The Whole and its Parts: Are Complementarity and Non-locality Intrinsic to Closed Systems?

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Abstract
Systems theory allows formulating general principles of systems behavior which can be applied to all kinds of systems irrespective of the specific nature of their components. In this paper we postulate that non-local correlations and complementarity of observables can be understood as properties intrinsic to all kinds of systems. Their occurrence depends on a number of systems theoretical parameters, most importantly the degree of closure of the system. We show in an exemplary way that this systems theoretical perspective could help elucidate observations in quantum mechanical systems (such as entanglement) as well as in other systems (such as psychic phenomena, phenomena in alternative medicine, the 'hard problem' of consciousness and evolution). This paper aims to inspire further thinking and research along these potentially fruitful lines.

Keywords: Non-locality, Complementarity, Systems theory, System closure.

1 Introduction

We will first explain what we mean by closure of a system and how it can be measured, then we describe the concepts of complementarity and non-local correlation and show how they can be understood as systems inherent properties resulting directly from the degree of closure of a system. This is not an entirely new idea: Its roots lie in the theory of synchronicity that Carl Gustav Jung developed together with Wolfgang Pauli (Jung and Pauli, 1952). It was further sophisticated and formalized in the 'Modell of Pragmatic Information' (Lucadou, 1995) and the 'Weak Quantum Theory' (Atmanspacher et al., 2002). We then go on to demonstrate how this systems theoretical understanding of complementarity and non-locality can be applied to the understanding of some phenomena that are difficult to interpret otherwise, such as entanglement in quantum systems, so called psychic phenomena, phenomena in alternative medicine, the 'hard problem' of consciousness and evolution. It will become clear that while this strictly naturalistic theoretical framework has the potential to explain a number of otherwise hard to explain observations, irrefutable experimental evidence is still lacking. Finally we describe some of the main issues to consider for experimental approaches.

2 What Makes a System Closed?

Whenever we define a system we are in essence drawing boundaries around elements in the universe. Where exactly we draw these boundaries is decided by assessing the relation between the elements under consideration. The same procedure can be used to determine the degree of closure of any given system. Strictly speaking, of course, there is only one closed system, the universe as a whole. When talking about closure of systems here, we allow a gradient of more and less closed systems. Specifically, we use the notion of pragmatic information to describe the relation between elements in order to measure the degree of closure of a system. Pragmatic information is a concept specified by E. U. von Weizsäcker (1974) and is widely used as the formal information theoretical concept representing what is colloquially called 'amount of meaning' (e.g. Weinberger, 2002). Simply speaking, it denotes the degree to which change in one system causes change in another system. If the pragmatic information exchanged between two systems {A} and {B} is large relative to the pragmatic information exchanged between either of these systems and other systems {X},{Y},{Z}, then {A} and {B} can be considered subsystems of a system {AB} which is to some degree closed relative to its environment consisting of {X},{Y} and {Z}. This situation can also be formulated as relative causal isolation of two causally interacting systems {A} and {B}.

3 Could Complementarity be an Intrinsic Feature of Closed Systems?

The term complementarity was introduced by Niels Bohr (1934) to describe the relationship between observables which are mutually exclusive and at the same time collectively required to adequately describe a system or an element. Observables in the widest sense can be understood as the result of the interaction of something to be observed with the observation mechanism.

It could be argued that in observing any closed system there will be complementarity of two kinds: Firstly, between a local observable pertaining to a subsystem (describing an individual entity) and a global observable pertaining to the system as a whole (describing the unity resulting from the interaction of those entities). This is for example mirrored in the complementarity between structure and function. Secondly there will be complementary between local observables pertaining to different subsystems, when these subsystems are mutually exclusive.

Since here we are looking at systems that are closed to a higher or lesser degree , also the "amount" of complementarity will be a gradual one. Regarding both types of complementarity it can be said that the more mutually exclusive the observables are, that is to say the less overlap there is, the better they will complement each other in the description of the system that is observed and the higher their degree of complementarity will be. Since, however, it is impossible to have two identical parts in a whole there will always be a degree of complementarity even if there is some overlap.

