과학철학 4(2000) pp. 81~107

Causal Explanation and Bell-Type Correlation*

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In this paper, I advocate causal explanation by proposing causal holism in Bell-type experimental context. Bell-type correlation is not an evidence against causal explanation but an evidence for holistic ontology in this world. I argue that in holistic ontology the world must be seen as a whole, at the one end, then as a particularistic world, at the other end, and between the two worlds, there are some spectrums. I suggest that the world satisfying the incomplete condition(in the Jarrett's sense of incompleteness), and the world satisfying the non-separable condition (Howard's sense) are the examples of holistic worlds in the spectrum.

【KEY WORDS】 Jarrett, causal explanation, holism, causal holism, Bell, incompleteness, non-separability

1. Introduction

The Bell type correlation is known as a big puzzle for causality. Some philosophers, such as A. Fine and van Fraassen, believe that this is a case in which the causal theory of explanation fails and instrumental interpretation wins. Fine argues that EPR-correlation does

* This research was supported by Korea Research Foundation for 1997.9-1998.8
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not need to be explained.[1] Van Fraassen argues that Bell-EPR correlations cannot be explained in terms of common cause and claims that causal theory of explanation cannot be applied to them.[2]

In my view, the Bell type correlation is not an evidence for the failure of causality, or causal explanation, but an evidence for the falsity of an assumption in the classical physics, that is the particularistic ontology. In this paper, I defend the causal explanation for the Bell-type correlation by proposing a new concept of cause, via causal holism. Many philosophers advocate holism. However, they do not mention the structure of holism itself. I argue that in the holistic ontology the world must be seen as a whole, at the one end, then as a particularistic world, the other end, and between the two worlds, there are some spectrums. I suggest that the world satisfying the incomplete condition (in the Jarrett's sense of incompleteness) and the world satisfying the non-separable condition(Howard's sense) are the examples of holistic worlds in the spectrum.

2. Bell-type Correlation and Non-locality[3]

Einstein, Podolsky, and Rosen argue in their paper published in 1935 that the quantum mechanical description of physical reality is incomplete.[4] In the 1960's John Bell extended the Einstein-Podolsky-Rosen(EPR) argument by discussing Bell's theorem that the

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1) Fine, 1989

2) Van Fraassen, 1982

3) For the notation, description, and characterization of the Bell-type phenomena, for the most part, I have followed J. Jarrett (1989, unpublished manuscript)

4) A. Einstein, B. Podolsky and N. Rosen, 1935, 777-780.

incompleteness horn of the dilemma does not avoid nonlocality either.[5]

In this section, I will discuss the Bell-type correlation and nonlocality by using 'Mermin Contraption' which represents the EPR-Bohm-Bell gedanken experiment.[6]

> Any empirical theory governing the Mermin Contraption must ascribe states to the measuring devices and the source emissions which determine (presumably by way of appropriate physical laws) functions of the form $P_{\lambda}^{AB}(x, y / i, j)$, where λ is the state of the source-emissions (the pair of particles) ; x and y are the measurement outcomes (red or green) at A and B respectively; and i and j are the A and B detector states, including the switch settings and whatever else may be relevant.[7]

What Bell's theorem shows is that the statistical predictions so generated by any such theory, satisfying certain other 'local realistic' constraints, must conflict with the experimentally well-confirmed predictions of quantum mechanics. This implies that one or more of the local realistic assumptions is false. According to Bell, the vital assumption is that the result for neither particle depends upon the setting of the distant detector.[8] There are various versions of Bell's theorem, corresponding to different sets of premises from which Bell's inequality is derived. Each version of the theorem, however, employs as such a premise some locality condition.[9] "More general versions of Bell's Theorem, those which apply to stochastic local realistic theories, make use of a strong locality condition."[10] This strong locality

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5) J. Bub, 1989, 198
6) N. D. Mermin, 1981, 397-408.
7) J. Jarrett, 1989, 65.
8) J. Bell, 1964, 15.
9) J. Jarrett, 1984, 569.
10) *Ibid.*.

condition is the following factorizability condition.

$$P_{\lambda}^{AB}(x,y/i,j) = P_{\lambda}^{A}(x/i,*)\,P_{\lambda}^{B}(y/*,j)$$

This strong locality condition can be decomposed into two logically independent weaker conditions.[11] Jarrett calls one condition 'locality' and the other 'completeness'. Shimony terms these 'parameter-independence' and 'outcome-independence'.

