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Synchronistic Phenomena as Entanglement Correlations in Generalized Quantum Theory

Abstract: *Synchronistic or psi phenomena are interpreted as entanglement correlations in a generalized quantum theory. From the principle that entanglement correlations cannot be used for transmitting information, we can deduce the decline effect, frequently observed in psi experiments, and we propose strategies for suppressing it and improving the visibility of psi effects. Some illustrative examples are discussed.*

1. Introduction

So-called paranormal phenomena like telepathy, psychokinesis or precognition are of notoriously eerie and elusive nature. Although by no means rare according to frequent reports (Greeley, 1987; 1991), (Bauer & Schetsche, 2003; Moore, 2005) all attempts to get a firm grasp of them and to produce them in a reliable way are invariably frustrated. For sceptics this is sufficient reason to doubt their existence altogether (Alcock, 2003).

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The synchronicity theory initiated by C.G. Jung and W. Pauli (Atmanspacher *et al*., 1995) interprets paranormal phenomena not as a result of any causal influence of mind on matter or other minds but as 'meaningful coincidences', correlations not produced by causal interaction of the kind physicists know and apply successfully but mediated by correspondences of sense and meaning. In fact, it is a common feature of paranormal phenomena that they are prima facie disturbing, unfitting, unlikely incidences and are often perceived as transporting a message of vital relevance for the persons involved and that they usually occur in situations of high emotional tension and receptivity for the meaning of such messages.

In view of the above mentioned failure of reliable production and reproduction of paranormal phenomena, rather than doggedly insisting on trying to identify causal mechanisms to understand and produce them, it seems wiser to us to investigate the synchronistic approach by casting it into a suitable formal framework and to see, what kind of insight it will give and to what conclusions and predictions it will lead us. This is what will be done in the present note.

Non-causal and non-local correlations as postulated in synchronicity theory are well known in quantum theory under the name of entanglement correlations. A composite quantum system in a so-called entangled state will show correlations between the results of measurements of observables which pertain to its components. A simple standard example is a system of two particles of spin 1/2 in a singlet or triplet state, which shows strict entanglement correlations between the measured values of the same spin component of each of the two particles. It is an elementary consequence of quantum theory that entanglement correlations cannot be used to transmit information or to exert controllable influences. (This consequence even holds if, by some violation of Einstein's locality entanglement correlations are produced by strange physical causes. For a more detailed discussion we refer to the appendix of this study.)

Starting from this similarity between synchronistic correlations and entanglement correlations in quantum systems there are many speculations that synchronistic correlations are actually an effect of physical quantum theory. We prefer to be cautious and to avoid such a strong assumption for at least two reasons. First it seems to presuppose a strong physical reductionism, which claims that mental entities, which after all are involved in synchronistic phenomena, can be completely described in physical terms. Secondly, physical quantum phenomena usually show up in microscopic systems, and the

amplification mechanisms proposed to prolongate them into macroscopic and psychic systems look rather artificial.

What is really needed is a formalism which generalizes physical quantum theory beyond the framework of ordinary physics in such a way that quantum concepts like complementarity and entanglement keep a well defined formal meaning. Such a formalism is indeed at hand under the name of Weak or Generalized Quantum Theory (Atmanspacher *et al.*, 2002). Generalized Quantum Theory takes over the notions of systems, states and observables from ordinary quantum theory, but the systems may be of a much more general kind, for instance, groups of conscious individuals. The set of states, unlike in ordinary quantum theory, is not in general a linear Hilbert space and observables are identified with procedures transforming states into other states and can be related to any feature of a system which can be investigated in a meaningful way. Similar to ordinary quantum theory, complementarity can be attributed to the fact that observables as functions on states need not commute with each other, and entanglement can arise in situations in which global observables pertaining to a system as a whole are not commuting with certain local observables pertaining to parts of the system.

The impossibility to transmit information or controllable causal action by means of entanglement correlations, easily provable in ordinary quantum theory, is raised to the status of an axiom in Generalized Quantum Theory. This yields a well defined formal implementation of the essential idea of synchronicity theory and allows to place it in a wider context. We shall demonstrate, how this apparently negative statement about an impossibility can be turned into positive predictions about the nature of psi phenomena, which are well confirmed in attempts of a systematic investigation of the paranormal. (Similarly, in physics, the second law of thermodynamics with its countless consequences can be derived from the negative statement of the impossibility of a perpetuum mobile of second kind.)

Some of the consequences to be derived are:

(a) The well known decline effect: Whenever a psi-experiment at first shows positive results, later data or replications will wipe out the primarily observed effect and will, possibly after tantalising revivals (see footnote 8) eventually level off to the null hypothesis.

(b) The reciprocity between effect strength and reliability of psi phenomena: the more drastic an effect, the less reproducible it turns out to be and vice versa.

(c) Elusiveness (evasion): When one tries to pinpoint psi phe-
nomena, they show a tendency to disappear, where they are
sought for and to surface at some other unexpected
place. This is the so-called displacement effect.

Based on our entanglement model for synchronistic phenomena we
shall propose strategies how to enhance the visibility of psi effects by
reducing the deteriorating influence of the decline effect and exploit-
ing evasion.

The material of this article is organized in the following way:

In section 2 we shall give a sketch of Generalized Quantum Theory
in order to make our presentation reasonably self sustained and to pro-
vide a basis for the understanding of the arguments to follow.

In section 3 we show how to apply Generalized Quantum Theory to
synchronistic phenomena.

In section 4 we describe strategies for planning psi experiments and
in section 5 we give some illustrative examples. Section 6 summarises
our conclusions. For the benefit of the reader, we add an appendix in
which we show how the impossibility of signal transmission by entan-
glement correlations follows from the formalism of quantum theory
and discuss the meaning of this result.

