

# Why Do we See a Classical World?

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## Abstract

From a general abstract system theoretical perspective, a quantum-like system description in the spirit of a generalized Quantum Theory may appear to be simpler and more natural than a classically inspired description. We investigate the reasons why we nevertheless conceive ourselves embedded into a classically structured world. Categorical, physical and pragmatic reasons are proposed as explanations.

*To Nikolai, who was always open for discussing such matters.*

## 1 Introduction

The underlying world views of classical and quantum physics are quite different. For contrasting purposes and neglecting intermediate positions they might be characterized as follows:

The world of classical physics is a realistic world of facts, which exist independently of their observation and are registered but not created by the act of measurement. On the other hand, the world of quantum theory is a world of potentialities, which, by the act of measurement, are elevated to a factual status as measurement results. As compared to classical physics, the role of the observer is not only a receptive, registering but an active and in part creative one. Indeed, the violation of Bell's inequalities [1] strongly suggests an exclusion of local realism in the spirit of classical physics and the Kochen-Specker theorem [2, 3] is an obstruction for any realistic hidden variable theory with non-contextual observables.

In our everyday world we are used and inclined to consider the classical world view as the view of common sense, whereas quantum physics looks like a rather extravagant view, admittedly imposed by experimental facts but emerging only lately and being mainly confined to the notoriously strange microphysical world. In this note, we shall present evidence that quantum features of the world are much more widespread and natural than suggested by current common sense, in fact to such an extent that one may wonder about the reasons for the strong favoring of the classical view.

For what follows it is essential to realize that the world is not directly given to us as such but only as and as far as it appears to us on our inner screen. (Using a common philosophical term we refer to this as to the *phenomenal character of the world*.) Probably, almost everybody will subscribe to this apparently trivial statement, but, taken seriously, it leads to far reaching consequences. The question is about the relationship between the phenomenal and the "real" world. Naive realism asserts that the world essentially appears to us as it really is. In the terminology of Thomas Metzinger [4] naïve realism employs a *transparent model*: We are modelling creatures, creating representations of the outer world, of our body and also higher order representations of our cognitive system. A model is called *opaque*, if it is recognizable as a representation and *transparent* (invisible), if its representational character is not manifest and if, hence, the representation is identified with the represented entity.

A reflection about the foundations of Quantum Theory and physics in general must contain an investigation of the prerequisites given by the basics of the human mode of existence and cognition, which are prior to any physical theory or act of measurement. It is safe to say that the classical world view is closer to the strong assumption of naïve realism than the quantum view, which, attributing an active constitutive role to the observer, is more aware of the phenomenal character of the world and, in a way, more cautious.

Caution and methodological prudence are no logically cogent reason for a widespread "ontophobic" attitude of contemporary philosophy, an abstention from any kind of ontological commitment in favor of phenomenal, existential, language or discourse analytical approaches. Later on we shall see that our cognitive system strongly urges if not compels us to build at least tentative ontological scenarios, for instance classically realistically inspired ones as for some interpretations of Bohmian mechanics [5], or scenarios of quantum type.

Early on from the advent of quantum mechanics Niels Bohr was convinced that the quantum theoretical figure of complementarity was of universal significance far beyond the realm of physics. Speculation along this line never ceased [6, 7]. In particular Wolfgang Pauli pointed out the possibly universal importance of quantum like entanglement [8, 9]. The idea of quantum reality gained unfortunate popularity in esoteric circles but it was also followed in a serious and formally well controlled way [10]. Indeed, a quantum analogue structure may be suspected to be realized, whenever the order of successive observations/measurements matters.

A world of strict quantum like constitution would be a world of potentialities. It would show a strongly phenomenal character, because it would be an appearing world whenever a measurement result becomes factual for an observer. From a less observer centered point of view and using a philosophical term, such a world might also be called a *worlding* (German: "weltend") world.