Locality : $P_{\lambda}^{A}(x/i,j) = P_{\lambda}^{A}(x/i,*)$; $P_{\lambda}^{B}(y/i,j) = P_{\lambda}^{B}(y/*,j)$

Completeness : $P_{\lambda}^{A}(x/i,j,y) = P_{\lambda}^{A}(x/i,j)$; $P_{\lambda}^{B}(y/i,j,x) = P_{\lambda}^{B}(y/i,j)$

In the actual experiment by Aspect, Grangier, and Roger[12][13], what we get is the strong locality condition being violated. There are two options. Either 'locality' is false or 'completeness' is false.

If locality is violated, the experimenter E_A at detector A and the experimenter E_B at detector B could communicate in a form which apparently is possible only through mechanisms which violate the relativistic prohibition of superluminal signals.[14] Relativity theory is a well-corroborated theory. We should not abandon it too quickly. So we take the option that completeness is violated. What does it mean that the completeness constraint is violated?

Completeness expresses a form of independence between outcomes

11) J.Jarrett, 1984.
12) Aspect, Grangier, Roger, 1982a.
13) Aspect, Dalibard, Roger, 1982b.
14) Jarrett, 1984, 1989.

> at the two wings of the Mermin Contraption. Complete state-descriptions render the outcomes uncorrelated. However, no correlation of the sort associated with violations of completeness can be exploited for superluminal communication because it is a consequence of the failure of determinism that measurement outcomes are not (even in principle) under the control of experimenters.[15]

Incompleteness is not incompatible with relativity theory, but it appears to represent some kind of connection between space-like separated events. What is this connection? How are we to interpret the correlation between the space-like related events? To interpret Bell-type correlations, philosophical issues as well as physics are involved. In the next section, I discuss the various philosophical interpretations surrounding Bell-type correlations.

3. Bell-type Correlations and their Realist Interpretation.

The violation of Bell's inequality invokes deep and important philosophical problems. According to A. Fine and Van Fraassen, it poses a significant threat to realism. Bas van Fraassen has offered an elegant account of this threat to realism.[16] Arthur Fine criticizes realism by arguing that Bell-type correlations do not need to be explained.[17]

Fine goes further in that he claims that the death of realism has been hastened by the debates over the interpretation of quantum

15) J. Jarrett, 1989, 77.
16) B. van Fraassen, 1982.
17) A. Fine, 1989.

theory, where Bohr's nonrealist philosophy was seen to win out over Einstein's passionate realism.[18]

Van Fraassen's critique of realism based upon interpreting Bell type correlations in his paper, "The Charybdis of realism: Epistemological implications of Bell's Inequality," is elegant and powerful. The point of his argument is as follows: first, he formulates a thesis that the realist subscribes to.

He raises a question, "*How is reasonable expectation about future events possible?*"[19] The realist's answer to this question is "*Reasonable expectation of future events is possible only on the basis of some understanding of (or reasonable certainty about) causal mechanisms that produce those events.*"[20] Van Fraassen calls realism of the above sort 'epistemic realism'.

Second, according to van Fraassen, there is a correlation between a pair of events we can expect to happen. The realist should find the underlying causal mechanism, a common cause for explaining the correlations. Suppose there is a correlation between the two (sorts of) events A and B, such as lung cancer and heavy smoking. Let Z represent a common cause for the two events A and B, and assume that Z is in the past of A and B. We will have, $P(A\&B / Z=x) = P(A/ Z=x).P(B/Z=x)$ for all values x of that quantity.[21]

Third, van Fraassen describes a conceivable phenomenon, the Bell-type correlation. However, he argues that no common cause can exist for the correlation. He concludes, therefore, that epistemic realism is false because there is not an adequate causal explanation for EPR-correlation. And he proposes an alternative.

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18) A. Fine 1984, 150.
19) B. van Fraassen, 1982, 98.
20) *Ibid.*.
21) *Ibid.*, 100.