2. A Sketch of Generalized Quantum Theory

Generalized Quantum Theory is a generalization of quantum theory
devised to be applicable beyond the range of ordinary physical sys-
tems. It was obtained starting out from the algebraic formulation of
quantum theory and relaxing all those axioms which seem to be spe-
cial to the physical world. The remaining structure is more general,
yet still rich enough to be able to describe quantum like phenomena
like complementarity (Walach & Römer, 2000), and entanglement in a
much more general setting. Here, we give a short sketch of the struc-
ture of Generalized Quantum Theory. For details as well as for several
applications of Generalized Quantum theory we refer to the original
publications (Atmanspacher *et al.*, 2002; Atmanspacher *et al.*, 2004;
Römer, 2004; 2006; Walach & Schmidt, 2005).

In Generalized Quantum Theory, the fundamental notions of *sys-
tem*, *state* and *observable* are taken over from ordinary quantum
theory:

- A *system* Σ is any part of reality in the most general sense, which
can, at least in principle, be isolated from the rest of the world
and be the object of an investigation.

- A system is assumed to have the capacity to reside in different *states*. The notion of state also has an epistemic side, reflecting the degree of knowledge an observer has about the system. Unlike in ordinary quantum mechanics, the set Z of states is not assumed to have an underlying linear Hilbert space structure.

- An *observable A* of a system Σ is any feature of Σ which can be investigated in a (more or less) meaningful way. Let $\mathcal{A}$ denote the set of observables. Just like in ordinary quantum mechanics, observables A in $\mathcal{A}$ can be identified with functions on the set of states: Any observable $A \in \mathcal{A}$ associates to every state $z \in Z$ another state $A(z) \in Z$. As functions on the set of states, observables A and B can be composed by applying A after B. The composed map AB defined as $AB(z) = A(B(z))$ is also assumed to be an observable. Observables A and B are called *compatible* or *commensurable* if they commute, i.e. if $AB = BA$. Noncommuting observables with $AB \neq BA$ are called *complementary* or *incompatible*. In ordinary quantum theory, observables can also be added, multiplied by complex numbers and conjugated, and the set of observables is endowed with a rich structure called *C**-algebra structure. In Generalized Quantum Theory, observables can only be multiplied by the above composition. This gives the set of observables a much simpler so-called *semigroup structure.* In Atmanspacher *et al*. (2002), Generalized Quantum Theory is characterized by a list of axioms. Here, we only give the most important properties:

- For every observable $A \in \mathcal{A}$ there is an associated set *specA*, which is called its *spectrum.* The set *specA* is just the set of different outcomes or results of the investigation ('measurement') corresponding to the observable A.

- *Propositions* are special observables P with $PP=P$ and *specP* $\subset$ {*yes,no*}. They simply correspond to yes-no questions about the system Σ. For every proposition P there is a negation $\overline{P}$ compatible with P. For compatible propositions P_1 and P_2 there exists a conjunction $P_1 \wedge P_2 = P_1 P_2$ and an adjunction $P_1 \vee P_2 = \overline{\overline{P}_1 \wedge \overline{P}_2}$. The laws of ordinary proposition logic are assumed to hold for compatible propositions.

- If z is a state and P is a proposition, and if a measurement of P in the state z gives the answer *'yes'* then $P(z)$ is a state for which P is true with certainty. This emphasizes the constructive nature of measurement as preparation and verification.

- The following property generalizes the spectral property of observables in ordinary quantum theory. To every observable A

and every element $\alpha \in specA$ there belongs a proposition A_α which is just the proposition that α is the outcome of a measurement of A. Then

$$A_\alpha A_\beta = A_\beta A_\alpha = 0 \text{ for } \alpha \neq \beta, \alpha,\beta \in specA \qquad (1)$$

$$A A_\alpha = A_\alpha A, \quad \bigvee_{\alpha \in specA} A_\alpha = 1 \qquad (2)$$

where 0 and 1 are just the trivial propositions which are never and always true respectively. Moreover, an observable B commutes with A if and only if B commutes with all A_α.

We already mentioned that Generalized Quantum Theory is rich enough to encompass the notions of complementarity and entanglement. For complementary observables A and B with $AB \neq BA$, the order of their measurement matters, and, just like in ordinary quantum mechanics, they will not, in general, possess states in which both of them have a well defined value with certainty.

Entanglement can arise if global observables pertaining to all of a system Σ are complementary to local observables pertaining to parts of Σ. If, in addition, the system is in an entangled state, for instance in a state in which a global observable has a well defined value, there are typical interactionless *entanglement correlations* between the results of measurements of local observables. In ordinary quantum theory, it can be proved that entanglement cannot be used for signal transmission or controlled causal intervention:[1] If Σ_1 and Σ_2 are different subsystems of a composite system Σ, the distribution of values of measurements performed on Σ_1 does not allow to tell whether or not measurements have been performed on Σ_2 unless the results of the measurements on Σ_2 are known at Σ_1. The proof of this fact is reproduced in the Appendix. It is independent of any assumption about the separation of the subsystems in space and time. If, however, the theory of special relativity is assumed to be valid, as suggested by all evidence, and if the separation of the subsystems is spacelike in the sense of the special theory of relativity, then the possibility of any causal physical interaction can be excluded as a mechanism to produce the entanglement correlations. In Generalized Quantum Theory, the impossibility of signal transfer by entanglement correlations probably cannot be derived from the other axioms, but it is strongly expected to

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[1] Jean Burns (Burns, 2003) has called this 'Eberhard's theorem' (Eberhard, 1978)

be true and it may be wise to postulate it as an additional axiom (Römer, 2003; 2004):

- Entanglement correlations cannot be used for transmitting signals or controllable causal influences.

In fact, violation of this axiom would bring about a very serious danger of emerging intervention paradoxes of the kind of killing one's own grandfather in a remote past.