Assuming that the significance of quantum like structural features beyond the realm of physics in the narrow sense were a plain direct effect of quantum physics would amount to an extreme physical reductionism of very low plausibility. Rather one should look for structural isomorphisms with quantum physics. In general, formal work on wider applicability of quantum theory sought to employ the full quantum theoretical formalism to non physical situations. An alternative is the isolation and formalization of a conceptual core of quantum theory followed by an investigation of the extended applicability of the resulting generalized scheme. This has been undertaken under the name of "*Weak Quantum Theory*" or "*Generalized Quantum Theory*" [11, 12, 13], which we are going to describe in the next section.

## 2 Generalized Quantum Theory

Weak Quantum Theory [11, 12] arose from an axiomatic formulation of physical quantum theory by leaving out all features which seemed to be special for physical systems. The term "Weak Quantum Theory" was chosen because the resulting system of axioms is weaker than quantum physics. It is of course stronger in as much as it has a wider range of applicability. In order to avoid misunderstandings we now prefer the term "Generalized Quantum Theory" (GQT). In order to make this presentation reasonably self sustained we here repeat a short account the vital structural features of GQT to which we can refer in the sequel. For recent developments and applications see [13].

The following notions are taken over from quantum physics:

*System*: A system is anything which can be (imagined to be) isolated from the rest of the world and be subject to an investigation. A system can be as general as an object or a school of art together with all persons involved in production and interpretation. Unlike the situation in, e.g., classical mechanics the identification of a system is not always a trivial procedure but sometimes a creative act. In many cases it is possible to define *subsystems* inside a system

*State*: A system must have the capacity to reside in different states without losing its identity as a system. One may differentiate between *pure states*, which correspond to maximal possible knowledge of the system and *mixed states* corresponding to incomplete knowledge.

*Observable*: An observable corresponds to a feature of a system, which can be investigated in a more or less meaningful way. *Global observables* pertain to the system as a whole, *local observables* pertain to subsystems. In the above mentioned example systems, observables may correspond to esthetic investigations for

systems of (schools of) art.

*Measurement:* Doing a measurement of an observable  $A$  means performing the investigation which belongs to the observable  $A$  and arriving at a result  $a$ , which can claim factual validity. What factual validity means depends on the system: Validity of a measurement result for a system of physics, internal conviction for self observation, consensus for groups of human beings. The result of the measurement of  $A$  will in general depend on the state  $z$  of the system before the measurement but will not be completely determined by it.

Moreover, to every observable  $A$  we associate its *spectrum*, a set  $\text{Spec } A$ , which is just the set of all possible measurement results of  $A$ . Immediately after a measurement of an observable  $A$  with result  $a$  in  $\text{Spec } A$ , the system will be in an *eigenstate*  $z_a$  of the observable  $A$  with *eigenvalue*  $a$ . The eigenstate  $z_a$  is a state, for which an immediate repetition of the measurement of the same observable  $A$  will again yield the same result  $a$  with certainty, and after this repeated measurement the system will still be in the same state  $z_a$ . This property, which is also crucial in quantum physics justifies the terminology “eigenstate of an observable  $A$ ” for  $z_a$  and “eigenvalue” for the result  $a$ . We emphasize that this is an idealized description of a measurement process abstracting from its detailed temporal structure.

Two observables  $A$  and  $B$  are called *complementary*, if the corresponding measurements are not interchangeable. This means that the state of the system depends on the order in which the measurement results, say  $a$  and  $b$ , were obtained. If the last measurement was a measurement of  $A$ , the system will end up in an eigenstate  $z_a$  of  $A$ , and if the last measurement was a measurement of  $B$ , an eigenstate  $z_b$  will result eventually. For complementary observables  $A$  and  $B$  there will be at least some eigenvalue, say  $a$ , of one of the observables for which no common eigenstate  $z_{ab}$  of both observables exists. This means that it is not generally possible to ascribe sharp values to the complementary observables  $A$  and  $B$ , although both of them may be equally important for the description of the system. This is the essence of quantum theoretical complementarity which is well defined also for GQT.

Non complementary observables, for which the order of measurement does not matter, are called *compatible*. After the measurement of compatible observables  $A$  and  $B$  with results  $a$  and  $b$ , the system will be in the same common eigenstate  $z_{ab}$  of  $A$  and  $B$  irrespective of the order in which the measurements were performed.