4 Could Non-local Correlations be an Inherent Feature of Closed Systems?

If we consider complementary observables, that is to say mutually exclusive descriptions of something that requires all of these mutually exclusive descriptions in order to be adequately described, we can also think of them as complementary parts of a whole.

It could be argued that states of complementary parts of a whole have to correlate even though there is, strictly speaking, no causal pathway connecting them. This is because the global observable describing a state of the whole and the process of partitioning the whole into local observables describing states of its parts are shared features of all the complementary parts. For a trivial and largely inadequate illustration we can imagine a two dimensional cake which has as a global observable a perfect circle. Now whichever way we cut this cake into pieces the local observables describing the pieces will correlate exactly even though there is no causal interaction between them.

Non-local correlations could from this perspective be seen as corresponding local manifestations of a property of the system as a whole rather than the transfer of information between parts of the system. This also means that it is not possible to transmit a signal through a non-local correlation. This can be called the "prohibition of signal transmission" theorem. This principle can also be expressed in terms of closure of a system, since the possibility to transmit a signal through a system reflects its connectedness to other systems. If the occurrence of non-local correlations is centrally related to the closure of a respective system, then an increasing ability to use such a correlation to transmit a signal would lead to a decrease in the very prerequisite for the non-local correlation to occur, even if this ability exists only in principle.

5 Possible Applications?

It may be worthwile to apply this systems theoretical perspective to

a) phenomena which appear difficult to explain within a purely local causal framework (such as true anticipatory behaviour, which actually seems to demand for a certain element of non-locality) and

b) phenomena that display irreconcilable characteristics which might turn out to be complementary.

5.1 Quantum Mechanics

Above, when we talked of a system {AB} consisting of subsystems {A}and {B} we already of course implied some independence and therefore closure of these subsystems {A} and {B}, which in turn is the result of the relationship of their respective subsystems and so on. This regress ends only at those systems whose elements are not composed of other elements. Possibly quanta such as photons or electrons can be considered such elements. The highest degree of closure would therefore be achieved by complete causal isolation of two or more causally linked elementary particles.

Various realisations of the famous thought experiment proposed by Einstein, Podolsky and Rosen (1935) such as the one by Aspect et al. (1982) could be considered examples of such a system. There the systemic closure is actually such that, before a measurement takes place, two quanta, for example two photons, can only be described by one common wave function. In fact, we can talk about *two* photons only after the measurement process destroyed the causal isolation of the biphoton system. Understanding the biphoton system as a unity may provide an intuitively plausible explanation of why non-local correlations occur between its parts. Only the partitioning which results from the measurement process, so to say, cuts the biphoton system into two spatially separated photons.

Keeping in mind the “prohibition of signal transmission” theorem, we can also understand why it has proven impossible to transmit supraluminal signals using entangled particles. This is because in order to deduce from one part of an entangled system (such as Einstein, Podolsky and Rosen’s biphoton) information about another part of the system, we have to have information about the nature of the partitioning. Since this partitioning happens through local measurement and since information about this measurement would have to be communicated classically, no supraluminal signal transmission is possible.

Naturally, partitioning of the biphoton system will result in complementarity between the (global) quantum description of the biphoton system as a superposition and the (local) classical description of the individual photons as mixed states. Also the local descriptions themselves will be complementary since together they have to fulfil the requirements of the global wavefunction.

5.2 Psychic Phenomena

The reports about phenomena such a telepathy and precognition as well as the scientific study of these and related phenomena over the last century show some interesting patterns, which may be interpreted in accordance with the systems theoretical principles established above.

Firstly it is striking that anecdotal reports of the occurrence of such phenomena stem considerably more often from situations that are marked by high emotional content or existential meaning. Telepathic experiences, for example, are more often reported between family members or couples than between strangers. Similarly, precognitive dreams, and thus anticipatory mental acts, more often concern meaningful events such as death, illness or accidents rather than more trivial matters. From a systems theoretical point of view these constellations can be described in terms of a high content of pragmatic information and therefore organisational closure.

