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CHAPTER 3

A SYSTEMS-THEORETICAL GENERALIZATION OF NON-LOCAL CORRELATIONS

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Non-local correlations between quantum events are not due to a causal interaction in the sense of one being the cause for the other. In principle, the correlated events can thus occur simultaneously.
Generalized Quantum Theory (GQT) formalizes the idea that non-local phenomena are not exclusive to quantum mechanics, e.g. due to some specific properties of (sub)atomic particles, but that they instead arise as a consequence of the way such particles are arranged into systems. Non-local phenomena should hence occur in any system which fulfils the necessary systems-theoretical parameters. The two most important parameters with respect to non-local correlations seem to be a conserved global property of the system as a whole and sufficient degrees of freedom of the corresponding property of its subsystems. Both factors place severe limitations on experimental observability of the phenomena, especially in terms of replicability.
It has been suggested that reported phenomena of so-called synchronistic, parapsychological or paranormal kind could be understood as instances of systems-inherent non-local correlations. From a systems theoretical perspective their phenomenology (including the favorable conditions for their occurrence and their lack of replicability) displays substantial similarities to non-local correlations in quantum systems and matches well with the before mentioned systems-theoretical parameters, thus providing circumstantial evidence for this hypothesis.

1. Introduction

C.G. Jung's and W. Pauli's "Theory of Synchronicity"[1, 2], W. v. Lucadou's "Model of Pragmatic Information"(MPI)[3, 4] and H. Atmanspacher's, H. Römers's and H. Walach's "Weak Quantum Theory" (WQT)[5, 6] (among others) have proposed that non-local (and in that sense acausal) correlations could underlie phenomena in psychology, parapsychology and alternative medicine which have thus far resisted a satisfying explanation within a purely causal theoretical framework. Due to the similarity and relatedness of these theories (in particular MPI and WQT), I will refer to them collectively as Generalized Quantum Theory (GQT). One of the central ideas of GQT is that in addition to the laws of causality there is a non-causal principle at work in shaping our reality. This principle was first scientifically formalized in quantum theory (hence the reference to quantum theory) but, according to GQT, its applicability is by no means limited to the quantum realm in the traditional sense (subatomic particles, etc.). Instead, non-locality is viewed as a much more universal principle which arises from the way in which systems function, given that they are (self)organized in the appropriate way. Of this universal principle, the non-local phenomena observed in quantum systems in the traditional sense are just one particular manifestation. Just like causality does not only work on apples, non-locality is thought to underlie phenomena in all kinds of systems, given that they fulfil certain systems-theoretical parameters.

In the following, I will introduce the concept of a systems-theoretical generalization of quantum theory with a particular focus on non-local correlations. Assuming that the readership of this book will be a rather interdisciplinary one, I will attempt to use as little technical language as possible. To begin with, let us first clarify what we mean by causal and acausal, local and non-local.

I will use the term causality in the limited sense in which it is used in the natural sciences today[a], the sense we are used to describing as "cause

[a] A more comprehensive, yet equally rigorous, concept of causality has, for example, been defined by Aristotle. The modern scientific definition of causality equates to only one of four Aristotelian types of causality, namely the *causa efficiens* ("efficient causality").

and effect"- relationship between events whereby the cause-event precedes the effect-event and where there has to be a space-time connection between the events.

If we chose to accept as a fundamental axiom Einstein's postulate that the speed of light in vacuum (c) is the upper speed limit of propagation in space (and currently there is no evidence to the contrary), this leads to the inevitable conclusion that two events which are separated in space will also always be separated in time if one of them is the cause of the other. The time by which they are separated (Δt) is at least their distance in space (d) divided by the speed of light (c).

This means that cause and effect can never be simultaneous, unless they happen in exactly the same space, in which case, we would not recognize them as distinct events. Locality thus means that simultaneously occurring events can therefore not be causally (and therefore predictably) correlated unless they are connected via a common causal 'root'-event, which again has to precede its effects.