*Entanglement* can also be defined in the framework of Generalized Quantum Theory [11, 12, 13, 14]. It may and will show up under the following conditions:

1. Subsystems can be identified within the system such that local observables pertaining to different subsystems are compatible.
2. There is a global observable of the total system, which is complementary to local observables of the subsystems.
3. The system is in an *entangled state* for instance in an eigenstate of the above mentioned global observable and not an eigenstate of the local observables.

Given these conditions, the measured values of the local observables will be uncertain because of the complementarity of the global and the local observables. However, so-called *entanglement correlations* will be observed between the measured values of the local observables pertaining to different subsystems. These correlations are non local and instantaneous.

Comparing Generalized with full physical quantum theory the following vital differences are worth noticing:

- In GQT there is no quantity like Planck's constant controlling the degree of complementarity of observables. Thus, contrary to physical quantum theory, where quantum effects are essentially restricted to the microscopic regime, macroscopic quantum like effects in GQT are to be expected.
- At least in its minimal version described here, GQT contains no direct reference to time or dynamics.
- In its minimal version GQT does not ascribe quantified probabilities to the outcomes of measurements of an observable  $A$  in a given state  $z$ . Indeed, to give just one example, for esthetic observables quantified probabilities seem to be inappropriate from the outset. What rather remains are modal logical qualifications like "impossible", "possible" and "certain". Related to the absence of quantified observables, the set of states in GQT is in general not modelled by a linear Hilbert space. Moreover, no addition of observables (operationally difficult to access even in quantum physics) is defined in GQT.
- Related to this, GQT in its minimal form provides no basis for the derivation of inequalities of Bell's type for measurement probabilities, which allow for the conclusion that the indeterminacies of measurement values are of an intrinsic ontic nature rather than an epistemic lack of knowledge. In many (but not all) applications of GQT indeterminacies may be epistemic and due to incomplete knowledge of the full state or uncontrollable perturbations by outside influences or by the process of measurement. Notice that complementarity in the sense of GQT may even occur in coarse grained classical dynamical systems [15, 7].

For some applications (see, e.g., [16, 17, 18, 19]) one may want to enrich the above described minimal scheme of GQT by adding further structure, e.g., an underlying Hilbert space structure for the states.

We should stress here that for very general systems like the above mentioned schools of art, observables are not so directly given by the system and read off from it like many mechanical observables. On the contrary, as already suggested by the name of an “observable”, the identification of an observable may be a highly creative act of the observer, which will be essentially determined by his horizon of questions and expectations. This marks a decidedly epistemic trait of the notion of observables in GQT even more so than in quantum physics. Moreover, the horizon of the observer will change, not the least as a result of his previous observations adding to the open and dynamical character of the set of observables. What has just been said about observables also applies to *partitioning* a system into subsystems. In fact, partitioning is achieved by means of *partition observables* whose different values differentiate between the subsystems. In general, subsystems do not preexist in a naïve way but are in a sense created in the constitutive act of their identification.

Quantum like phenomena like complementarity in the sense of GQT may be expected whenever “measurement” operations change system states and are not commutable. Such situations should abound in cognitive science and in everyday life. They apply in a paradigmatic way to the human mind as seen from a first person perspective, because the state of mind will invariably be changed by the very act of its conscious realization. Human communities provide another important field of possible applications of GQT. Detailed empirical investigations of quantum features in psychological systems have been performed for bistable perception [16, 17, 18], decision processes, semantic networks, learning and order effects in questionnaires [19]. (See [20] for further information.)

From the general system theoretic point of view adopted in our account of GQT and also from everyday experience, classical as opposed to quantum like systems should be a rather special and rare case. They correspond to systems without complementarities: All measurement operations commute without limitation and reveal an underlying objective reality essentially untouched by the measurements. This is a very strong assumption and a quantal world view in the sense of GQT looks quite natural and suggested by ontological parsimony. The natural and to some extent even a priori character of quantum structure is clearly pointed out by M. Bitbol. (See [21] and references therein.) Asking for the reasons why nevertheless a classical world view is widely favored seems to be a legitimate task.