> Assuming (as we surely all agree) that it is reasonable to base one's expectations on well-supported scientific theories, we are reasonable to expect the persistence, whenever the relevant conditions obtain, of the correlations predicted by such theories.[22]

Does this argument sound all right? Is epistemic realism wrong? I think there are various ways to defend realism and the causal explanation of EPR-correlation from van Fraassen's argument. Here I will discuss a few such ways. First of all, one might reply that van Fraassen's formulation of realism is problematic. For example, his epistemic realism is not the best version of realism but an inappropriately narrow realism and what van Fraassen proves is only that the epistemic realism which he formulates is wrong. If so, van Fraassen's argument is not a significant threat to realism. In my view, epistemic realism is approximately the same as, or a very similar version of causal and explanatory realism which I think is a very important version of realism. Although epistemological realism may not be the best version of realism, van Fraassen's critique of epistemic realism is neverthless a significant attack on causal and explanatory realism. Therefore, especially for those who want to keep causal explanation in realist sense, van Frassen's critique should be answered anyway.

Second, one might claim that the application of Reichenbach's common cause model to EPR correlation is not adequate. Salmon and others[23] argue that Reichenbach's principle can not apply to all types of common cause.

M. Readhead tries to resolve the problem of EPR type correlation through clarifying the concept of causal relation more rigorously.

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22) *Ibid.*, 108-109.

23) Salmon, 1984, N. Cartwright,1988, M. Readhead, 1987, 1989, 145-151.

Readhead has proposed a condition called 'robustness' which, he argues, a relation must satisfy in order to be causal.[24] With this condition of 'robustness', he argues that EPR-type correlations are not the result of common cause associated with the source of the particle pairs which feature in the two events. Using the same robustness condition as Redhead, Andrew Elby argues that we cannot explain the EPR correlations causally unless we adopt a non-local hidden variable theory.[25] These considerations regarding robustness provide a very powerful argument against causal explanation for the Bell-type correlation.

Third, one might claim that quantum mechanics itself yields an explanation of these correlations which may with some justification be classified as causal.[26] Here one would appeal to the ontology of the quantum world to resolve the problem of non-locality in Bell-type correlations. According to this view, the inapplicability of the common-cause principle to EPR correlations is not due to the falsity of epistemic realism but due to the falsity of our preconception that the characteristics of composite particle systems can be reduced to the conjunction of separable properties of parts of the whole system.[27] I am going to advocate this holistic argument. The point of the objection to epistemic realism by the second line of argument above is this: in order to explain the entailment of a spin at the left by a spin at the right causally, we have to acknowledge a causal agent which has superluminal velocity. This account is incompatible with the requirement of relativity theory that there can be no direct causal connection between the two space-like separated events. Therefore we

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24) M. Readhead, 1987, 1989.
25) A. Elby, 1992.
26) R. Healy, 1992, 291.
27) R. Healey, 1989, Miller, 1987, 515-603, P. Teller, 1989, 208-223.

must reject any causal account for explaining Bell-type correlations, and epistemic realism is wrong.

I think there are two premises underlying this argument. One is that the spatio-temporally separated events always have separable states. The other is that causation is interpreted in terms of some kind of signal transfer between the two events. These two premises are related in some sense. In realist view of causation, causation cannot be identified with something describable in non-causal terms. For example, neither the regularity theory nor the energy transfer theory is sufficient to define causation. Therefore the rejection of causal explanation based upon the signal account of causation as signal (energy) transfer is not adequate.

How about the first premise? The spatio-temporal separation principle(separability principle for short) is the fundamental ontological principle governing the individuation of physical systems and their associated states in classical physics.

> It asserts that the contents of any two regions of space-time separated by a nonvanishing spatio-temporal interval constitute separable physical systems, in the sense that (1) each possesses its own, distinct physical state, and (2) the joint state of the two systems is wholly determined by these separate states.[28]

But in a Bell-type experimental context, violation of Jarrett's completeness condition is the evidence that epistemic realism is not wrong. So we don't need to adopt the superluminal signal to explain the correlation and to adopt an instrumental interpretation. This strategy seems good. But in order to defend a realist interpretation we should explain the causation between the two non-separable events.

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28) D. Howard, 1989, 225-6.

How can we explain the encounter of the failure of outcome independence, or Jarrett's completeness condition in the Bell-type context? I think there are two ways of explaining the failure of outcome-independence. One is to deny particularism, keeping causal relation between the two events. The other is to claim that there need be no explanation for such correlations like Fine's argument.