Secondly it is interesting that, while the overall database of psychic research does not provide overwhelming evidence, individual experimental studies have observed, under well controlled conditions, remarkable phenomena that do convincingly point to the existence of the phenomena in question. (Schmidt et al., 2004) These observations have, however, in general proven to be impossible to reproduce reliably. (Walach et al., 2005) From the systems theoretical view sketched out in this paper, this can be explained as follows: if these phenomena are in deed instances of system inherent non-local correlations, arising in systems of sufficient systemic closure, they should be sensitive to the violation of the "prohibition of signal transmission" theorem. The classic experimental setup, however, specifically aims to do just that: we actually optimize an experimental system for signal transmission by defining an independent variable that can be modified by the experimenters and a dependent variable which is monitored for change while controlling any confounding parameters as closely as possible. This problem increases with each replication of the experiment: in an initial experiment the behaviour of the experimental system cannot be predicted very well, thereby making it difficult to obtain exact information about the independent variable just by observing the dependent variable. With repetitions, however, the experimenters gain confidence about the exact relationship between independent and dependent variable thereby allowing them to transmit a signal with higher accuracy. This can also be expressed as a breaking of the systems closure, which will inevitably lead to the disappearance of non-local correlations, leaving only causal correlations to be detectable by the experimental setup (See also Lucadou, 2001).

Following from this analysis it becomes clear that it is a challenge to devise experimental set-ups in which systems-inherent non-local correlations could be observed reliably without destroying them.

5.3 Complementary and Alternative Medicine

Interestingly, the overall data accumulated through the scientific study of some healing techniques such as homeopathy, distant healing or prayer shows somewhat similar patterns. While anecdotal reports of purported effectiveness abound, controlled clinical trials have yet to show any reproducible, reliable effect. Nevertheless some studies did observe outcomes that are difficult to explain with purely statistical or psychological effects. It is tempting to see these therapeutic settings as facilitating the creation of a temporarily closed system which is conducive to non-local correlations (Walach, 2005). Symbolic and ritualistic elements can further enhance this effect. It might therefore be hypothesised that systems inherent non-local correlations play a role in these healing techniques. If that was really the case, it would be understandable that a classic experimental paradigm is not only unsuitable to investigate them, but bound to destroy the effects on the long run.

5.4 Evolution

There is some disagreement about the question whether a mechanism composed solely of random mutation and environmental selection would have been able to produce the complex and varied biosphere that we encounter today, given the observed rates of mutation and the time available since the formation of the planet. From a systems theoretical perspective, we are looking at ecosystems composed of subsystems of more or less co-dependent and interacting species and environmental parameters. One could argue that, if non-local correlations do occur as a result of systems closure, random environmental changes and mutations might in fact correlate in such a way that a given global observable (e.g. system stability or maximal entropy) is adhered to.

In fact, it has been argued that it would be very strange if nature had not used non-local coupling as a means of coordinating behaviour (Josephson et al., 1991) and recent simulation experiments prove that biological systems are more efficient in reaching their goal when they can use non-local coupling (Summhammer, 2005). Our view, however, differs from these ideas. We do not suppose that actual quantum mechanical non-local correlations in the strict sense extend and survive in high entropy macroscopic biological organisms. This seems highly unlikely due to decoherence effects. Rather we suggest that the non-local correlations observed in quantum physics are a specific case of a much more general systems inherent principle which may be at work also in macroscopic systems.

5.5 Consciousness, Brain and Mysticism

A very central question in consciousness research, the so called 'hard problem' of consciousness, concerns the way in which subjective states of consciousness are connected to their neurophysiolological correlates. Physical and mental states, objective observation and subjective experience are of such radically different quality that presently there is no scientific consensus about the nature of their relationship. According to the definition introduced above, however, these incompatible qualities may be described as complementary. In fact already Wolfgang Pauli stated that mind and matter appeared complementary to him (Jung and Pauli, 1952, p.164).