### 3 Fundamentals of the Mode of Human Existence

Any reflection about the phenomenal character of the world requires a detailed analysis of the mode of human existence as a conscious being. This has been a main subject of philosophy since the second half of the 19th century in particular of its the phenomenological line. Of course, in this study we can in no way do justice to the vast body of work and thought done along this line associated to prominent names like Franz Brentano, Edmund Husserl, Martin Heidegger or Jean-Paul Sartre. For a deep and comprehensive account see [22]. For our purposes, it must suffice to point out a few constitutive characteristic basics of human existence emerging from its analysis:

#### a) The figure of oppositeness

world as an observer, set apart from and to some extent opposed to the object of his attention. Ernst Tugendhat [23, 24, 25] from the position of analytic philosophy refers to this basic human existential as to the "*egocentricity*" of man as an "I-sayer". In quantum physics the separation between observer and observed system is known as the Heisenberg cut, which is movable but not removable. In our more general framework we shall talk about the *epistemic cut*: Every cognition of a form accessible to us is the cognition of someone about something. The location of the epistemic cut may change depending on whether attention is directed to an object outside or introspectively inside to the own state of mind, but the epistemic cut never disappears altogether.

#### b) Temporality

Man's mode of existence is inescapably time-bounded. The world appears to us not in the form of a simultaneous panoramic picture but rather in the form of a movie: A narrow window of a "now" is shifted over our reality giving a free direct view only over an ever-changing small part of it. This internal mental time is of a type denoted by Mc Taggart [26] as an *A-Time*, which is characterized by the existence of a privileged instance of a "now" and by its directedness towards a future. In strong contrast to this, the outer time of physics is what Mc Taggart calls a *B-Time*, a scale time without privileged points and not necessarily directed. For the physical origin of time directedness see [27]. More about the difficult problem of the relationship between inner and outer time in the framework of GQT may be found in [28] and [29]. On an increasingly fundamental level of physics, proceeding from Newtonian Mechanics to Special and General Relativity Theory, physical B-Time shows a tendency to become more and more similar to space and eventually to fade away as a fundamental notion if quantum effects of space-time and very strong gravitational fields are considered. (See [28] and references therein.) However, internal A-Time persists and leaves deep traces

in thermodynamics via the close relationship between the thermodynamic time arrow [27] and the so-called psychological time arrow and, as we shall see in a moment also in Quantum Theory. The two basic existentials to be mentioned next are closely related to temporality.

#### c) Facticity

We conceive ourselves as living in a world of facts. The feeling of certainty of a visual perception and the immediate presence in introspection all carry an inexorable imprint of facticity. The "now" is located in the heart of both temporality and facticity. Facts underly Boolean Logic.

#### d) Causality and freedom

Causality and freedom of action are both offshoots of the same common root of a developed temporality unfolded into past, presence and future. Rather than being in an exclusively contradictory relationship they rely on each other, because freedom is only possible if actions have foreseeable consequences and causality can only be seen if there is freedom in the choice of causes and initial conditions.

#### e) Agentivity

In our existence we experience ourself as agents, who actively steer the focus of their attention and their bodily motions. Planning, worrying and procuring are our future directed activities and attitudes. In this context it is also worth remembering that "factum" literally means "made".

#### f) Emotionality

This study is centered around the cognitional activity of man. Nevertheless, it should be kept in mind that emotions color all our perceptions and cognitions. We are continuously assessing and judging. Emotions guide our will and intentions, are constitutive for our personality and lie at the basis of our creativity.