Fine argues as follows: Supposing that we have a pair of separated objects, each having such an objective probability for a certain display property and the pair of objects display an objective probability for correlation, we can regard the system as having a disposition to manifest their display properties in a correlated way, without benefit of any common cause or directed causal chain. In this case, why should this be any more mysterious than objective, undetermined chance behavior of the individual objects? So Fine claims that we have no reason to explain it and such system is just 'random harmony devices'.

I think this is wrong. We can arrange the Bell-type experimental system in various ways with the objects we choose in different ways under different environments. But the correlation appears. If these strange and very regular cases do not need to be explained, which phenomena in the world are we asked to explain? There had to be some explanation, some mechanism which could account for the coordination.[29] I think Fine's claim is to beg the question or cost too much sacrifices, so that a lot of physical phenomena which need explantion in normal view, slip away into random phenomena.

If Fine's response to the Bell-type correlation is not adequate, the way we have to choose without going into instrumentalism is to deny particularism. If the particularistic world view is wrong, there is some

29) *Ibid.*, 222.

sort of connectedness between the two spacelike seperated events. What is this connectedness? There are many names for this connectedness: 'quantum connectedness', 'passion-at-a-distance'[30], 'incompleteness'[31]. This nonaccidental correlation needs explanation.

In my view, there are two ways of interpreting violations of completeness or outcome independence realistically. One way is to adopt some kind of holism as an ontology of the world. The other is to acknowledge weak non-causal connections and to pursue what they are.

Bell-type correlations are physical relations which are proved by the experiments. The latter way does not seem to be appropriate since there are no non-causal connections which affect an object physically in realistic perspectives.

Through relativity theory, what we find is that causal signal should not exceed light velocity. If the Bell-type correlation is causal relation in the world, we should admit a kind of superluminal cause violating relativistic theory. This is the dilema of the realist interpretation as we mentioned earlier. The relativistic theory assumes particularistic ontology as domain. I think the insistance to keep relativistic causality is the legacy of Humean concept of causation, i.e. contiguity. Once we reject particularism, we can adopt the notion of a new concept of cause, an extra-relativistic cause[32] including superluminal cause without violating relativity. Therefore for holistic ontology, there is no reason we have to keep relativistic cause only.

> In the realist quantum physics,... real properties of systems, described using distinctively quantum physical means are all that

30) Shimony's term.

31) Jarrett's term.

32) The term 'extra-relativistic cause' I got from a discussion with Jon Jarrett

> influences events within the systems. The mistake in the events hypothesis is the assumption that events and their separable properties are the cause of the events; rather, properties of systems, typically superpositions irreducible to separable properties of parts, govern the cause of events.[33]

If we adopt non-separable properties of system, we may also adopt some kind of system cause, causal holism. To clarify holistic ontology, we need to discuss, non-separability, incompletness in detail. Through these discussions, we can give good justification of interpreting the Bell-type correlation realistically. In the following sections, I discuss non-separability, incompleteness related with holism and causal holism .

4. Holism, Incompleteness, and Non-separability

Howard proposes the separability principle and the possibilities for a nonseparate ontology.

> The separability principle asserts that each of the two previously interacting systems in the Bell experiments possesses its own physical states, the joint state being the product of separate states.[34]

The Bell-type experimement shows that the composite system is non-separable because the separation principles are violated. The components of the composite system are connected with each other in the sense that neither of them has a state of its own. Yet there is a well defined state of the composite system. This non-separability thesis

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33) R. Miller, 1987, 592.

34) D. Howard, 1989, 230.

requires us to adopt a certain holistic ontology instead of a 'particularistic' ontology. I think there are some fine distinction between non-separability and incompleteness conditions for holistic ontology.

Jarrett interprets the outcome-independence condition as a 'completeness' condition, and he discusses this completeness condition.[35] His term 'incompleteness' (expressing the violation of completeness) is not just a name but is indicative of some important feature of the world.

> The motivation for the completeness condition as a constraint on theories of Bell-type phenomena lies in the great appeal of common cause accounts of correlations. Complete state descriptions (while by no means necessarily deterministic) are to be regarded as including all causally relevant factors contributing to the outcomes of measurement events.[36]

By classical intuition, the violation of outcome-independence can be naturally interpreted as an omission of causally relevant factors from the state descriptions; state descriptions were not sufficiently fine grained; the correlation of measurement outcomes would have to be explained in terms of some unknown common causal factor, all of which are to be included (at least implicitly) in those state descriptions worthy of this name 'complete'.[37]

In the classical viewpoint, the fact that the state description does not contain all the causally relevant factors is an indication that the theory (or the state description) is incomplete. Incompleteness in this sense means that theory is defective because the world includes all the

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35) J. Jarrett, 1989.