So far so good, but not so in the case of non-local correlations as observed in quantum physics: Here we find situations where two (or more) events occur in such a way that the outcomes of the events are reliably correlated, even if they are separated in space and occur simultaneously. This is basically saying that two events, even though there is no possibility for them to influence each other, nevertheless always occur in a correlated fashion. The only way in which we can classically imagine something like this to work is by a common causal root for both of these events. But quantum physics says that there cannot possibly be, not even in principle, a way in which any third event in the common past of these events could determine them to happen in this particular way, unless we are willing to assume that the *entire* universe and *all* events therein are precisely predetermined in exactly this way by a common root cause.

2. Non-local correlations in quantum mechanics

To understand these weird claims a bit better, let me first introduce quantum physics to those readers who are not yet familiar with it. Despite the outlandish appearance of the phenomena such as the one described above, quantum physics is not concerned with some peculiar fringe area but actually with the very fundamental units out of which our entire physical reality is composed. Quanta are sometimes defined as the naturally occurring units of physical reality; they can be visualized as waves of energy or particles of matter. Usually quanta are considered to be of extremely small scale. For example, an atom can be thought of as consisting of electrons, protons and photons, which are all considered quanta. There is, however, no definite boundary in terms of size. Depending on the conditions, atoms and even large molecules are also considered quanta[7]. More important than actual size is the possibility to talk about the object in question as a truly distinct unit, which means it must be possible to completely isolate it from the rest of the universe, at least regarding certain properties. The object can then be considered a quantum with respect to these properties.

The phenomenon of non-local correlations is also known as the Einstein-Podolsky-Rosen (EPR-) paradox as it was originally deduced in 1935 on a purely theoretical basis from the quantum-theoretical formalism by these authors. It led them to claim that a formalism which allows for such clearly inconceivable correlations must be incorrect or at least incomplete[8]. Proponents of quantum theory, however, maintained that physical reality should behave in precisely this way. It took almost two decades until this question became at least in principle decidable through the ingenious work of J. Bell[9] who thought up an experimental setup for which the predictions of quantum theory were clearly different from the predictions based on classical physical theory (resulting in the so-called Bell's inequalities). Another 18 years later, physics was finally advanced enough to allow A. Aspect to carry out the experiments with sufficient precision[10]: And lo and behold: nature violated common sense and quantum theory proved to be correct.

The experiments which have up to now been replicated in many different forms with fundamentally analogous results usually consist of the following setup[11]: two quanta (most often photons or electrons) are generated in such a way that there is a fixed overall quality which describes the pair, such as, for example, the total energy or the total spin. (This can, for example, be achieved by splitting one photon with a known energy or spin into two photons) After that, the two quanta are kept causally isolated from the rest of the universe with respect to this particular quality. When, for example, considering spin, the photons must not collide or interfere with other quanta in such a way that spin could be exchanged in the process. The quanta are now separated in space. Next, the spin will be measured on both of them simultaneously (or at least within a time span $\Delta t < d/c$). This means that there can be no 'cause and effect'-type relationship between the two measurement events. What is more, the outcome of this measurement cannot, in principle, be predicted based on the history of the quantum, which means it is usually considered undetermined or random. This means that there is a high degree of freedom regarding the quantity of the particular quality (e.g. 'spin') in each of the quanta, while the total quantity of that quality is known and cannot change. (This is expressed in the so-called conservation laws, for example, the laws of conservation of energy and momentum.) When the spin measurements are analyzed, it becomes apparent that the individual spins on each of the quanta always add up to give the correct total. While this would not be surprising if we could assume that the distribution is already determined at the moment when the two quanta are generated, careful analysis of the experiments reveals that this cannot be the case, unless one assumes that the state of the quanta before the measurement is not independent of the state of the measuring device. Since the state of the measuring device is, however, dependent on a large number of factors including the experimenters' will and, more likely than not, the entire rest of the universe, this would mean that the entire universe would have to be determined in this particular way.