We already saw that (Generalized) Quantum theory, more than classical theory, takes into account the phenomenal character of our world. So, we should ask ourselves, whether the basic categorical existentials enumerated above are reflected in the structure of GQT. This, indeed, turns out to be true to a large extent:

a) The structures of *oppositeness and epistemic cut* are deeply rooted in the distinction between system and observer as well as in the central role attributed to measurement. Observables neither exclusively pertain to the observer nor to the observed system but could be said to be located astride of the epistemic cut.

b) *Temporality* leaves a subtle trace in the vital importance of the (temporal) order of measurements. If observables  $A$  and  $B$  can be composed, their compo-



sition  $AB$  means  $A$  after  $B$ . In addition, the facticity of measurement results, mentioned under point c), enters via the "now" of human A-Time.

c) *Facticity* is strongly present in the factual validity of measurement results. In a quantum picture of the world, a quantum state before measurement describes a world of potentialities or, more precisely, of timelessly extended simultaneity rather than factual localization in a "now". From this point of view, every completed measurement corresponds to an inroad of a classical world into a quantum world.

d) and e) become apparent in GQT in the planning and execution of experiments, and in the choice of observables to be measured. They may also be formalized in dynamical equations of motion.

f) Beyond its general great importance, *emotionality* does not play any special role in GQT, which is essentially a theory of cognition. Moreover, and for good reasons, science strives for emotional neutrality. However, systems of GQT may possess emotional observables concerning e.g. mood, contention, pleasantness, esthetic or moral value. Such variables pertain to the cognitive, assessing component of emotions, which after all is almost never missing.

The above-mentioned categorical existentials are to some extent suggestive of a classical world view. *Evolutionary epistemology* [30, 31] asserts that our cognitional system, which is based on these existentials adaptively arose by Darwinian evolution: mutation and selection. Comparison with other forms of life and with older pre-lingual stages of man shows beyond any doubt that an evolution indeed occurred. It is also clear that our cognitional system should not jeopardize our chances of survival. On the other hand, one should not overlook some problematic features of evolutionary epistemology, at least in its most popular interpretation:

- The environment, to which adaptation of the cognitional system has to proceed is normally conceived as being of classical type, often even identified with a classical physical system. Quantum notions are usually not assumed to be relevant. This classical environment is normally considered to be rigid and not subject to evolution, at least as long as cultural evolution does not become topical. Evolution time is identified with a directed physical time of B-type in the sense of Mc Taggart [26]. In addition, evolutionary epistemology often relies on a strong classical background materialism and reductionism. This implies the danger of a gross underestimation of the phenomenal character of our world. The world view of classical physics arises from a particular modelization of the world. As already mentioned in the Introduction, this is not completely illegitimate as a tentative ontological scenario. However, in a naïve realistic world view this model has

become completely transparent and a certain degree of opaqueness seems to be desirable.

- Even if we take the correctness of the central hypotheses of evolutionary epistemology for granted, the survival success of the evolved cognitive system in no way guarantees the ontological validity of the emerging culture dependent world view, let alone of reductive classical materialism. On the contrary, there are many examples, in particular in cultural history demonstrating that the evolutionally more viable view is not necessary the more correct one.

## 4 Excursus: Language

Language is an inseparable part of our human psychic endowment. So, we should not be surprised to find the basic existentials of the previous section in human language. We shall demonstrate this for 1) Facticity, 2) Temporality and 3) Agenticity:

### 1) Facticity

Facticity is reflected in what is called the *propositional character of language* [23, 24, 25]: A normal uttering in human language is either a clause of statement or question. The former directly claims facticity, and the latter asks about facticity. The only exceptions are exclamations and imperative sentences. Both are archaic and syntactically isolated. Imperatives are typically the most simple forms of the verb.

### 2) Temporality

Temporality is met in human languages in various forms

- It is manifest in the threefold temporal sequentiality of language in sounds, words and sentences.
- Reference to time is expressed in the verb in many ways. *Tenses* express temporal location with respect to the speaker (ex: "He wrote") and sometimes also with respect to the reported action (ex: "He had written"). *Modes of action* are related to the lexical meaning of a verb and describe the temporal form of the action (durative, ingressive, iterative, punctual,...) and *aspects*, which are of key importance e.g. in Slavic languages, are forms of the verb allowing to express whether the speaker wants to report on the action as ongoing or as a completed entity [32]. (English ex: "He was writing a letter" vs "He wrote a letter")