This axiom will be used frequently in the following and its consequences will be investigated in the formal framework of Generalized Quantum Theory. Let us call it the *NT* ('non transmission') *axiom*.

As in ordinary quantum theory, the result of a measurement is in general not determined by the state, but notice, that Generalized Quantum Theory, at least in its minimal version presented here, does not associate quantified probabilities to the outcomes of a measurement of an observable *A*. This is related to the absence of a Hilbert state structure of the set *Z* of states. Moreover, the notion of time is completely absent in the general formulation of Generalized Quantum Theory.

Planck's constant *h* which controls the degree of noncommutativity in ordinary quantum theory, does not enter into Generalized Quantum Theory. Hence, macroscopic effects of complementarity and entanglement are to be expected under suitable circumstances.

In ordinary quantum mechanics it is possible to derive Bell's inequalities and to conclude that the indeterminacy of quantum theory is not epistemic i.e.due to an incomplete knowledge of the 'true' state of the system but ontic and deeply rooted in the very notion of a quantum state. In Generalized Quantum Theory there is no basis for such a deduction. On the contrary, quite frequently Generalized Quantum Theory will be a phenomenological description of complicated systems with strong coupling and limited control, and the quantum features like indeterminacy, complementarity and entanglement will arise from rather innocent epistemic reasons like incomplete knowledge, uncontrollable interactions and, in particular, unavoidable disturbances by the process of measurement. In this situation it cannot be excluded that entanglement correlations are produced by causal interactions, but still they cannot be used to transmit information or causal influences in any controllable way, and the NT axiom remains true.

This remark will be important in the following section.

3. Synchronicity and Generalized Quantum Theory

Paranormal or synchronistic phenomena occur in complex systems of persons and parts of the physical world, which are strongly coupled by many physical, mental and in particular emotional ties. Systems of this kind have a property, called *organizational closure* in system theory. Varela formulated the 'Closure Thesis' in the following way: 'Every autonomous system is organizationally closed'. The cellular system or the immune system may serve as an example from biology and human consciousness may be an example from psychology. He defines an organizationally closed unity as a network of interactions that recursively regenerate the network as a unity in space (for details see (Varela, 1981)). Observation will have uncontrollable effects on the state of such systems, and this makes them privileged objects for the application of Generalized Quantum Theory. Organizationally closed systems are composite and thus have the capacity to reside in entangled states. As already mentioned in the Introduction, we shall pay special attention to entanglement correlations between parts of such highly complex systems and associate them with synchronistic phenomena. Much research and discussion is fixed on the exclusion of any 'normal' mechanism, which could produce these phenomena. In our terminology, this amounts to the question, whether the quantum features of the system described by Generalized Quantum Theory are of ontic or epistemic origin. In favourable situations, the possibility of causal physical interactions between parts of a system can be ruled out, for instance, if spatial separation and time differences are such that signals would have to be supraluminal.[2] Another fortunate case are phenomena like precognition where the time order of cause and effect is inverted and where the existence of such inverted pairs of events would produce intervention paradoxes like killing one's own grandfather. In general, however, and in particular in the most interesting cases, it is extremely difficult if not impossible to decide on this question, and it does not make any difference for our phenomenological description and analysis, either.

The identification of the organizationally closed systems to which our formalism should be applied is a non trivial problem, in particular because entanglement correlations between apparently disjoint systems can never be excluded with certainty. One of the smallest systems conceivable would be a single person, on which one could observe psychosomatic phenomena like somatization. But such

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[2] The so-called 'presentiment experiments' may serve as an example (Bierman & Radin, 1997).

phenomena are not normally counted as paranormal or synchronistic, and in Generalized Quantum Theory they should rather be considered as an effect that the complementarity of mind and body has on individuals. However, there seems to be a sliding transition to 'poltergeist' phenomena, which might be interpreted as a prolongation of somatization into the outside world, and as a major example of entanglement correlations.

Next in complexity would come systems of intermediate complexity consisting of several persons and physical objects and showing phenomena like telepathy, psychokinesis or precognition. The largest conceivable system would be C.G.Jung's unus mundus, the totality of the world, neutral with respect to the distinction of mind and matter. It might be possible to shed some light on phenomena of cultural history, emergence of styles in art, invention of philosophical or scientific concepts and their mutual relationship, but also on mass movements and hysteria by applying Generalized Quantum Theory to the unus mundus and looking at entanglement correlations.

Paranormal phenomena are usually associated with the intermediate level of complexity just mentioned.

Synchronistic phenomena are expected, if such a system is prepared in an entangled state. This can in general be done by making sure that the system is in an eigenstate z of a global observable A, i.e. in a state, in which the system resides after a measurement of A has yielded some definite result $\alpha \in specA$. For instance, for an operationally closed system of several persons, A may be an observable which measures the degree of their 'emotional tuning in' or their fundamental connectedness, for instance, by family ties. In an entangled state, correlations between measured values of local observables for different parts of the system will be observed. As already mentioned and formulated as Axiom NT and in accordance with much experience with psi phenomena, these correlations cannot be interpreted as resulting from any controllable causal interactions or signals between parts of the system.

The precise meaning of the terms 'signal' or 'controllable causal interaction' as we mean and use it in this study is defined by the fulfillment of the following conditions:

- There is a **predefined** pair of quantities, one at the emitter side Σ_2 one at the receiver side Σ_1.

- There is a stable correlation between the registered values of the quantities.

- Controllable manipulations at the emitter side are possible, and their effect can be registered at the receiver side.

- Conclusions on the nature of the manipulations must be possible.