Thus, according to J. Bell[12, 13] (and largely undisputed since), there are four possible interpretations of this experimental data. If we ignore for the moment the (rather unlikely) option that the observations are an artifact due to some error in the experimental equipment and if we resist the conclusion that it is futile to say anything at all about the nature of reality, we are left with two possible world views, both of which are somewhat hard for the common sense to digest: We either have to assume that quantum events (and therefore all of reality) are indeed fundamentally undetermined, which means they occur in a certain way for absolutely no reason whatsoever while, at the same time, they are entirely reliably correlated with other such undetermined events, which means they must be connected in some non-causal way. Or we have to assume that there are no such things as undetermined events and that even events which we would like to consider as independent (for example, an experimenter's decision as to when, where and how to conduct an experiment and the spin of a particular photon, let alone the precise relative position of all the rest of the universe) are, in actual fact, absolutely determined and, more than that, they are orchestrated in such a way that they produce exactly such a pattern of spin measurements that does not allow us, even in principle, to differentiate it from the first possible interpretation.

Those of you who have not yet delved into quantum physics may doubt my sanity or at least my competence, but luckily you don't have to rely on either, since non-local correlations are one of the most central features of quantum physics and have been discussed in an overwhelming wealth of literature with which you can follow the matter up further. I am only able to attempt a very rough sketch of an outline of a few relevant issues here.

Even though in recent literature, the second interpretation (truly undetermined events with non-local correlations) is usually preferred over the first (universal causal determinism), there is no rational justification for doing so and, in contexts where philosophical accuracy is demanded, also the most respected mainstream physicists (e.g. A. Zeiliger[14]) admit that both interpretations are possible. The relationship of such mutually exclusive and, at the same time, collectively required interpretations is often termed 'complementarity'. Complementarity is another very intriguing and central feature of quantum physics (for example, with regard to the wave-particle-duality) and also of great interest for systems-theoretical interpretations and generalizations of quantum theory[15, 16] but we will have to leave it at that for the purpose of this chapter and refocus on non-local correlations by summarizing that, no matter how one chooses to interpret this phenomenon, it is indeed possible to observe correlations that can not be explained by direct causal interaction between the two or more events involved, nor by a common causal root event connecting them but not the rest of the universe.

Since it may be of interest in the context of temporal structures, I should mention that, depending on the experimental setup, non-local correlations of energy can also appear as non-local correlations of detection time points[17]. It may also be noteworthy that it was the phenomenon of temporal coincidence of meaningfully related but not causally connected events that led C.G. Jung to formulate the Theory of Synchronicity in collaboration with W. Pauli. MPI and WQT have also explored the temporal aspects of generalized non-locality, for example in H. Römer's article on the emergence of time[18] and W. v. Lucadou's on self-organizing temporal structures[4].

Another very important feature of non-local correlations is also best explained from a temporal perspective, namely the impossibility of using non-local correlations for signal transfer, also sometimes referred to as Eberhard's Principle[6, 19]. Although space does not translate directly into time, it can be said that instantaneous signaling across space is equivalent to signaling into the past since it means sending a signal outside of the light cone[20]. This would thus imply the possibility to change things in the past, which could lead to so-called 'time-travellers paradoxes', like, for example, preventing one's own birth and hence not existing, hence not being able to prevent one's birth, hence existing and thus preventing oneself being born etc. Fortunately, however, this is prevented by the nature of non-local correlations, which, as we have stated above, are closely connected with the unpredictability (degree of freedom) of the correlated subsystems. This means that while, by observing one of two non-locally correlated events, one can instantaneously know with certainty the outcome of the other event even if it happens far away, one *cannot* influence either of the events. We will return to this principle in the discussion of generalized non-locality.

