence, one would have to think of it as an *emergence of the distinction of mind and matter rather than the emergence of mind from matter.*

In the history of philosophy, such a conception has been discussed by, e.g., Spinoza and Leibniz. For Spinoza, there is one fundamental substance, a "causa sui", from which all particular manifestations derive as differentiations. In Leibniz's conception, mental and material domains of reality exist in parallel, and their parallelism is guaranteed by "preestablished harmony". Of course, there are many more details to these two frameworks of thinking, which I cannot discuss here.[3] What I want to discuss in the following is related to some physically inspired ideas, which are guided by the same general scenario. Here are some corresponding voices from the last five decades, all speculating on the emergence of a mind-matter distinction from an assumed distinction-free domain.

- In his discussions and correspondence with C.G. Jung, *Wolfgang Pauli* often made indications to the effect that mental and material domains might be epistemologically distinct domains. They originate from an integral domain prior to the distinction of mind and matter ("unus mundus" in Jung's terms). This integral domain can be characterized by the nonconscious from a mental perspective and by the non-observed from a material (physical) perspective. In Jungian depth psychology, this "unus mundus" is the domain of "archetypes" which can manifest themselves in the mental and material domains and in this way produce "synchronicities" (for more details and references, see Atmanspacher and Primas (1996)).

[3]More specific remarks in this context can, for instance, by found in Popper and Eccles (1977). A modern version of such a kind of "double aspect" approach has been advocated by Chalmers (1996) in the context of his discussion of the "hard problem" of consciousness. Some critical remarks about this approach can be found in Atmanspacher (1997).

In a letter to his colleague Markus Fierz of Jan 7, 1948, Pauli wrote (von Meyenn 1993): "The inner images are psychic manifestations of the archetypes ... The laws of the material world would refer to the physical manifestations of the archetypes ... Each natural law should then have an inner correspondence and vice versa."

- *Eugene Wigner* is another eminent physicist who was strongly interested in mind-matter questions. A major guiding framework in Wigner's work can be characterized by invariance and symmetry principles. In addition to his questionable conjectures about the role of consciousness in the reduction of wavepackets, his deliberations concerning the relationship between mind and matter often took shape as symmetry arguments, see, e.g., Wigner (1964, 1972). Wigner's remarks in his article "Physics and the Explanation of Life" (Wigner 1970) indicate the possibility of a mind-matter distinction according to a symmetry breaking (violation of invariance) of an underlying, unifying level of description: "A picture will be discovered which will provide us with a view encompassing both mental and physical phenomena and describe regularities in both domains from a unified point of view."

- Apart from attempts to formulate hidden variable approaches to give a more intuitive understanding of quantum theory, there are other, more philosophical aspects of the work of *David Bohm*. In particular, his ideas about explicate and implicate order is appealing with respect to the interpretation of quantum theory and (maybe) beyond. While explicate order characterizes an operationally accessible reality (cf. epistemic descriptions), implicate order deals with ontological questions (cf. ontic descriptions). Bohm's conception is a precursor of the concept of relative onticity, recently introduced (Atmanspacher and Kronz 1999) as an attempt to make Quine's ontological relativity precise enough to be applicable to physical situations. Its essence is that each implicate order can be viewed as explicate if another, "more" implicate order is found. In this spirit, Bohm (1990) refers to the mind-matter distinction at the level of an explicate order, which is based on an implicate order without that distinction: "At each level of subtlety there will be a 'mental pole' and a 'physical pole'... But the deeper reality is something beyond either mind or matter, both of which are only aspects that serve as terms for analysis."

- In two of his recent contributions, *Bernard d'Espagnat* has made explicit indications with respect to the relationship between mind and matter (d'Espagnat 1997, 1999). In his article of 1999, d'Espagnat uses the notion of an independent " 'Ultimate Reality' that is neither mental nor material (or, equivalently, is both), for it is conceptually prior to the mind-matter splitting" (p. 267). It is interesting to note that on d'Espagnat's view there is an additional distinction between an "independent reality" and an "empirical reality" within the material domain (p. 268), which is conceptually posterior to the mind-matter distinction and should in principle be in the realm of physical theories, excluding any reference to mental states or processes.