According to the sytems theoretical deduction of complementarity one could postulate that two such incompatible observables are likely to point towards a whole that is adequately described only by both of those observables and whose global observable is at the same time complementary to the observation of these partitions. This is reminiscent of the notion of personality that is put forward by a number of spiritual traditions which postulates that there is an underlying unity, a core entity of the person that manifest itself in mind and body but at the same time is independent of them (Walach, 2005 II).

It may be of interest in this context to note that a feature shared by many of the mystic traditions (mysticism being the experiential aspect of religion (Walach and Reich, 2005)) is the use of techniques which aim to induce a state of consciousness which is described as acategorial and all-encompassing and which is thought to be the state of being of the true self. Also in regard to other issues, many mystical traditions share the view that truth lies within the paradox, a view not entirely dissimilar to the notion of complementarity. Nils Bohr may have already pointed to this connection when he chose the taoist yin-yang symbol as his coat of arms with the inscription "contraria sunt complementa – contrary parts complement each other. The quote "The opposite of a great truth may well be another big truth." which is attributed to Bohr, suggests that scientific thinking and mystical experience may in fact, at least for Bohr, be complementary themselves.

6 Experimental investigation of complementarity

Currently no experimental paradigm is known to the authors which could satisfyingly prove or falsify the claims made about the role of complementarity as a fundamental principle of systems behaviour. So far the only circumstantial evidence in support of the theory are its inherent logic and simplicity and its potentially large explanatory power.

It therefore seems worthwhile to further try to apply this concept to whatever situations we encounter, in order to see if the applicability of the notion of complementarity is really as general as could be suspected from a systems theoretical point of view. Simultaneously efforts should be made to devise experimental approaches which are suitable to investigate this question.

7 Experimental investigation of non-local correlations

From the theoretical reasoning above it has become clear that experimental treatment of non-local correlations has to differ distinctly from experimental treatment of causal correlations. Generally speaking, a number of central elements can be formulated, which are to be taken into account when attempting to reliably observe system inherent non-local correlations:

1) The experimental system has to be as closed as possible.
2) Observables describing the subsystems have to be complementary to an observable describing the system as a whole (possibly equivalent to the first point).
3) There are variables in the system that can be measured (i.e. observables) and which can take on more than one value (degrees of freedom).
4) We have to be able to determine if these variables correlate.
5) We have to be able to exclude a causal pathway as the substrate of a potential correlation.
6) It has to be impossible (even in principle) to transmit a signal using this correlation. The transmission of a signal has to be excluded by the experimental set-up itself.

Our current interest is in designing and implementing actual experimental setups where these parameters are fulfilled and concrete predictions can be made.

At this moment experimental research into the validity of the hypotheses derived from the systems-theoretical considerations above is at an early stage. While there are a number of promising experimental paradigms in our laboratory and others (e.g. Wackermann, 2003) and even some intriguing initial data we refrain from going into detail here. Since replicability is such a crucial issue, this certainty has to be obtained first.

Both theoretical reasoning and practical operationalization should occur in an interdependent circular fashion ('Experimenters Regress') because at this stage a negative result can mean either that the hypothesis has been falsified or that the requirements of the hypothesis have not been understood or implemented properly.

It is obvious that implementation of all of these parameters may not be trivial and could in fact be principally impossible. One main challenge is certainly the task to observe a system and at the same time excluding the possibility for causal correlations without reducing the system's closure too much.

8 Conclusion

A systems theoretical interpretation of complementarity and non-local correlations is logically consistent and does not conflict with established scientific knowledge. It predicts the occurrence of complementary observables and non-local correlations in quantum mechanical systems of as well as other systems. Its central characteristics and predictions are consistent with the phenomenology of reported observations. In this view a number of phenomena can be explained naturalistically which are difficult to explain with current scientific theory. Experimental testing, however, may prove difficult, since existing experimental methodologies are aimed at detecting local causal correlations and may be unsuitable for detecting non-local correlations. However the large potential explanatory power of the proposed theoretical perspective in our view warrants further efforts.

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