3. Non-local correlations as a general systems-inherent principle

Although the potential implications may be much more far-reaching[16, 21, 22], GQT's conception of non-local correlations as a general systems-inherent principle is motivated among other factors by an effort to find a new approach to a longstanding dilemma regarding the controversy around anecdotal and experimental data about so called psi-, parapsychological, paranormal or synchronistic phenomena: Largely unnoticed by mainstream science, phenomena such as telepathy, psychokinesis and precognition have been thoroughly investigated for more than a century. Not least due to the high level of skepticism towards this area within the scientific community, the research was, on the whole, conducted according to quite high scientific standards, especially in more recent decades[23]. The overall result of this research effort is at first sight perplexing: there is up to now still not the slightest sign of a consensus regarding even the very existence of the phenomena in question, let alone an accepted explanation of the underlying mechanisms. This becomes understandable when analyzing the nature of the accumulated evidence: On the one hand, there is a wealth of high quality field reports, experimental observations and meta-analyses which, taken by themselves, make plausible beyond necessary doubt the reality of the phenomena such as psychokinesis[24, 25], telepathy[26], precognition[27, 28] or extrasensory perception[28-30]. On the other hand, there is a large body of failed replication attempts and, to date, not a single experimental setup or field-case exists which allows reliable replication of the observations.

Unfortunately, it is beyond the scope of this chapter to review in more detail the field of parapsychology. I will thus pick just one example which in my view illustrates the general situation very well.

In this study[31], which was conducted by R. Targ and H. Puthoff and their research group at the Stanford Research Institute, a subject who claimed to have psychic abilities was isolated in a visually, acoustically and electromagnetically shielded room. After the room had been locked, a ‘target’ picture was produced in an office nearby. The content of this picture was (a) determined by opening a dictionary arbitrarily and drawing the first word that could be drawn (for Experiments 1-4); (b) prepared independently by scientists outside of the experimental group (following the subject’s isolation) and provided to the experimenters during the course of the experiment (Experiments 5-7, 11-13); and (c) arbitrarily selected from a target pool decided upon in advance of daily experimentation (Experiments 8-10).

Under supervision through a one-way monitor, the subject then attempted to draw a 'response-picture' which was supposed to resemble as closely as possible the target picture. In 3 of the 13 experiments (experiments 5-7), the subject did not produce a picture. The target and response pictures of all other experiments are presented in Figure 1. (No data was omitted.)

I think it is quite obvious why, on the basis of experimental observations like this, some scientists have become strongly convinced that 'there is something to' the so-called paranormal and have even risked their reputation and careers in an effort to convince others of this matter. And truly, if a person like the one studied here could at liberty reproduce this kind of experiment with the same rate of success for all those of us who need to see with their own eyes, soon only those who refuse to look would be left with doubts.

Such success, however, seems to have remained an unfulfilled hope for this as well as other similarly remarkable experiments, of which there are quite a few. A frequently observed pattern is that as soon as replication studies are undertaken, the effects seem, sooner or later, to disappear.

Several possible explanations have been advanced for this situation. Those who feel that the phenomena are real argue that possibly the psychic subject loses motivation and gets bored or tired by the replication attempts. Others doubt the existence of the phenomena in question, arguing that the successful experiments are due to chance, since trying often enough will here and there produce astonishing results by mere statistical coincidence. In the worst cases, the authors of successful experiments which fail to replicate are accused of fraud.

All of these explanations have their 'pros' and 'cons' and none are entirely satisfying, leaving important questions open. Wouldn't it keep a subject motivated to know that so much depends on a successful replication? How many trials would be required to come across a level of coincidence as high as depicted in Figure 1 by mere luck? And why would scientists risk their credibility and career by publishing fraud which they know will get exposed because others will not be able to replicate the findings?