There are several interesting differences between a scenario (A) in which reduction and/or emergence relations between a mental and a material domain are considered and a scenario (B) in which a distinction-free level of description is added. First of all, scenario (A) restricts scientific discourse to relationships (interactions, correlations, etc.) between the mental and the material. By contrast, scenario (B) would allow us to talk about relationships between mind and matter that might be "caused" by a third domain, neutral with respect to the mind-matter distinction and prior to their separation.[4]

Second, a scenario of type (B) is capable of combining dualistic and monistic elements that appear as strict alternatives in scenario (A). Scenario (B) also makes it possible to ask questions that are irrelevant under (A), such as: why is the decomposition into mental and material domains so significant as compared to other decompositions that might also be conceivable? What are the referents of a description of the distinction-free domain? Which symmetry is broken when mental and material domains emerge? What would a detailed description of this symmetry breaking look like?

Unfortunately, the quoted authors do not give details about the sense in which their speculations could be worked out in order to – finally – lead to researchable problems or problem areas. It is the purpose of the next section of this article to elaborate on this issue. Of course, it is to be understood that any explicit remark made in the remainder of

[4]Scenario (B) might even be conceived in a way that allows "feedback" from the separated domains to the distinction-free domain. Also, the separation of mental and material domains should not be understood as one unique event. It might rather be conceived in terms of ongoing symmetry breakings, due to a plurality of contingent conditions.

this article will be entirely hypothetical. But given the fact that philosophers such as Spinoza and Leibniz lived centuries ago, it might be timely to use the extended body of knowledge that modern science has provided since then to speculate about ways in which a symmetry breaking yielding a Cartesian distinction of mind and matter can be conceived.

As mentioned above, physical concepts will be utilized as the main source of inspiration for corresponding conjectures. In particular, these conjectures will be based on the assumption that the distinction-free domain of description, prior to the mind-matter separation, is described in terms of a formalism that has the mathematical structure of a quantum theory *in a general sense*, not restricted to applications dealing with material systems alone. This must not be confused, however, with the position that quantum theory *as it exists today* is sufficient to describe both mind and matter exhaustively. Quantum theory in the general sense just mentioned is intended as a tool to describe the distinction-free domain in terms which are neutral with respect to the mind-matter distinction. Based on such a description, the goal is to derive descriptions for the material and mental domains separately. In their technical aspects, the following speculations will be developed within the terminology of algebraic quantum theory.

# 3 Possible Features of an Emerging Mind-Matter Distinction

Let us assume a basic domain of description $X$, which is neutral with respect to the distinction between mind and matter, i.e., which lacks this distinction. Assume further that this description is basically non-Boolean (such as a quantum description in terms of a non-commutative algebra). Beyond that, the evolution of states in $X$ is assumed to be given by a group of automorphisms, and $X$ is assumed to be an infinite system.[5]

Under these conditions, the pure formalism of algebraic quantum theory (without specific reference to anything in the material world) implies that there exist representations of (the commutation relations between observables in) $X$ that are not unitarily equivalent. The construction of these inequivalent representations depends on contextual conditions that are not given at the level of $X$ but have to be added depending on the situation considered (such as the GNS-representation in physical applications). The emergence of such inequivalent representations can be conceived as a symmetry breaking. (A relevant example in physical applications is the symmetry breaking into different thermodynamical phases.)

I am aware that these characterizations are far too short to give the reader a formally intelligible or even intuitively accessible picture of the formal framework. Illuminating conceptual introductions into the material, together with the necessary mathematical background, can be found in Primas (1990, 1993, 1997, 2000).

Under the assumptions given above it is possible to propose two possible features of a mind-matter distinction as in scenario (B).