## 3) Agentivity

The default attitude whether a speaker understands himself primarily as (a) an acting or as (b) an experiencing being differs between various languages. It has several linguistic reflexes which show a tendency to be correlated:

- Most European languages favor attitude (a). For these languages the main distinction is between tenses, which is morphologically most clearly expressed is the distinction between past and non-past (present/future), because it coincides with the distinction between "non influenciabile" and "influenciabile". For attitude (b) the main distinction tends to be between future and non future (presence/past), which corresponds to the distinction between invisible and visible. Eskimo languages are an example for this state of affairs [33].
- European peoples normally conceive the future as approaching us from the front and receding to the past which lies behind us. This is in line with an active attitude (a), which considers the future as something to be faced and influenced. The converse view, in accordance with attitude (b), for which the invisible future approaches from the back side and turns into the visible presence and past in front of us has been observed in Babylonian [34] and Aymara [35]. For instance, in Babylonian future literally means "lying in the back" and past "lying in front". Aymara speakers point backwards when referring to the future.
- The difference between the active attitude (a) and the receptive attitude (b) may also be mirrored in a preference for a *accusativic* and *ergativic* [36, 33] sentence structure. Let us briefly explain this: Intransitive verbs (ex: "to sit") have only one participant, the *subject* (S) (ex: "Peter (S) is sitting"). The subject normally stands in the most simple unmarked case, the *nominative*. Transitive verbs (ex: "to hit") have (at least) two participants, the *actor* (A) and the *experiencer* (E) (ex: "Peter (A) hits the ball (E)"). Almost all European languages except Basque employ an accusativic sentence structure for transitive verbs: The actor (A) of a transitive verb stands in the nominative case just like the subject (S) of the intransitive verb, whereas the experiencer (E) stands in a different case, the *accusative*. (In English, where nominative and accusative are morphologically differentiated only for pronouns, both (S) and (A) stand before the verb and (E) behind the verb.) This parallel treatment of (S) and (A) signals an active attitude placing the actor in a privileged primary position.

Basque and many languages outside Europe (Caucasian languages, Eskimo languages, Maya languages, Australian aboriginal languages, Chukotian languages,...) choose a different sentence construction for transitive verbs: The syntactic position of (E) runs in parallel with (S), whereas (A) stands in a

different case called *ergative*. Here, the pivotal position is occupied by the receptive experiencer (E). The ergatic sentence construction is somewhat similar to the passive construction in European languages (ex: "The ball (E) is hit by Peter (A)"). However, the European passive only arises by an additional transformation of an active sentence and the accusative construction is the default. In ergative languages the ergative structure is the default. (Indeed, many ergative languages have an "antipassive" transformation yielding an analogue of the normal sentence construction of accusative languages.) Let us finally mention that many languages (e.g. Georgian and Sumerian) have what is called an *split ergative* structure: Depending on the tense of the transitive verb an accusative or ergative construction is applied. Not surprisingly, the ergative sentence structure is favored in the past tense, because an action in the past cannot be really performed but only reported or imagined.

## 5 Why Classical?

We have argued that in many respects a quantum like world view seems to be more natural and ontologically parsimonious. Moreover, our introspective world as well as much of our outside world, at least on closer inspection, makes a quantum like impression. In what follows we shall give (A) categorial, (B) physical and (C) pragmatic reasons for our strong inclination to conceive ourselves as living in a classical world. None of them is completely cogent. After all, by a special intellectual effort, man has proved to be capable to device a quantum-like world view and even to get acquainted to it to some extent. But taking all these reasons together, our predilection for a classical world view becomes almost irresistible, at least for everyday life.

A) We already mentioned that the basic categorial existentials of section 3 rather suggest a classical world view. This in particular applies to the existential of facticity. Our world, as we experience it, is inescapably fact like, which is also reflected in the propositional character of our language. From our very nature we have a deeply rooted tendency to be naïve realists unhesitatingly taking the representations on our internal screen as the real world. Metzinger [4] asserts that transparent models are evolutionally favored. In fact, in view of an approaching predator it would be a waste of time and energy for life saving reaction to realize the representational character of its appearance on our inner stage. On a higher level, we are naturally inclined to ontologize what on closer scrutiny could only be granted a phenomenal status. This predilection for ontological scenarios is an inseparable part of our mental endowment and of our culture. We already pointed out that an ontophobic ascetism may be barren. Ontologization is invaluable for understanding and orientation in our world, as long as some degree of fluidity is

preserved, which sometimes allows us to look behind the screen and to correct inappropriate one-sidedness, petrification and sclerotization.