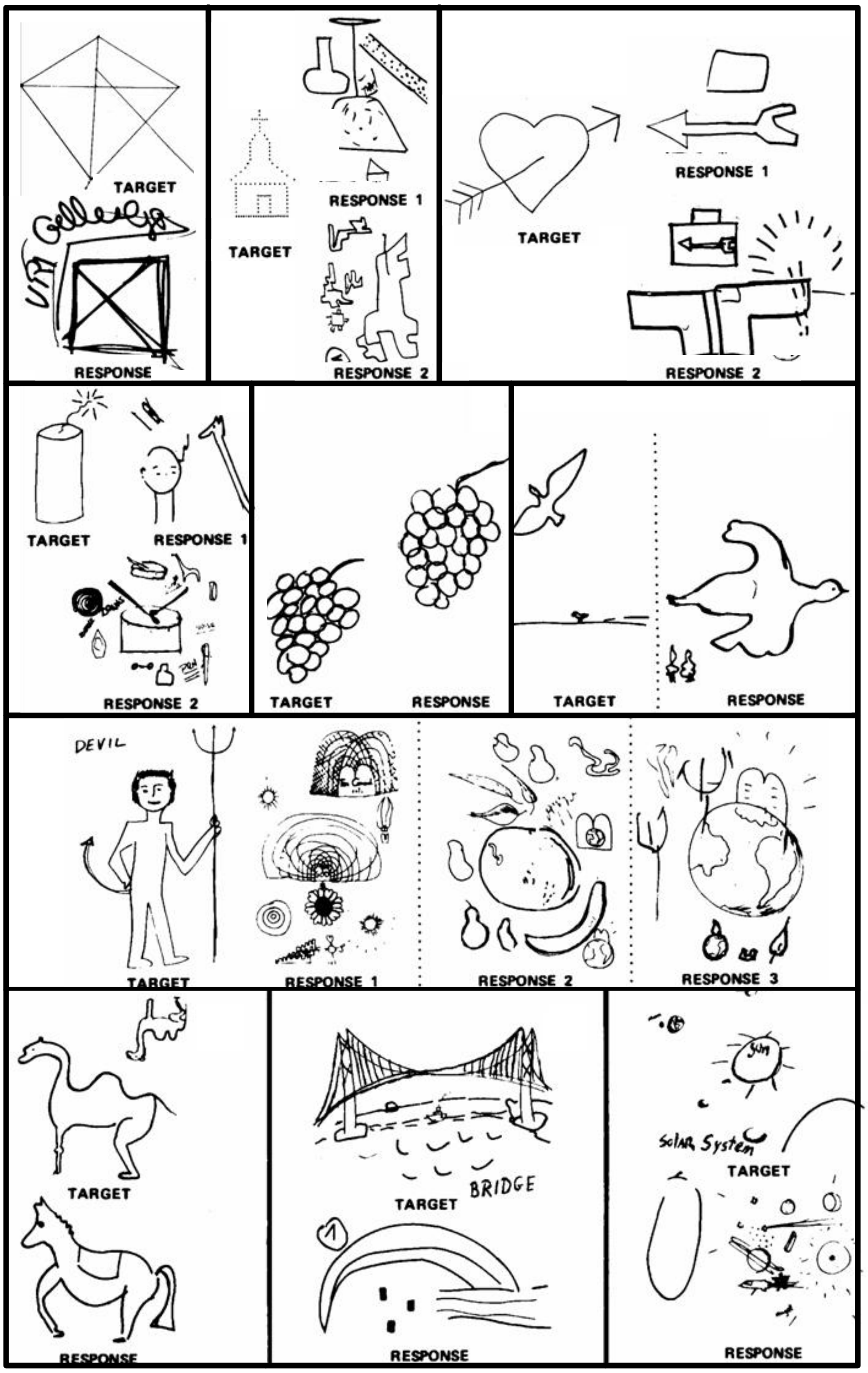

Fig.1 (Adapted by permission from Macmillan Publishers Ltd: NATURE, © 1974)

Again, there are no unambiguous answers to questions like these and the 'reproducibility-problem' remains at the core of an ongoing controversy. Expectedly, 'believers' and 'skeptics' have focused on the respective part of the evidence which is in keeping with their own convictions. As a consequence, both sides accuse the other of a bias. This can cause personal conflicts which lead to the formation of even more stubbornly divided camps.