1. Mental and material states can be conceived as correlated in a way that mimics nonlocal correlations in quantum physics. A sketch of a corresponding tentative proposal was given by Primas (1996). If inequivalent representations of $X$ are taken into account, it would be possible to speculate about correlations between mind and matter that are not generic and permanent, but are time-dependent. Asymptotically (i.e., for $t \to \infty$), one might think of disjoint states, without any nonlocal correlations, in different superselection sectors of a properly chosen state space. For finite but long times, these states would be approximately disjoint, so that faint correlations should remain.

2. The emergence of separate domains of mind and matter might be associated with the breaking of the time-reversal symmetry of the automorphic dynamics in $X$, leading to two semigroup evolutions with opposite temporal direction. The basic idea here would be that the forward semigroup ($t \geq 0$) applies to the evolution of material states, whereas the backward semigroup ($t \leq 0$) applies to the evolution of mental states. As usual, the forward semigroup would be associated with efficient causation. Its counterpart, the backward semigroup could be associated with features alluding to something like final causation – a topic expunged from the natural sciences long ago.

[5] Since the restriction of $X$ onto the material domain has to reproduce the known physical theories, it must give rise to physically infinite systems, i.e., systems with infinitely many physical degrees of freedom. This is only possible if $X$ itself is infinite.

### 3.1 Decay of Nonlocal Correlations Provides Asymptotically Disjoint Mental and Material States

In an article entitled "Synchronizität und Zufall" (synchronicity and chance), Primas (1996) discussed a generalized derivation of Bell's inequalities in the framework of algebraic quantum theory. The derivation itself was published by Landau (1987) and Baez (1987). It does not use typical Hilbert space characteristics such as the norm topology, which means that it is very much independent of the state space used for the representation of the states of a system under study. In a few words, the conceptual consequence of the generalized version of Bell's inequalities can be formulated in the following manner:

> If a system $X$ is decomposed into two subsystems I and II with non-commutative properties in each of them, then there are nonlocal correlations between subsystems I and II.

It is remarkable that the only condition for nonlocal correlations between the two subsystems is that there are non-commutative properties in each of the subsystems, such as

$$[A(I), B(I)] \neq 0, \quad [A(II), B(II)] \neq 0.$$

It is not required that properties of subsystems I and II are *mutually* non-commutative, such as $[A(I), A(II)] \neq 0$, or other permutations.

Since the formulation of this type of nonlocal correlations is so general, Primas explored relaxing the restriction that the systems considered must be of physical nature. This leads to the conjecture that the subsystems I and II would be subsystems corresponding to the mental and material domains resulting from a mind-matter distinction imposed upon a distinction-free system $X$. Taking this conjecture seriously, it predicts that nonlocal correlations (in a generalized sense, beyond physics) between mind and matter are generic. For instance, synchronicities as discussed by Pauli and Jung might then be due to such nonlocal correlations.

An important implication of the generic nature of nonlocal correlations according to this picture is that they should be ubiquitous. This in turn generates pressing questions as to their observability. Where and how should one look for them? Are they so generic that we overlook them because they are pervasive? For instance, mind-brain correlations in the sense of correlations between mental states of being conscious and material brain states might be an issue along these lines of argument. Insofar as conscious states (such as in cognition, perception, emotion, attention, memory, etc.) are always correlated with certain features of brain states, these correlations can be considered as quasi-permanent. One interesting proposal in this context is to look for mental states or brain states for which these correlations are suppressed, blocked or simply nonexistent.

The other alternative is that nonlocal correlations, if they are relevant at all, are not constant but time dependent and decay as time increases. This would mean that they are fully developed only at a time $t = 0$, the instant at which the symmetry between mind and matter is broken. A possible formal conceptualization of this idea could be based on the asymptotic disjointness of the relevant states. This is to say that inequivalent representations of $X$ in terms of mental and material states are *asymptotically disjoint*. This is to say that they are located in different *superselection sectors* (of a properly chosen state space), so that for $t \to \infty$ no superpositions of those states are possible and no nonlocal correlations are left. But the disjointness is approached gradually: for large but finite times mental and material states are *approximately disjoint* so that faint correlations may remain. In close analogy to the emergence of classical states in quantum systems, a viable tool to characterize the decay rate might be due to large deviation entropies (Amann and Atmanspacher 1998, 1999). Other approaches to deal with this issue can be imagined in terms of robustness criteria (cf. Primas 2000) or stability properties (cf. Zurek 2000) determining the decay of the state of $X$ into asymptotically disjoint states in the material and mental domain.[6]