36) J. Jarrett, unpublished manuscript.

37) *Ibid.*.

causally relevant factors but theory does not describe all of them. EPR just assumes that the world should contain all the causally relevant factors for the scientific phenomena within the world. But quantum mechanics is not capable of describing all of them in the above 'classical' way. So quantum mechanics is incomplete both in Jarrett's sense and in the sense intended by EPR.

EPR's incompleteness in this sense suggests that quantum mechanics is defective. According to the empirical evidence which they had at that time, we can understand why EPR employed such an unproven assumption. EPR simply didn't have available evidence we have today (from the results of the Bell-type experiment that empirical adequacy might demand such a theory (i.e. one that violates completeness).[38] If EPR had the results of Bell-type experiments, they would not have argued that some causal factor is missing in quantum mechanics, and hence that quantum mechanics is incomplete in the sense of defectiveness. The evidence we now have suggests that quantum mechanics is incomplete in Jarrett's sense, but for all we know, quantum mechanics might still give a full account of all causally relevant factors.

The violation of completeness (the outcome independence) in Bell-type experiments reflects genuine features of the world. So no complete theory is empirically adequate. There is no implicit requirement that an incomplete theory be completeable by supplementation of the original state descriptions so as to satisfy Jarrett's completenss condition.[39] "The incompleteness..., or whatever we choose to call it... might simply be an accurate reflection of some genuine characteristic of the non-classical world."[40] So Jarrett's

38) *Ibid.*.
39) *Ibid.*.
40) *Ibid.*.

completeness condition captures EPR's intention and reflects some genuine feature of the world itself.

The world is such that the state descriptions of any empirically adequate theory that *does* give a full account of all causally relevant factors will not screen off Bell-type correlations (i.e., the theory will violate the completeness condition).[41]

Howard's giving up separability is not enough and completeness must go as well.[42] When completeness is satisfied, the probabilities to be associated with state descriptions representing the two sub-systems are as follows :

$$P_{\lambda_A}(x/i,j) = \Sigma_y P_\lambda(x,y/i,j) \;;\; P_{\lambda_B}(y/i,j) = \Sigma_x P_\lambda(x,y/i,j) \quad \text{..... (1)}$$

for all values of λ, x, y, i and j.

Here, λ is to be regarded as 'separable' into two components λ_A and λ_B representing sub-systems A and B respectively. We can draw a distinction between (i) separability of the composite system state description and (ii) separability of the composite system itself.[43]

On the basis of considerations such as Howard's, Jarrett regards (i) as a legitimate characterization of the completeness condition and (ii) as a stronger constraint than (i). A state description very well might separate in accordance with (i), even though ii) were violated. What is the separability of the composite system itself? Instead of a fully general definition for separability of a composite system itself, Jarrett recommends a rough characterization of a necessary condition:

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41) *Ibid.*.
42) *Ibid.*.
43) *Ibid.*.

> Let λ represent the composite system and let λ_A and λ_B represent sub-systems A and B respectively. For every fundamental property-type Q that the theory posits as well defined for the composite system, Q is also well defined for both A and B. Moreover, the relationship between Q and λ is relavantly similar to both the one between Q and λ_A and the one between Q and λ_B.[44]

I agree with Jarrett that the separability of the composite state description and the separability of the composite system itself should be regarded as logically independent. Although Howard argues that equation (1) is a criterion of the separability principle and the probabilities we get from the Bell-type experiment satisfy Howard's separability criterion, the separability of the composite system itself is left still untouched. Completeness may be seen as the separability of the composite system state description, a constraint that is weeker than the separability of the composite system itself.[45] Therefore, there is a possibility that completeness is not violated even though separability is violated. From this we can conclude that the world satisfying non-separbility is less holistic than the world satisfying incompletness.

Before closing this section, let's discuss the background and significance of separability in more detail.