B) The macroscopic validity of Classical Mechanics is often invoked as the reason for the classical appearance of the world. In the macroscopic regime, to which Classical mechanics applies, quantum uncertainties are normally invisible because of the smallness of Planck's constant  $\hbar$ . Moreover, by the *quantum Zeno effect* [37], repeated measuring and monitoring of the system will prevent an uncontrolled growth of uncertainties. From a fundamental point of view, the macroscopic classical limit of Quantum Theory and the measurement process as an interaction with a macroscopic measurement device are not completely understood in quantum physical terms, at least not for individual systems, rather than ensembles. Decoherence theory [38] goes an important step in this direction. It explains how normal unitary time evolution of pure states of macroscopic systems coupled to an environment leads to states which, by local measurements on the system, are indistinguishable from mixed states. The decoherence time needed to reach such states quickly decreases with the sizes of the system and the environment and is typically very small. What is not described by decoherence theory is the collapse of the wave function, the transition from potentiality to measured facticity, which does not correspond to a unitary evolution in time. Indeed, for individual physical systems instead of ensembles there is so far no description of the collapse in terms of normal unmodified Quantum Theory. This may be interpreted as a hint that measurement is not exclusively to be understood as a physical process but as an act of cognition, which is, of course, accompanied by a physical process on a physical substrate but not to be identified with this physical process. In fact, no clear physical criterium seems to be in sight qualifying a physical process as a measurement process or as an act of cognition. This remark about a possible non physical but cognitive nature of the measurement process applies to GQT even more than to quantum physics. A physical analysis of a measurement process is important even if it does not capture all its cognitional aspects. The situation presents itself as follows: The requirement of the possibility of cognition is of course logically prior to any kind of physics and physical measurement. The result of an investigation of the physical process accompanying an act of cognition and measurement must be consistent with this possibility. The Quantum Theory of the measurement process meets this requirement very well. The measurement process is described by a quantum theoretical system containing the measured system  $S$ , the measuring device  $M$  and possibly some environment  $E$ . An entangled state evolves by unitary time evolution, which, by reduction to the measuring device  $M$  yields a mixed state of  $M$  reproducing exactly the probabilities of measurement results for  $S$  predicted by Quantum Theory for a state  $\rho$  of  $S$  before measurement. The same probabilities are also obtained by applying the measurement of  $S$  in the state  $\rho'$  of  $S$  arising by decoherence theory after reducing an evolved entangled state  $\rho''$  of  $S + M(+E)$  to  $S$ .

Given the macroscopic validity of Classical mechanics, we should not forget that Classical Mechanics only describes a narrow and highly idealized sector of the world in which we find ourselves living. As already mentioned, other important parts of it, including our inner and social world, are rather quantum-like constituted in the sense of GQT. So, the hint to Classical Mechanics does not really answer our original question but rather rephrases it in the form: Why do we attribute so much importance to Classical Mechanics in the formation of our world model? A categorial reason for this inclination has already been given under (A). There are other logically not completely unrelated reasons for favoring a classical world view:

C1) Man in his temporal mode of existence has good reasons to keep to the more stable and reliable features of his physical and social environment. In the material world, a bow spanned and pointed the same way must produce the same shot and a leap done with the same force must carry over the same distance. The necessary stability of a human society is based on a common stock of accepted facts and values and a collection of compatible observables and of histories whose consistency [39] is generally acknowledged. A cultural habitat of (floating) islands of stability is woven as a result of continuous collective work. (This comparison comes from a visit of the Uru-Chipaya tribe, who really lives on floating islands on lake Titicaca built from reed and continuously enlarged and repaired also by incorporation of waste.) The subtle and impressive building of classical natural science is a monumental example of probably the largest consistent structure of our time. Historiography and belief systems build other islands. Hans Primas [40] talks about *partially Boolean Systems*. Our cultural activity tries to extend them as much as possible. Consistency between different islands and sometimes even inside the islands cannot always be achieved, if complementarity is really a general constitutive feature of the world. For the sake of cohesion of society it is natural not to stress but rather to suppress such inconsistencies and anomalies. All this leads to the stabilization of a world view of predominantly classical type.