The synchronistic entanglement correlations may sometimes look spectacular, but if, by some episodical fluctuation, they look as if they were due to causal interaction, this apparent effect will be wiped out, if one tries to corroborate it by improving statistics through attempts at replicating the effect. This is the well known and often experienced decline effect. The decline effect will be faster, if the original effect was stronger: the reciprocity of effect strength and reproducibility is a further prediction of Generalized Quantum Theory. One may even with some confidence turn the logic around and conclude, that a reproducibly observed influence on parts of the system onto each other is not a psi effect but the result of ordinary physics. Another phenomenon expected from Generalized Quantum Theory may be called 'evasion' or 'elusiveness'. Correlations, if one tries to interpret them as signals and to validate them statistically, may even change sign or disappear altogether, or else show up again in different observables and/or between different parts of the system. This evasion phenomenon is expected to be observed in particular, if the number of observable correlations is large and if the preparation in the entangled state is of limited stability.

Especially synchronistic events are good examples for situations occurring in systems which include a large number of possible meaningful nonlocal correlations. C. G. Jung's initial example of a patient's dream of the scarabaeus and the corresponding rose-beetle, which flew to the window in the moment the patient reported the dream, is a good illustration. The synchronistic correlation has nothing to do with the precise object and its location but with the semantics (state) (or 'meaning') of the relevant objects. The 'Model of Pragmatic Information' (MPI) provides a phenomenological description of the semantic processes of such synchronistic situations. It proposes a possible operationalization[3] of the term 'meaning' (pragmatic information) by introducing complementary observables such as 'novelty' and 'confirmation' (Weizsäcker, 1974; Lucadou, 1998). It is obvious that the

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[3]   It has been argued that, it was by no means clear that Varela's concept of 'organizational closure' or Weizsaecker's concept of 'pragmatic information' can be operationalized in a sufficiently rigorous fashion. It is true that, until now, there is no standard-operationalization of these concepts available, but in (Lucadou, 1986), experimenal approaches are described which can be interpreted along these lines and Generalized Quantum Theory can also be considered as first step in this direction.

MPI can be considered as a special case of Generalized Quantum The-ory. Pragmatic information is not localisable in physical terms and cannot be 'labeled'. In Jung's example the meaning of the scarabaeus could correspond to any similar looking beetle or even to the word 'beetle' if it had been written on a paper flying, for instance, through the door etc. According to Rössler (1992), objects which cannot be labeled create non-classical properties. In spontaneous psi-experiences the number of possible semantic states is open, but in experiments it is fixed by the experimental setting. If in an experimental setting the 'ef-fect' would be fixed to a single localised state (e.g. a rose-beetle is expected) any other realization with the same meaning would be excluded. This is the reason why post hoc evaluations in parapsycho-logical experiments very often show highly significant meaningful post-hoc correlations, which had not been considered beforehand (see examples). In 'poltergeist' cases new phenomena usually occur when previously observed phenomena are expected (Lucadou & Zahradnik, 2004). Such 'displacement-effects' are typical of parapsychology.

4. Planning of Psi Experiments

In psi experiments one tries to observe psi effects under conditions which are as controllable as possible, laboratory conditions being the ideal case. From the outset, one has to expect only rather small effects in such situations. To improve the visibility of synchronistic effects one should, according to Generalized Quantum theory obey the fol-lowing strategies:

- One should take care that the organizational closure of the sys-tem and its preparation in an entangled state are not destroyed by the observations.

- One should concentrate one's search on conspicuous correla-tions between different parts of the system rather than on (iso-lated) causal influences.

- In order to reduce the decline effect, one should make positive use of the evasion phenomenon. This can be done by simulta-neous registration of as many different correlations as possible. Psi effects will then show up as transitory, jumping unexpected and statistically unlikely patterns in the correlation matrix.

Clearly, by such measures it will never be possible to overcome the decline effect completely and to convince every sceptic. But at least the visibility of synchronistic phenomena may be increased considerably.

In a conventional mono-causal experimental setting the independent variable *A* could always be used in a strict replication to code a signal which shows up in the dependent variable *B* by switching the independent variable *A* on and off. If it is erroneously assumed that a correlation between *A* and *B*, that has been found in previous experiments, is causal in nature the replication must fail due to the NT axiom, if the system under study is governed by non-local correlations. Moreover this gives a criterion for an upper limit of the effect-size *E* in any replication study: If it is assumed that the usual statistical Z-score is a criterion to decide only by means of the dependent variable *B*, whether *A* is switched on or off, at least one bit of information is transferred. In the simplest case $E < const/\sqrt{n}$ holds if n is the number of replication. Only for strict replications *const* is really a constant which depends of the experimental setting. Since many details differ even with strict replications the formula is merely a rule of thumb. As shown in (Lucadou, 2000), the size of *const* is not necessarily small and revivals are possible (see footnote 8). Since this is also true for each trial in a single experiment, the effect-size of each psi-experiment should decline with the size of trials. A recent meta-analysis of 357 PK-experiments (Steinkamp *et al.*, 2002) corroborates this prediction. The funnel-plot (Fig. 1) shows an overwhelming evidence for the decline of the effect-size with number of trials. The authors of the meta-analysis interpret the result as an indication that a PK-effect does not exist and is merely a statistical artefact due to selective reporting etc.[4]

From this result (see the following section) it seems not useful to perpetuate the research strategy of 'proof oriented' experiments, because a strict replication is the best recipe to destroy the effect. Since the NT axiom is assumed to be responsible for this fact one could solve the problem in two ways:

(1) The experimental setting is designed in such a way that only correlations could be measured, which cannot be (mis-) used for any signal-transfer, like in the EPR-case[5] and,

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[4] One may remark that the meta-analysis in (Bösch *et al.*, 2006) has been extensively criticized, with other meta-analyses coming to different conclusions, and a rebuttal in the same journal that published it. To the authors knowledge, this critique, however, mainly deals with the question of the selection of studies for the meta-analysis and has nothing to do with the obvious decline of the effect-size in dependency of *n*.