In my view, separability is related to individuation. According to Einstein, the separability principle is fundamental to field theories. Einstein argued that the separability principle is necessary because "without such an assumption of mutually independent existence (the "being-thus") of spatially distant things....physical thought in the sense familiar to us would not be possible. Nor does one see how physical

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44) *Ibid.*.

45) Jarrett, unpublished manuscript.

laws could be formulated and tested without such a clean separation"[46]

I think Einstein's claim of clean separation implies that without individuation of an object we cannot investigate the system, so separability is the objective criterion of individuation. Without individuation, how do we investigate the whole system which has parts? This question seems to be obviously right. And nobody seems to deny this. There are, however, some problems in Einstein's claim that needs to be answered. If separability is so important to physics and the objective criterion of individuation, is it due to convention? Do we need individuation prior to investigating the system? If so, why? Is separability the only imaginable or conceivable objective criterion? Einstein did not say that separability is the only *possible* objective criterion for individuation, but that it is the only *imaginable* or *conceivable* objective criterion. Einstein said, "I do not see how one is supposed to divide up the world objectively so that one can make statements about the parts."[47]

This separability thesis can be traced to the Greek atomist tradition which derives the following three doctrines: the Cartesian and Newtonian conclusion that only the 'numerical' or 'mathematical' properties of physical bodies count as objective, primary qualities; the doctrine of the divisibility of matter; and the view that 'spaces' between atoms must be filled continuously by something capable of mediating interactions.[48]

Criticizing the three doctrines, Leibniz argued from the relational doctrine of space that position has no absolute significance and thus cannot serve as the ground for distinguishing physical systems. "All things which are different must be distinguished in some way, and in

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46) D. Howard, 1989, 240. This is the translation of Einstein (1943, 321)
47) *Ibid.*,243.
48) *Ibid.*.

the case of real things, position alone is not a sufficient means of distinction."[49] Einstein inherits this tradition, but he takes the spatio-temporal interval as an objective ground for individuation since it is a relativistic invariant. "The metric interval being the only invariant among the geometrical properties, and hence the only objective property, means that it is the only candidate as a ground for individuation."[50] As Einstein argues, if we do not accept the metric interval as a ground of individuation, we do not see how one is supposed to divide up the world objectively so that one can make statements about the parts; individuation is a necessary condition prior to investigating nature. This appears to be obviously true, but it is not yet proven as true that the metric interval is the ground for individuation. Individuation need not be given prior to investigation. There is no necessary reason for that. The priority of individuation depends upon empirical science and nature. We may find the law governing the whole system or the descriptions of the system properties which are not reducible to the properties of the parts of the system. From these descriptions of the system properties, we can derive the properties of parts into which the system is individuated based upon the metric interval as the criterion of individuation. The distinction between the system properties and the properties of the individuated object can be drawn by scientific theory. We do not have *a priori* reason to disregard the holistic concept of cause, system cause or causal holism. Quantum mechanics implies it.

5. Causal holism

49) *Ibid.*, 243-244.
50) *Ibid.*, 244.

Suppose a system composed of two subsystems. By the criterion of the metric interval, we can individuate the system into its parts. Let's assume that we disturb one subsystem or result in an individual event in one part and this event in one subsystem causes an event in a spatio-temporally separated part. If the interval between the two events is space-like, how is causation possible? If causation is interpreted as causal signal propagating from one part of the system to another part of the system or (direct) causal connection, it's impossible. I think this idea of cause presupposes a certain particularistic ontology or parts of the doctrine that causation must be explicated in term of some kind of signal (or energy) transfer. In my view, both assumptions are false. Causation need not necessarily be signal propagation between the cause and the effect. This signal propagation is the legacy of one of Hume's concepts of cause, 'contiguity'. If we adopt the nonHumean causation giving up 'contiguity', we can relax the constraint of signal propagation as a necessary condition of causation, and we get a broader concept of causation which gives us room for causal holism.

Prior to investigating causal holism, let's define what holistic system is, although very rough. The broad and popular concept of holism, though vague, is shown in the following sentence, "the whole is more than the sum of the parts." In this sentence, the main aspect of the concept of holism is emphasized on the emergent properties which are neither determined by, nor supervened on the dynamical properties of its component systems.