Of course, it is clear that the above remarks are extremely speculative. There is an increasing number of publications (often by non-physicists), in which analogies between standard quantum theory, referring to the material domain alone, and a generalized quantum theory, including a domain for which mind and matter are unseparated, are markedly overemphasized or carried over in an uncritical way.[7] For this reason it cannot be repeated

[6] Note that this idea does not contradict the fact that automorphisms cannot change the equivalence class of a representation. Hepp's no-go theorem for the generation of disjoint states from non-disjoint states under automorphisms is not a no-go theorem for the possibility of a theoretical description of measurement-type processes (see Primas (1997, 2000), Lockhart and Misra (1986), Hepp (1972)).

[7] In this context, cf. some critical remarks by Mermin (1998)

often enough that such analogies so far are mainly intended to inspire further creative work.[8] Using analogies taken from formal sciences, such as physics, offers the advantage that resulting conjectures are not entirely uncontrolled but entail an element of consistency that might enable future research to falsify or confirm them.

Among the tentative ideas listed in Sect. 2.2, the scenario sketched by Pauli and Jung can indeed be interpreted in terms of a symmetry breaking of $X$, leading to correlations between mind and matter. More precisely, it is suggestive to relate the archetypal "unus mundus" to the distinction-free domain $X$, whereas synchronistic events could be related to nonlocal correlations between mental and material states (for more details see Atmanspacher and Primas (1996) and references given there). For a long time, Jung had insisted that the concept of synchronicity should be reserved for cases of distinctly numinous character. With this interpretation, corresponding nonlocal correlations would be extremely rare, thus contradicting their supposedly generic nature. Only in later years, Jung opened up toward the possibility that synchronicity might be a notion that should be conceived as ubiquitous as indicated above.

Pauli and Jung discussed a possible complementarity of statistical method and synchronistic events, indicating that synchronistic phenomena cannot be corroborated by statistical methods as they are usually applied. In a letter to Fierz of June 3, 1952, Pauli wrote (von Meyenn 1996): "... synchronistic phenomena ... elude from being captured in natural 'laws' since they are not reproducible, i.e., unique, and are blurred by the statistics of large numbers. By contrast, 'acausalities' in physics are precisely described by statistical laws (of large numbers)." As far as we know today, chance on the non-psychological, purely physical level is "blind chance", hence governed by the statistical rules of mathematical probability theory. As opposed to this, some psychological experiments suggest the existence of a "decline effect", characterized by decreasing statistical significance with increasing number of "identical" experiments (see, e.g., Thompson 1994).

[8] In this context, see Walach and Römer (2000). A more elaborated formal approach has been published recently by Atmanspacher et al. (2002).

## 3.2 Time-Reversal Symmetry Breaking as a Superselection Rule for Mental and Material States

Starting with an automorphic dynamics within a description of the mind-matter distinction-free domain $X$, the dynamics of states is given by a group of automorphisms with time-reversal symmetry. It is well-known that a reversible temporal evolution is a feature of fundamental laws, referring to isolated (closed) systems without any interaction with their environment. Using the distinction of ontic and epistemic descriptions, fundamental laws are to be ascribed to the ontic, empirically inaccessible level of description.