Interestingly, the area of research into complementary and alternative medicine (CAM), which has received growing interest in the last decades, seems to be encountering a similar situation[32]: Individuals report substantial benefits from alternative methods such as homeopathy and the CAM market is booming (even though people are often paying out of their own pocket, since CAM is not covered by most health insurances). At the same time, scientific proof and therefore recognition is largely lacking. Individual studies may detect very promising effects of various treatments, but a reliably reproducible paradigm has not yet been discovered.

More and more, the reproducibility-problem is attracting scientific research as a phenomenon in its own right[33-35].

GQT does not provide new evidence to tip the scale to either side but it offers a different interpretation of the phenomena which allows logically consistent sense to be made of *both* sides of the existing evidence. How?

Instead of starting with the question about the existence of the purported phenomena, let us first ask: "If the phenomenon were real, what could the underlying mechanism be?" A thorough assessment of the phenomenology leads to the conclusion that any explanation based on causal mechanisms faces serious challenges: Not taking into account large scale fraud, what causal explanation could there be, for example, for the telepathic-picture-guessing results? Even more difficult to imagine, even in principle, is a potential causal mechanism linking a precognitive dream to the event it foresees. And how should pure intention be able to causally influence physical processes? Or how can a homeopathic remedy possibly have a specific causal effect if it does not even contain a single atom of the substance it was originally prepared from? While arguments of this sort can by no means rule out the possibility of some hitherto undiscovered or overlooked causal explanation, they do make plausible why it may be worthwhile to also consider thinking along totally different lines. In this spirit, let us assume as a working hypothesis that instead of a causal mechanism there is an acausal one underlying this class of (causally) 'inexplicable' phenomena.

If it weren't for quantum physics, probably no one would have thought about that possibility (which seems only fair, since it was physics which demanded the more limited concept of causality in the first place). Since, however, non-local (and, in that sense, acausal) correlations have been thoroughly investigated in quantum physics, we can now even make predictions based upon our working hypothesis: If there are non-local correlations at work also in systems other than those traditionally considered in quantum physics, would it not be plausible to assume that all of those non-local correlations should behave according to the same common principles? We can thus predict that (possibly among other features) non-local correlations should occur in systems which are defined by a conserved global variable and a high degree of freedom of the corresponding variables in the correlated subsystems. And, indeed, there are some indications which support this prediction:

In terms of conserved global variables, we are reminded of 'eigenvalues' or 'eigenstates' of self-organizing systems as they have been described, for example, in the theory of autopoiesis by H. Maturana and F. Varela[36]. From there, it is also known that the more organizationally closed a complex system is, the more stable its eigenvalues will be. W. v. Lucadou[3, 4, 6] has demonstrated the applicability of the concept of organizational closure to reports of paranormal and synchronistic phenomena and shown that their intensity correlates with the level of organizational closure[37]. For example, in the case of telepathic or precognitive perceptions, the relationship between the people and/or events involved is often characterized by intensity and importance (close relatives, couples, deaths and accidents). For experimental investigations, those with a high degree of positive personal motivation on the part of experimenters and subjects are known to be more successful[38].

With regard to the necessary degrees of freedom in the subsystems, it is of interest to note that many of the paranormal divinatory techniques such as the I-Ging, Tarot cards, pendula etc. consist of chance processes of very low predictability. What is more, psychological studies have shown that more 'volatile' states of consciousness (such as trance, deep meditation and dreaming) and less predictable personalities marked by high levels of dissociativity, associativity, fantasy proneness, intuition and creativity are associated with a higher prevalence of psychic experiences.

We can further predict that, if psychic or similar phenomena are really based on non-local correlations, it should not be possible to use them for transmitting signals. This is a crucial point in relation to the reproducibility problem, because what a usual experimental setup does, from a systems-theoretical point of view, is to optimize the system under investigation for signal transfer.