There is another concept of holism, which is well expressed in the sentence "the separate parts are not distinct ones, but they are one as a whole." Non-locality or non-separability is a main aspect of this concept. Of course this non-seperability is an emergent property. It's logically possible that a system has emergent properties without having non-locality. Although the two concepts are not equivalent, the holism

of second kind is a subset of first kind of holism. The first kind is a necessary condition on the second kind of holism. The emergent properties come from 'relations' or 'relational properties' which are neither determined by, nor supervened on the entity properties of its component systems. Then, how can we distinguish between relational properties which have or generate emergent properties and those which can not generate them. In order to discuss these problems, I think another long paper is needed.

Here I confine myself to the second kind of holism the main aspect of which is non-locality or non-separability. Suppose that S represents a composite system and Q represents a dynamical property of S. And each of A and B represents spatio-temporally separate parts of system S respectively. A and B are called non-locally separate parts or non-separable parts with respect to property Q if and only if the measurement of property Q in A(or B) affects the measurement of property Q in B(or A) superluminally. The system S is called holistic if and only if there is at least one pair of the non-separable parts or non-locally separable parts.

System S is holistic in n-degree, if and only if there are n pairs of non-separable parts(or connected parts) in system S. Using this definition of holism, we can define the particularistic system as holistic system in 0-degree. In this view, the particularistic ontology is a limit of holistic ontology or an instance of holistic ontology. In this definition, the meaning that "the system is just one as a whole" can be called infinite-degree holistic. When we arrange the worlds according to the degree of holistic ontology or the degree of connection, or degree of holism(we may call whatever), there are some spectrums. The particularistic world lies at one end of the spectrum and the world as whole(in extreme sense) lies at the opposite end of the spectrum. Between the two, we may find many holisic worlds in the spectrum

through more developed science and philosophy.

Suppose that A1 and A2 are holistic worlds. A1 is less holistic than A2 if and only if A2 has more degrees of holism than A2 or there is at least holistic condition which A1 satisfies but A2 does not satisfy.

If the world is incomplete ((in Jarrett's sense), it is non-separable (Howard's sense). But non-separable world is not always incomplete as we have seen above. This means that in view of degree of holism, incomplete world is more holistic. Now we can arrange them as follows: the world as a whole, the incomplete world(in Jarrett's sense), non-separable world(Howard's sense), particularistic world. There may be finer distinction among the holistic worlds. A holistic process is then a process in which non-separable parts are involved. Causal holism acknowledges the holistic process as cause of the event.

Let's consider a system in EPR-Bell-Bohm experimental context. Suppose that A $\oplus$ B is a whole (composite) system in an EPR-Bohm-Bell experimental set-up. A and B are parts of the composite system. Let E_a (E_b) be an event consisting of the selection and performance of a measurement of a spin-component of A(B) along some axis during a joint measurement on both particles. Prior to any measurement interaction, neither A nor B has any definite spin-component. The composite system A $\oplus$ B, being in the singlet quantum state, has many irreducible spin properties. When we define E_s as the state of the composite system, E_a is the measurement of the particle in the A wing and E_b the measurement of the particle in the B wing. In Bell type experiment, E_a affects the change of E_b, and without E_a no change of E_b occurs. So one might think that E_a obviously directly influences E_b. It's wrong. If E_a is a cause of some change of E_b, we can find the causal chains which lead to the change of E_b from E_a. It's impossible because the influence is superluminal. Holistic cause is not exhausted in terms of component causes. E_a influences E_b through the whole system.

Let's consider the Salmon's causal process. I think Reichenbach's and Salmon's mark transmission, which is a criterion distinguishing causal process from pseudo-process, is valid only in particularistic system. So this holistic cause is compatible with Salmon.

Let's take a look at the famous two-slit system in quantum mechanics. Suppose the slits are called A and B, respectively. Suppose that the emitted electrons from the electron source pass through the two slits, arriving at the screen behind the two slits. Let us also assume that no individual electron passes both slits simultaneously. Each electron passes only one slit each time. The two slits are separated and superluminal effects from one slit to the other are prohibited by relativity theory. In the classical viewpoint presupposing particulaism, if there is no possibility of interaction between the two slits, the resulting two-slit distribution pattern is a superposition of the results in the two cases, 'slit A open and slit B closed', and 'slit A closed and slit B open'. But the observed results are different from expected. Why? For holism, superposition of the results in the two cases is not equivalent to the results of the case, 'both slits open'.