If one wants to take interactions with an environment, particularly measurement, into account, it is necessary to discuss open systems. In general, this requires that the time-reversal symmetry of isolated systems is broken. As a result, two semigroups are obtained. One of them is directed forward in time, the other backward. In situations as they are treated in physics, the forward semigroup is then selected to describe the time-directed evolution of a system. The argument for this selection is essentially that effects must not precede their causes. Causality, or more precisely efficient causation, is used as a criterion for the selection of the time direction that is consistent with our experience.[9]

Here are some examples. (1) While the dynamics of isolated (closed) quantum systems is described by the time-reversal invariant Schrödinger equation, open quantum systems require dynamical semigroups for their description. They can be derived by restricting the time-reversible dynamics of a joint system consisting of an object and its environment to the object system alone (see, e.g., Davies 1976). This procedure always yields two semigroups, from which the forward semigroup is selected in accordance with experience; excited states do spontaneously decay to states of lower energy, whereas lower-energy states are not spontaneously excited. (2) The second law of thermodynamics uses the increase of entropy to define the forward direction of time with respect to thermal processes. Here the backward semigroup would correspond to decreasing entropy, which is not observed (for a properly defined entropy). Recent work of Prigogine and collaborators have made some progress to describe the emergence of two semigroups for related types of irreversibility (K-systems, large Poincaré systems) in a generalized formulation (see, e.g., Antoniou and

[9] Vitiello (2001) recently presented an interesting quantum approach for brain dynamics in which both directions of time play significant roles.

Prigogine 1993). (3) Solving the problem of the transmission of electromagnetic radiation leads to two solutions with broken time symmetry, known as the retarded and the advanced solution.[10] Since the transmission of radiation is considered as an effect caused by a source, the retarded solution is selected in order to describe the evolution of the outgoing wave consistent with efficient causation. The advanced solution would describe an incoming wave, which is not observed and therefore disregarded.

From the perspective of physics, it is obvious that the basic selection criterion, efficient causation, is *assumed* in all relevant examples. It is a philosophical premise rather than a physical argument. This premise is based on a decision in favor of efficient causes as opposed to final causes. Although final or teleological thinking used to play a vital role in the early days of the sciences, efficient causation in the sense of modern science has definitely taken over since the last two centuries. Today, no reasonable scientist would consider final causation as a useful scientific concept insofar as "scientific" is understood in terms of the natural sciences.

The last pillar of final thinking, teleology in biology, fell with Darwin's theory of biological evolution. In an interesting remark, Pauli interpreted Darwin's mechanisms of natural selection and mutation as the substitution of finality by chance (Pauli 1954): "This model of evolution is an attempt to theoretically cling, according to the ideas of the second half of the 19th century, to the total elimination of any finality. As a consequence, this has in some way to be replaced by the introduction of chance." Pauli suggested that the concept of synchronicity might lead to a revival of the historically repressed concept of final causation as a complement to efficient causation. In *Die Vorlesung an die fremden Leute* (part of the very personal essay *Die Klavierstunde*, Pauli 1953), Pauli speculated about a "third family of natural laws which consists in correcting the fluctuations of chance by meaningful or functional coincidences of causally non-connected events."

Even within a worldview dominated by efficient causation, at least two essentially different types of causality must be distinguished. In part of the literature they are denoted as strong causality and weak causality (Atmanspacher 2000). They can roughly be characterized, according to Maxwell's terms, as:

> *Strong causality:* similar causes lead to similar effects.

> *Weak causality:* similar causes can lead to very different effects, only identical causes lead to identical effects.

Strong causality is consistent with the conceptions that are central to classical point mechanics at least as far as linear systems are concerned. For a special class of nonlinear systems, such as K-flows or chaotic systems, strong causality is violated by the extreme dependence of the evolution of such systems on initial conditions. In this case, weak causality still holds. Its main implication is limited predictability. Strong causality can be discussed in the framework of singular stochastic processes, whereas weak causality can be discussed in the framework of regular stochastic processes (cf. Primas 1992).

These two types of causality bear crucial relationships to the temporal characterization of events. The two main ingredients of such a characterization are (1) the discrimination of events in time and (2) their sequentialization in time. Discrimination requires the precise localization of an event on a time axis; sequentialization requires a well-defined before-after relation on a time axis. It is obvious that (2) $\Rightarrow$ (1): no sequentialization without discrimination. But the converse, (1) $\Rightarrow$ (2), generally does not hold. There are indeed situations in which the discrimination of successive events is possible, but their sequentialization is not.