[5] This is naturally the case in psi-experiments which use neurophysiological sampling method (Bierman & Radin, 1997; Wackermann *et al.*, 2003), because the signal cannot be extracted from the data stream, since it is only after averaging many episodes of EEG associated with stimulation that the correlations can be seen (see above). Apart from the fact
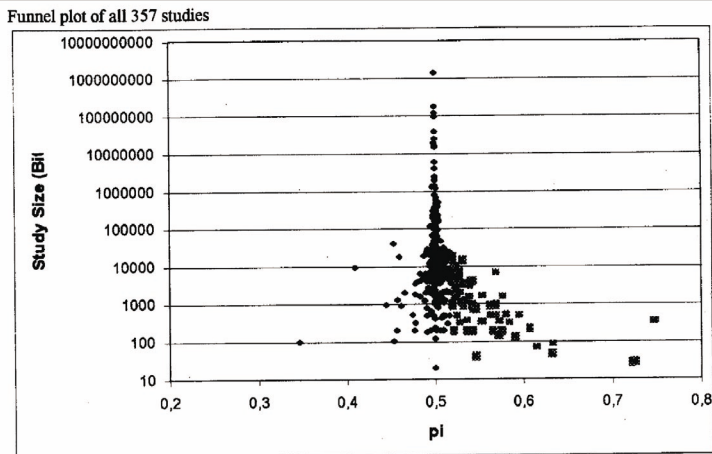
Funnel plot of all 357 studies

Figure 1
Funnel-plot of 357 PK-studie (Steinkamp *et al.*, 2002)

(2)   the experimental setting allows the effect to 'displace' in an
       unpredictable way.[6]

The first condition is difficult to achieve in a psycho-physical experi-
ment, because the psychological variables must be measured before
the psycho-physical interaction. These data could always be used to
make predictions about the physical variables. It does not matter
whether this information is actually used or not. This is an important
difference to the EPR-situation. Only if the interpretation of the psy-
chological data would be generated post hoc (e.g. by a new factor
analysis of the data) this problem could be circumvented, but this is
already very similar to the following method.

    The second condition can be realized by using large sets of psycho-
logical and physical variables which may or may not correlate in the
psycho-physical system. In this case the result is a correlation matrix

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hat the system allows for many degrees of freedom through the application of multiple
electrodes and by considering both positive and negative directions of the correlation (see
below).

[6]   A third possibility would be to mix non-local variables with causal ones in an indistin-
       guishable way. In this case the signals would enhance the organizational closure of the
       system and thus amplify the non-causal correlation within the psycho-physical system.
       However, this design would never convince a sceptic, since one could always argue, that
       all measured correlations are due to causal interactions and no 'psi-effect' occurred. It
       must be admitted, that most spontaneous paranormal experiences suffer from this method-
       ological deficiency.

which shows the psycho-physical correlations. The organizational closure which is created by the experimental conditions (such as instruction to the subjects, vividness of the display, motivation of the subjects etc.) enables the psycho-physical interaction which shows up in the number and strength of the correlations in the matrix. The null-hypothesis is given by the number of chance-correlations. With any replication of the experiment the structure, direction, and strength of these correlations may change, but the total number and total strength can remain high if the experimental conditions are the same. It is impossible to violate the NT axiom because it is not known in advance which correlations will show up and with which signs. This situation is comparable with the EPR-situation.

As stated above, the creation of the organizational closure of the psycho-physical system is of paramount importance. Furthermore, one has to take care, that it is created mainly by the experimental conditions for the subjects and not for the experimenter. Sometimes experimenters are more motivated than the subjects and then the data are difficult to interpret and lead to so-called experimenter-effects (Lucadou, 2000).

5. Examples

The most impressive example of decline effect after a strict replication is the replication study of the Princeton (PEAR) PK-studies (Jahn, 1981; Jahn *et al*., 2000). The authors write:

> A consortium of research groups at Freiburg, Giessen, and Princeton was formed in 1996 to pursue multidisciplinary studies of mind/machine interaction anomalies. The first collaborative project undertaken was an attempted replication of prior Princeton experiments that had demonstrated anomalous deviations of the outputs of electronic random event generators in correlation with prestated intentions of human operators. For this replication, each of the three participating laboratories collected data from 250 * 3000-trial * 200 binary-sample experimental sessions, generated by 227 human operators. Identical noise-source equipment was used throughout, and essentially similar protocols and data analysis procedures were followed. Data were binned in terms of operator intention to increase the mean of the 200-binary-sample distributions (HI); to decrease the mean (LO); or not to attempt any influence (BL). Contiguous unattended calibrations were carried forward throughout. The agreed upon primary criterion for the anomalous effect was the magnitude of the HI-LO data separation, but data also were collected on a number of secondary correlates. The primary result of this replication effort was that whereas the overall HI-LO mean separations proceeded in the intended direction at all three laboratories, the overall sizes of these deviations failed by an order of

magnitude to attain that of the prior experiments, or to achieve any per-
suasive level of statistical significance.

If the results are compared with the first study of the Princeton group,
published in 1981 a strong decline of the effect-size can be observed.

First PEAR(1981) report	$E_{hi-lo} = 6000/13050$	$= 0.46$
All PEAR studies before replication	$E_{hi-lo} = 35000/834000$	$= 0.042$
Replication (2002) study	$E_{hi-lo} = 7070/750000$	$= 0.0094$

Table 1

Effect-size of the PEAR-Experiments and its replications
(the numbers are taken from the figures in the references)[7]

In table 1 the effect-size is defined as follows:
$E_{hi-lo} = (T_{hi} - T_{lo})/n$, T = Number of hits, n = Number of trials

It is evident, that effect-size declines continuously with each replica-
tion.[8] However, the 'psi-effect' does not disappear completely, it
shows up in other variables in the post-hoc evaluation. The authors
state: 'Various portions of the data displayed a substantial number of
interior structural anomalies in such features as a reduction in
trial-level standard deviations; irregular series-position patterns; and
differential dependencies on various secondary parameters, such as
feedback type or experimental run length, to a composite extent well
beyond chance expectation.'; see also Pallikari (2001); Atmanspacher
et al.(1999).