From the 'whole system' point of view, the division and combination of the system to understand it, which is the normal way in the viewpoint of particularism, is different from the way that deals with the holistic world. It may lose the system properties which cannot be exhausted by the properties of the parts. The change in part of the system should be viewed from the whole system. From this, it follows that we should not consider that a change in a part of a system directly affects other parts of the system. Once there is some change in one part, it influences other parts of the system through the whole system. Similarly, in the context of EPR-Bell-Bohm experimental context, the measurement of the spin of the particle in the A-wing influences the outcome of the measurement of the spin of the particle in the

B-wing through the whole system.

Does the causal holism resolve the puzzle which the Bell-type phenomena have given us? The thing we have to be careful about is that just by extending the notion of cause to causal holism to preserve causal explanation we cannot say that we have given a causal explanation of the Bell-type phenomena. The worry is that we have fooled ourselves somehow. Maybe we have only tricked ourselves into thinking that now we understand something but still we don't until we have more of the story, more information, a deeper account. When we define E_s as the state of the composite system, E_a as the measurement of the particle in the A wing and E_b as the measurement of the particle in the B wing, the measurement of the spin of the particle in the A wing does not directly change the outcome of the measurement of the spin of the particle in the B wing. It changes the outcome of the measurement of the spin of the particle in the B wing through the whole system, or the sort of mechanism[51] of causal holism. This is a strong challenge to causal holism.

We can respond to this challenge as follows: According to realistic concept of causation, cause cannot be defined *a priori*. As science changes, the understanding of cause changes. The concept of cause of motion in Aristotle's theory is different from that of Newtonian mechanics. And from quantum mechanics, scientists now admit probabilistic cause. Likewise, confronted with the puzzling Bell-type phenomena, we find that our old concept of cause may not be sufficient. We adopt a new kind of cause, extra-relativistic cause without violating relativity to resolve the puzzle. Once we abandon the particularistic ontology, relativity theory is not necessarily incompatible

51) I don't like to use the word 'mechanism' because the word 'mechanism' always has a connotation of the old notion of cause. So, I use 'the sort of mechanism' instead of the word 'mechanism'.

with superluminal velocity (or cause). Of course, in present level of science and philosophy, we do not know what causal holism exactly looks like. The study of the details of causal holism is our future task for philosophy and science.

The world is connected in certain parts. So, to explain the phenomena of the connected part, non-separable region, we need the concept of extra-relativistic cause. In the other parts described by particularistic ontology, relativistic cause is used to explain the phenomena. As I mentioned above, the particularistic ontology is approximation or limit of holistic ontology, i.e. 0-degree holistic. So the particularistic world is a continuation of the holistic world. Likewise the two causes are not different kinds but the same kind in essence. There is some continuity between them.

In my view, Bell-type phenomena imply the possibility of holism and holistic cause in this world. The next project is to develop the model of causal holism. Once we get into the realm of holistic cause, what we need to do is to investigate the mechanism, nuts and bolts of holistic cause. This job cannot be achieved by philosophical analysis only. It can be achieved by the joint work of philosophy and empirical science. As physics is developed more, we can have more light on this subject.

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인과적 설명과 벨 타입 상관관계

김 유 신

벨 타잎 상관 관계는 인과적 설명 이론에 대한 크나큰 도전으로 생각하고 많은 비판이 있다. 이 논문에서는 벨타잎 실험 상황에서도 인과적 설명 이론이 타당하는 것을 보인다. 이를 위해 벨 타잎 상관관계를 실재론적으로 해석하고 세계에 대해 개별자 존재론보다는 전체론적인 존재론을 받아들인다. 인과 개념에서 상대론적 인과개념과 다른 인과전체론을 제안하여 벨타잎 상관관계도 인과적 설명이론이 적용된다고 옹호한다. 개별자 존재론은 전체론적 존재론의 한 특수한 형태라고 주장하고, 전체론은 스펙트럼을 가진다고 본다. 즉 세계의 존재론은 한 쪽 끝에 '전체로서 하나'라는 존재론이 있고, 다른 한 쪽 끝에는 개별자 존재론이 있다. 그 둘 사이에 자레의 불완전성을 만족하는 전체론적 세계와 하워드의 비분리성 원리를 만족하는 전체론적 세계가 있다고 제시한다.