C2) All kind of information is factual, even information about Quantum Theory. In our life we are swamped with (hard) facts, which peremptorily call for attention, respect and action. The inevitability of death is a particularly grim example of impending factuality. The possibility to store and accumulate facts as documents further adds to their overwhelming dominance.

C3) In a world of surprises and unpredictability man tends to explain uncertainties by lack of knowledge or understanding. This suggests a classical background model of the world, which is difficult empirically to tell apart from a quantum-like model. The key paradigm of unpredictability is the autonomous behavior of personal beings. Quite naturally in earlier stages of mankind animistic world models prevailed and soothing and reconciling strategies were largely employed to in-

fluence potentially dangerous or helpful personal instances. Even for the rather quantum-like internal world intuitions and dreams were widely interpreted as messages from outside intelligences. The development proceeded in the direction of successively substituting personal agents by "natural" ones, which promised a higher degree of control and understanding. A culmination of this development is marked by the success of deterministic Classical Mechanics together with a program of replacing all spiritual aspects of the world by physical reductionism. In addition, classical logic seemed to imply a classical world view. (In fact, also Quantum Theory can be formulated with classical logic.)

Finally, we should mention that also in GQT a quantum Zeno effect [37, 16, 17, 18] strengthens the facticity of measurement results, which can be stabilized and held fixed by continuous observation and sufficiently frequent repetition of a measurement.

## 6 Concluding Remarks

Although many factors, including our categorical framework, urge us to adopt a classical world view, this tendency is not an inescapable fate. Man at least has the capability to reflect on his categorial endowment, to question it and to try a glimpse behind this curtain.

We already mentioned several times that large parts of our world are organized in a quantum like way, even if a classical background model prevents us from acknowledging this explicitly and suggests alternative terminologies and explanations. The human mind and its products, the internal and social world of human beings are quantum reservations.

The simultaneous presence of alternatives in a quantum state has an enormous creative potential, which may very well be active in such highly creative processes like formation of concepts, identification of systems, detection of observables and also in social empathy and cultural activities like poesy and fine arts. The notion of *implicate order* developed by D. Bohm and B. Hiley [41, 5] is closely related to this creative potential. It would be surprising if evolution had not made use of it, and the work on the development of a quantum computer is an endeavor to exploit it even technically.

Moreover, the quantum theory of measurement teaches us that measurement/cognition are realized by means of quantum entanglement correlations.

There is another reason that the limitations imposed on us by the framework of our categorial existentials are not unsurmountable: Mankind is continuously striving to transcend its own categorial framework. In fact, the very term of "existence" literally means "stepping out". This tendency is already prepared in the phylogeny of man and repeated in its ontogeny. The temporality of simple animals strictly confines them to a narrow "now". The unfolding of temporality into present, past and future is an act of emancipation. The possibility to re-present other instances of time enormously widens the temporal screen. Planning, worrying and freedom of action now become possible. Language enables symbolic representations and an emancipation from blunt facts in a mode of contrafactuality, in which the space of possibilities can be freely explored. Under this perspective, the emergence of quantum theory may be interpreted as a late highlight in this emancipatory process.

Man also rebels against the limitation by oppositeness and the epistemic cut trying to see himself integrated and secured in an all-comprising world. Seeking mystic unity [23, 24, 25] or strict mechanistic reductionism can be seen to stand for two opposite extremal attempts to overcome the structure of an individuum confronted to its world. Both of them tend to neglect the phenomenal character of the world, which is taken into account in a balanced and subtle way by quantum theory.



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