A most convincing way to demonstrate such situations goes back to an experimental paradigm first described by Pöppel (1968). The experiment is basically a stimulus-reaction experiment in which the test subjects are asked to determine the sequence of two successive visual stimuli. If the stimuli are separated by $\tau$, where 3 msec $< \tau <$ 30 msec, they register two distinct stimuli whose sequence they cannot determine (for further details see Ruhnau 1994, Pöppel 1997). The time scale of approximately 30 msec is known as the order threshold of perception.

There are indications that the processes underlying this feature can be related to the behavior of chaotic systems exhibiting weak causality. In a recent publication it has been suggested (Atmanspacher and Filk 2002) that the lack of sequentialization below the order threshold can be interpreted in terms of a temporal nonlocality along the lines introduced by Misra and Prigogine (1983). An essential feature of such an interpretation would be that it refers to an *epistemic* nonlocality. Temporal nonlocality in the sense indicated is related to coarse graining effects. It is not ontic in the sense of a genuinely "extended now" which is, independent of any observation or knowledge, spread over a certain time interval.

[10]The usual textbook derivation of these solutions is done in terms of potentials, not semigroups.

K-flows or chaotic systems are also of crucial importance for the generation of asymptotically disjoint states (Primas 1997, 2000). The relaxation time of such systems is tightly related to the (epistemic) nonlocality time scale. For finite times much larger than the relaxation time, asymptotically disjoint states are approximately disjoint in the sense of section 3.1.

Traditional Hilbert space quantum theory with its algebra of observables does not offer room for a kind of temporal nonlocality that can be considered as ontic as the well-known EPR quantum nonlocality. However, non-commutative time operators can be defined in other algebras of observables (see, e.g., Atmanspacher and Amann 1998). Of course, these observables do still refer to properties of the material world. By contrast, Gernert (2000) has recently proposed non-commutative algebras of observables for mental states. It would be interesting to try to formulate a non-commutative observable corresponding to psychological time and specify the observables with which it does not commute. This might be a first step to study the relation between physical and psychological time in more detail and perhaps lead to more concrete ideas concerning the scenario sketched in section 3.1

# 4 Conclusion

This contribution consists of two parts. First, it discusses a dualistic framework of conceiving the mind-matter distinction in terms of an emergent feature. Mental and material domains of our description of reality are understood due to a symmetry breaking referring to a domain $X$ of description that is neutral with respect to the mind-matter distinction. So far, this is not a novel proposal in the history of philosophy. A common element in this class of proposals is that there are neither specific ideas about the domain $X$ nor specific ideas about the precise nature of the symmetry breaking.

The second part of this paper tries, at a blatantly speculative level, to suggest some such ideas. They are borrowed from certain formal approaches in quantum physics, in particular from algebraic quantum theory. Therefore, it has to be kept in mind that these ideas are to be understood in a metaphoric sense as long as they cannot be made more concrete. Contemporary physics is still a science of the material world, and, rigorously speaking, this does not include any mental states or processes.

The core of the speculative part of the paper can be summarized as follows. Mental and material states are proposed as being disjoint in the sense of inequivalent representations of $X$. Nonlocal correlations between them can be conceived as remnants of the unbroken symmetry in $X$. They decay as a function of time, so that there can be faint correlations between approximately disjoint mental and material states for large but finite times. Asymptotically, there are no correlations left.

The symmetry breaking in $X$ is proposed as a breaking of a fundamental time-reversal symmetry of an automorphic dynamics in $X$. The two semigroups obtained have different time arrows, forward and backward, which can be used as a superselection rule for the distinction of the inequivalent representations of $X$.

I have tried to sketch these speculations in a way that leaves no doubt about their metaphoric nature and yet expresses that they are not entirely arbitrary and pointless. After all, the relationship between mind and matter is one of the most difficult topics in modern science and philosophy. The present outline is presented in the hope that it might inspire future research in this topic.

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