By precisely defining dependent and independent variables and eliminating or controlling for confounding variables, ultimately the state of the independent variable can be predicted from observations of the dependent variable. This is equivalent with a signal having been transmitted. With each replication of an experiment, the uncertainty about the precise relationship between independent and dependent variables decreases and thus its suitability for signal-transfer increases[b]. While this is exactly what one is looking for in scientific experiments dealing with causal mechanisms, it may be a fatal hindrance for all attempts at observing acausal non-local correlations, because it would lead to a violation of Eberhard's Principle[c]. In the context of the

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[b] For illustration: Consider measuring the attention span of a person (dependent variable) after she has consumed on one occasion coffee and on another beer (independent variable). If a month later you measure her attention span again, you may from that not be able to predict with certainty if she just had a coffee or a beer, because there are many possible confounding factors (tiredness, weather, medication etc…). If however, you repeat these measurements many times and in addition start controlling for confounding variables, you will soon be able to tell exactly. This means, in theory, someone else could send you a (one bit) message by deciding what drink to buy that person before she comes to have the measurements taken.

[c] The problem could also be formulated in a different way: in the process of investigating a non-local phenomenon in a classical experimental procedure, one destroys the very prerequisites of the phenomenon to occur, namely the organizational closure of the original system and the degrees of freedom of its subsystems. W. v. Lucadou has used the concept of pragmatic information (first introduced by E.v.Weizsäcker[39]) to formalize the information-theoretical connectedness of sub-systems within a system and between the system and its environment. He has shown that the decline in effect sizes with increasing

telepathy study mentioned above, it is for example interesting that the relationship between response and target is not always of the same kind: sometimes it is a more or less identical copy (e.g. the grapes) and at other times it reflects some meaningful connotations (e.g. dynamite and drum). Thus one cannot reliably transmit a signal from the place where the target is produced to the place where the response is produced. The more replications of the experiment are conducted, however, the more possible this would become and, conversely, the less reliable the phenomenon will have to become which is exactly what is found to happen[d].

For quantum systems in the traditional sense, the same principle applies, but does not lead to quite the same problem because one is dealing with *absolutely* unpredictable variables and *completely* isolated systems. A rigorous experimental proof of the existence of quantum physical non-local correlations was therefore possible. Nevertheless, the limitations imposed by the nature of non-local correlations are also noticeable there, for example, in the fact that each of the correlated quanta can only be used for one measurement: After it interacts with the measurement apparatus isolation and unpredictability break down and the correlations are no longer discernible.

In macroscopic systems, unpredictability and organizational closure are only ever possible to a *relative* degree. Since their facilitation is, however, a crucial prerequisite for non-local correlations, the most promising observer perspective for observing non-local correlations in such systems is thus the one that applies the least external constraints on them. This may possibly be a more subjective rather that objective one: becoming part of a system and as part of the system behaving in accordance with the required parameters, i.e. taking a very flexible state of mind while being strongly and authentically motivated and at the same time in keeping with higher order system dynamics.

Summing up, we can say that the view of non-local correlations as universal system-inherent processes offers an alternative interpretation of

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replications corresponds to the increase of pragmatic information extracted from the system[40].

[d] As an interesting aside, it is precisely this pattern that is reported in the CIA's final report on their decades-long psi-research program which concludes that „psychic power is real, but no good for spying"[41]

otherwise hard-to-explain and highly controversial observations, which is grounded in well established scientific concepts and does not require additional metaphysical assumptions. The lack of replicability of the phenomena in question not only becomes more understandable, but actually provides additional circumstantial evidence for this hypothesis. The similarity between non-local quantum correlations and some so-called paranormal phenomena does not provide further evidence for the existence of the latter but it can explain the specific restrictions on their observability as well as indicating ways in which these phenomena can be experienced and dealt with constructively in real life situations[42, 43].

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