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[7] In this case the data fit quite well with the formula given above and *const* ≈ 50.

[8] It was objected '...that the authors apparently read (Jahn et. al. 2000) without noticing that
that paper's review of the chronological sequence of the PEAR REG data (Fig. 12 and
associated discussion) shows a strong early effect, a decline to null performance, followed
by an increase to strong effects again, which is in stark contradiction to the authors' no-
signaling model.' In contrast to this opinion this is what has to be expected from the MPI
and Generalized Quantum Theory. 'No signal' does not mean that an extra-chance effect
cannot occur, but the data must behave in such a way that they cannot be used to 'recon-
struct' the initial conditions (HI, LO, BASELINE) on the basis of the random-data alone.
If in the second epoch (see Fig 12 of Jahn *et al.*, 2000) the data would have been the same
as in the first epoch an identification of the three conditions would have been possible.
Therefore a return to a zero effect has to be expected by the NT-axiom. As a result, in the
third epoch such a criterion is missing. And even a weaker criterion which would be avail-
able by combining the first two epochs is ruled out by the fact that in epoch three the
BASELINE-condition cannot be distinguished from the HI-condition. From this consid-
eration it is clear that the given formula only holds for very simple situations. In real stud-
ies it can only be used as a rule of thumb which, however, fits astonishingly well. To make
a more precise prediction, it would be necessary to know the history of each experiment
and the development of the signal-criteria, which can be derived from the data. This
includes also changes in the setting during the experiment. From this point of view only
the final results of the studies are used in the table above.

It should be mentioned here, that on the basis of the MPI a clear-cut prediction about the outcome of the replication study was made in advance. It was kept in the minutes before the final evaluation began, but, unfortunately, it is not mentioned in the final research report.

The same feature can also be found in another field, where non-local correlations may play a crucial role, namely homeopathy (Lucadou, 2002). However, in homeopathy there is not such a clear-cut separation between the independent variables (homeopathic treatment) and the dependent ones (cure of the patient). Nevertheless a causal mechanism seems unlikely, because in high dilutions which are used in homeopathy nearly no molecule of the healing substance is present (Walach, 2003).

Although a series of clinical trials has been launched recently to test homeopathy according to the conventional methodological standard of placebo controlled, randomised, trials the outcomes are inconclusive. Very often a similar pattern can be seen: Initial experimental paradigms are promising and show large deviations from chance expectation, not compatible with the hypothesis of random fluctuation. However, when probed for replicability, these effects vanish. (It is not the aim of this paper to give an overview of the present debate, for further details see Walach (2003); Walach *et al*.(2005).
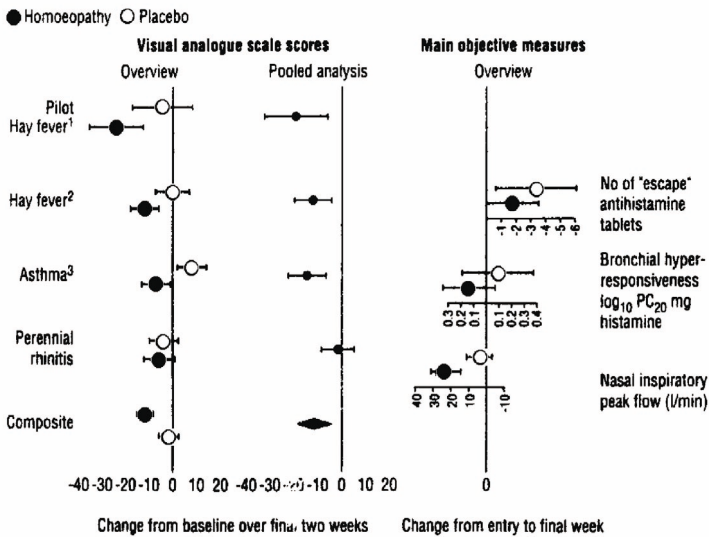

Figure 2. Meta-analysis of four homeopathy studie (Taylor *et al*., 2000).

The main problem of such studies thus seems to be their lack of repeatability. There might be many reasons for the lack of repeatability such as psychological ones, or differences in environmental variables, or regression to the mean, and last but not least the axiom of no-signal-transfer (NT). In most meta-analyses it is difficult to decide between these reasons. However, in the following meta-analysis (Taylor *et al*., 2000) of four subsequent homeopathy-studies the results can be interpreted as an effect of the axiom of no-signal-transfer (NT).

In figure 2 the results are shown. The first column gives the name of the study. The second column shows the difference between the homeopathy and the placebo group measured by the visual analogue scale. The third column shows the overall effect size and the fourth column the difference of the homeopathy and the placebo group measured with different methods. The row 'Composite' gives the composite effect of all four studies.

Two kinds of dependent variables had been used to measure the therapeutic effect: 1. the subjective visual analogue scale and 2. different objective measures like histamine concentrations and nasal inspiratory peak flow. From our theoretical point of view it is important that for all studies one variable (1.) had been used which was the same for all studies and, additionally, non-comparable variables (2.). If the assumption is correct that non-local correlations play an important role the following result would be expected:

(1)   The therapeutic effect measured with the same variable, comparable in all studies (1.) will decline during the replication studies as the statistical reliability of this variable is increased due to the increasing number of cases (n) (decline-effect).

(2)   The therapeutic effect measured with non comparable variables (2.) will increase and 'compensate' the decline of the effect size of the comparable variable, thus the certainty to predict future outcomes does not increase with n for non comparable variables, because the direction and strength of the effect is unknown (displacement-effect).

Notice the opposite tendencies in column 2 and column 4. The decline effect of column 2 seems to be compensated by the increase of the difference measured with a new variable in column 4. Due to the homogeneity of the studies it can be assumed that the organizational closure of the whole system and herewith its non-local entanglement stays

constant during the four studies. The results of the meta-analysis (figure 2) show astonishing agreement with these predictions.

Finally, an example can be provided, where the decline effect is at least partially avoided by circumventing the axiom NT due to the correlation-matrix technique (see above). In these experiments (Lucadou, 1986; 1991; 2006; Radin, 1993) (table 2) psychological variables were correlated with outcome in PK experiments, with feedback and without (control). Only the number of (significant) correlations between psychological variables and physical variables of a PK-experiment are counted and compared with controls (runs without feedback or runs without subjects).

The psychological variables were measured before the PK-Experiment by standard personality-questionnaires. Only in the last two studies (Lucadou 2005a,b in table 2) the psychological variables were behavioral variables (pressing of buttons, for details see (Lucadou, 2006)). The physical variables were several statistical test-values, which describe properties (such as mean-value, variance, autocorrelation etc.) of a binary random sequence (Markov-chain) produced by a quantum-physical random event generator. The physical random event generator was carefully shielded against any physical influence of the subjects.

It turned out that in all studies the overall-distribution of the physical variables showed no deviation from the theoretical expectation-values for both experimental and control conditions. Several techniques were applied to find a PK-signal (tracer) within the experimental random-sequences, but none was found. This is a strong argument for the assumption, that indeed no signal transfer between the observing subject and the random event generator was involved. Nevertheless the number of (significant) correlations between the psychological and physical variables is significantly increased for the experimental runs compared with the number of correlations of the control runs. The deviation is given in table 2 by Z-values.

In these experiments the effect-size ($E = Z/\sqrt{n}$, n = number of correlations) depends primarily on the organizational closure of the system. This can mainly be seen in the last two experiments (Lucadou, 2005 a,b) of table 2. Both studies had an identical design and were carried out in parallel. The next to last one in the table (2005b), which was not significant, was performed by unselected subjects with low motivation (during an exhibition) whereas all significant studies (1986; 1991; 2005a) were performed by highly motivated subjects, who came to the lab because they were interested in taking part in a parapsychological experiment. A more detailed analysis shows,

however, that the unselected subjects (2005b) were not completely unsuccessful. A subgroup (2005c), who showed more 'innovative behavior' got also an increase of correlations. Finally, it could be demonstrated in the study, that the structure of the correlation matrix is not stable if the experiment is repeated, but the number of correlations remains roughly the same (for details, see Lucadou, 2006).[9]

The study of D. Radin (1993) is the only independent experiment in the literature that used the correlation technique. In this case however, there was only one subject and the 'psychological variables' contained also environmental variables and therefore the study is not completely comparable.

Study	$N_{sigcorr}$	N_{subj}	$PsVar$	$PhVar$	$\#corr$	Z	E
Luc1986[34]	75	299	24	23	552	5.13	0.218
Luc1991[35]	28	307	16	8	128	3.10	0.274
Rad1993[37]	32	1	16	23	368	2.63	0.137
Luc2005a[36]	39	386	27	18	216	6.22	0.423
Luc2005b[36]	11	386	27	18	216	0.04	0.003
Luc2005c[36]	21	220	27	18	216	2.25	0.153

Table 2

Result of all correlation studies ($N_{sigcorr}$ = number of significant correlations, N_{subj} = number of subjects, *PsVar* = number of psychological variables, *PhVar* = number of physical variables, *#corr* = number of correlations, *Z = z-value, E* = effect size).

The examples, given here, which show decline and displacement, could easily be augmented by many other ones, and it would be an interesting research task to implement the presented ideas in future meta-analysis of experiments including non-local effects.

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[9] It had been criticized that 'The discussion of several experiments by von Lucadou suggests that the authors have a peculiar understanding of the concept of a 'signal'. Although they failed to 'find a PK-signal' in individual random sequences, the robust and repeatable correlations reported in table 2 in fact constitute a signal'. This argument is only true if and only if the individual correlations between a given psychological- and a given physical variable would be stable if the experiment is repeated. But this is obviously not the case, as only the number of correlations is conserved, but not the precise position of correlated variables. In section 3 an explanation of the term 'signal' is given. This fact, however, does not exclude the possibility that certain pairs of psychological and physical variables show stronger correlations which occur more frequently with replications. This means that certain regions in the correlation-matrix may show a somewhat predominant structure indicating certain characteristics of the psycho-physical system in question, but it does not mean that a signal is hidden in the matrix.

6. Conclusion

We have made an argument that synchronistic, anomalistic or PSI-effects are likely due to non-local correlations that can be expected according to Generalised Quantum Theory in systems with sufficient closure that contain complementary local and global features or observables. We have pointed out that such an interpretation gets rid of the fact that all purported direct mental influences on physical systems using alleged PSI-signals would create theoretical difficulties violating various theorems of invariance. On the contrary, it allows a rational interpretation of PSI effects as non-local correlations between elements of a system that are not causal and hence not usable for signal transmission. The downside of this fact is the difficulty to experimentally isolate such effects, since every experimental attempt at isolating an effect is in fact the isolation of a causal signal from background noise. This approach explains two pervasive features of PSI effects: The elusiveness and the decline of experimental results through replication. We have pointed out that indirect strategies exist, though, which could be used for experimental validation of our claim. We contend that this is a rational explanation in line with mainstream scientific approaches and hope that this paves the way for further creative research and eventual integration within a broader scientific framework.

7. Appendix: 'Eberhard's Theorem'

In this Appendix we show that the impossibility of transmitting information by entanglement correlations, sometimes referred to as 'Eberhards theorem', is a direct consequence of the formalism of quantum theory. In adddition, we discuss the relevance of this result. Let us assume that the Hilbert space $\mathcal{H}$ of a quantum system Σ is the tensor product of two Hilbert spaces $\mathcal{H}_1$ and $\mathcal{H}_2$:

$$\mathcal{H} = \mathcal{H}_1 \otimes \mathcal{H}_2 \qquad (3)$$

Such a tensor product decomposition will be given if Σ is composed of two subsystems Σ_1 and Σ_2 with Hilbert spaces, $\mathcal{H}_1$ and $\mathcal{H}_2$ respectively.

Consider any density matrix ρ on $\mathcal{H} = \mathcal{H}_1 \otimes \mathcal{H}_2$. The density matrix ρ is called *decomposable* if it is of the form $\rho = \rho^{(1)} \otimes \rho^{(2)}$, where $\rho^{(1)}$ and $\rho^{(2)}$, are density matrices on $\mathcal{H}_1$ and $\mathcal{H}_2$ and *undecomposable* otherwise. Let A and B be two observables on $\mathcal{H}_1$ and $\mathcal{H}_2$, respectively, with projection operators P_i and Q_j and spectral decomposition

$$A = \sum_i a_i P_i, \quad B = \sum_j b_j Q_j,$$

$$P_i P_j = \delta_{ij} P_i, \quad Q_i Q_j = \delta_{ij} Q_i, \tag{4}$$

$$\sum_i P_i = 1_{\mathcal{H}_1}, \quad \sum_j Q_j = 1_{\mathcal{H}_2}$$

The observables $A \otimes 1$ and $1 \otimes B$ are commensurable and can be measured simultaneously.

The probability of measuring the pair (a_i, b_j) of values of A and B is given by

$$w_{ij}^{(1,2)} = \text{tr}(P_i \otimes Q_j \rho) \tag{5}$$

If only is $A \otimes 1$ or $1 \otimes B$ measured, the probabilities for the result a_i or b_j are

$$w_i^{(1)} = \text{tr}(P_i \otimes 1\rho)$$

$$\tag{6}$$

$$w_j^{(2)} = \text{tr}(P_i \otimes Q_j \rho)$$

Once the observers have chosen the observables they want to measure, they, of course, have no control over the result of their measurement. From eq. (4) we see that

$$w_i^{(1)} = \sum_j w_{ij}^{(1,2)}, \quad w_j^{(2)} = \sum_i w_{ij}^{(1,2)}. \tag{7}$$

Imagine now that a measurement of B has yielded the result b_j. The conditional probability $w_{i|j}^{(1)}$ that a subsequent measurement of A will yield a_i is given by

$$w_{ij}^{(1,2)} = w_{i|j}^{(1)} w_j^{(2)}. \tag{8}$$

Evidently, we have

$$\sum_i w_{i|j}^{(1)} = 1. \tag{9}$$

For undecomposable states, the conditional probabilities $w_{i|j}^{(1)}$ may depend strongly on j, and this is also the place where the entanglement correlations show up. If, however, the outcome of the measurement of the observable B is unknown to an observer measuring A, the observer will see the distribution

$$\overline{w}_i^{(1)} = \sum_j w_{i|j}^{(1)} w_j^2 = \sum_j w_{ij}^{(1,2)} = w_i^{(1)}. \tag{10}$$

This distribution of measured values a_i is the same for all observables B and coincides with the distribution $w_i^{(1)}$ obtained if no measurement at all is performed on the second part of the compound system. Hence, the observer measuring A cannot decide from the probability distribution obtained whether a measurement at the other side has been

performed nor what observable has been measured. So, no signal can be transferred by choosing and measuring an observable *B* on the other part of the system. This is 'property 4' in Eberhard (1978).

Entanglement correlations could only be used for signal transmission, if, on a different channel and for every act of measurement, the observer at the other end were informed, which observable has been measured and which of his measured values he should keep or discard.

The result about the distributions of measured values is independent of the spatial or temporal separation of the measurement events. But if the separation of any pair of measurements on both sides of the compound system is spacelike and if Einstein's special theory of relativity is assumed to hold (as it should), then the entanglement correlations cannot be the result of any physical interaction.

Without special relativity, for instance if instantaneous interactions at a distance are assumed to be possible, this conclusion, of cause, cannot be drawn. Eberhard (1978) proposes a violation of special relativity by the existence of a preferred inertial system, in which an event E_1 can be the cause of an event E_2 whenever E_1 is prior to E_2. In a different system, obtained by a Lorentz transformation, the two events could be in reversed temporal order.

Even if by some violation of special relativity, entanglement correlations could be due to physical causes, this does not invalidate our general result that, as a simple consequence of the formalism of quantum theory, entanglement correlations cannot be used for signal transmission without the aid of another information channel.

The impossibility of signal transmission by means of entanglement correlations is a straightforward consequence of the basic formalism of quantum theory. Peacock and Hepburn (Peacock, Hepburn, 1999), give a useful list of references on this question, but in view of the above considerations, their assertion,that the proofs of the no signal property are question begging and that the transfer of information and even energy by means of entanglement correlations could not be excluded is very daring indeed.

The remaining way to destroy 'no signal' would be a change in the basics of quantum theory, for instance by describing observables pertaining to subsystems no more by observables of the type $A \otimes 1$ but by some other operator. But it seems to be impossible to do so without contradicting innumerable well established experimental facts, for example of the physics of atoms with several electrons. Moreover, with the ensuing violation of Einstein locality, intervention paradoxes would be lingering right around the corner.

Quite generally, the quantum theoretical reduction of state does not lead to an inconsistency between Einstein locality and quantum field theory. Converse assertions by Hegerfeld have been disproved in a convincing and generally accepted way by Buchholz and Yngvason (1994).

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