COMMENTS

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I am grateful to the Parapsychology Foundation for enabling me to read in advance the text of most of the papers that are going to be presented at the Conference. I greatly regret that academic and other responsibilities have compelled me to present my paper *in absentia*. I am sure that I am losing something, for this is an immensely interesting Conference. Distinguished scientists, with varied attainments and varied approaches, have agreed to discuss the perplexities of parapsychology as well as of quantum physics. I hope that the following comments of mine, sent in advance of the Conference, will serve to promote friendly and stimulating exchanges.

Since the "quantum logic" approach seems to be characteristic only of my paper, I shall offer a few additional remarks which may bring the relevant problems into sharp focus. Classical physics used a probability defined as a real function on a Boolean lattice. Boolean algebra underlies a great deal of current computer logic, various proposed hypothetical neural networks, and axiomatized information theory over wide ranges. In the classical framework, events can be thought of as connected by the logical constants, "and," "or," "if-then." Propositions about these events can generate a Boolean logic under the operations of disjunction, conjunction, and negation.

It has been suggested by von Weizsäcker and Satosi Watanabe that a logic for contingent events may not perhaps be quite Boolean. Aristotle held that a statement about the future could not be given a definite truth-value. We may have conceivably a semantics with truth-value gaps. This is not what I mean in speaking of non-Boolean departures in quantum mechanics as well as in parapsychology.

I share with Professor Jeffrey Bub a more radical non-Boolean approach to the problem of quantum mechanical measurement. The Kochen-Specker definition of "compatible magnitudes" in quantum mechanics suggests that the set of idempotent magnitudes forms a partial algebra. For two "compatible" magnitudes, say A_1 and A_2, we have, given a third magnitude B,

$$p_W[\mathrm{val}(A_1) \in S] = p_W[\mathrm{val}(B) \in g_1^{-1}(S)]$$

and

$$p_W[\mathrm{val}(A_2) \in S] = p_W[\mathrm{val}(B) \in g_2^{-1}(S)],$$

for every statistical state W and every Borel set S. The required partial algebra is a partially ordered set with a reflexive and symmetric (but not necessarily transitive) relation termed "compatibility" such that each maximal compatible subset is a Boolean algebra. The partial algebra of quantum logic may be pictured as "pasted together" from its maximal Boolean subalgebras. Professor Bub maintains (and I completely agree with him on this point) that the peculiarity of quantum mechanics, as an intrinsically statistical or "complete" theory, lies in the irresistible conclusion that the logical space of micro-events is not Boolean at all. The 1-1 correspondence, of which textbooks speak, is between projective operators and subspaces in the algebra. If classical logic fails in quantum mechanics, I hold that it collapses in the parapsychological domain. I agree with R. D. Horst [J. Math. Phys. **11,** 851 (1970)] that non-Boolean extensions of logic to real events signify that there are systems for which the acquisition of knowledge has become highly problematic. Adapting a dictum of E. P. Wigner, I shall say that the old-fashioned "material reality" behind the scenes has become more old-fashioned than ever. I shall examine, from my point of view, the various approaches unfolded by my fellow participants in the Conference.

Professor J. H. M. Whiteman's paper strikes sympathetic chords in me; for it has its undeniable kinship not only with Eddington's fundamental theory of E-spaces but also with the inscrutable scheme of *kālas* sketched in the Indian *Upanishads*. I believe that Professor Whiteman has given a deeper rendering of what he has said on other occasions. He is to be congratulated on having produced so recondite a paper. Neither quantum physics nor parapsychology is kindergarten stuff. As an Indian metaphysician, I would confront Professor Whiteman with the Upanishadic challenge. The *Ātman*, the theme of the higher knowledge or *Parā Vidya*, stands over and against *all* mathematical systems with an almost super-Gödelian flourish. "By what means can the Knower be known?" All means of knowing are but the lower knowledge, the *aparā vidya*.

It is significant that so resolute a thinker as Professor Mandel Sachs, in exploring some generalized quantum field theories, encounters the Gödelian paradox, though he tries to make light of it. One cannot start with a *complete* logico-mathematical system, because the *thinker* or the investigator must have the freedom to decide the how, the where, and the when of it. The truth of *any* theory can be defined only on the pain of inconsistency, if Gödel's Second Incompleteness Theorem is taken in a comprehensive sense. Recent work, both in logic and in the mathematics of von Neumann's self-reproducing automata, has shown that, when a system exceeds a certain level of complexity, the description of the system has to be of even higher order of complexity. The Upanishadic maze is ever round us. Gödel's undecidability implies that, in the Platonic world of ideal mathematical objects, there are many, in fact there *must be* infinitely many, objects that satisfy the axioms of the real-number line, since each undecidable theorem about the line may be true in one model and false in another.

These metaphysical and mystical difficulties apart, I have three misgivings about Professor Whiteman's program. (1) It is, of course, a fundamental, and not only a unified, theory that he is hankering after. But can we afford to be overoptimistic just now even about a generalized field theory, either in particle or quantum physics? Gell-Mann's "eightfold" way of understanding the fundamental brickwork of the atomic world was a notable achievement. But complete and exact prediction of symmetries, especially in experimental work, still eludes us. Appeals to "quark" models do not suffice. There has been, again, a great deal of recent probing of generalized and nonlinear quantum field theories. Komar starts with a nonlinear model and hopes to break the superposition principle of quantum mechanics. But the Stern-Gerlach, the Wu-Shaknov, and the electron capture experiments do not spell any failure of superposition. Attempts have been made to construct fields with twistors which are generalizations of spinors. Yet the fate of these theories is uncertain. (2) It seems to me that Professor Whiteman makes no significant advance over the usual "Copenhagen" interpretation by suggesting that the "state vector" in quantum mechanics is "potentiality" rather than specific objectified structure. In my opinion, this does not solve either the logical or the statistical problem of "completeness." (3) I doubt whether the hypothesis of a "precognized event in cosmic time '75" can take care of precognition in all its experimental ranges. Can a rodent, for instance, have access to a "projected event in time '75" as "manifested in a thought-image sphere"? I agree with Professor Whiteman that what he calls "physicalistic reductionism" flounders dreadfully in parapsychology and perhaps in quantum mechanics, too. Yet I doubt whether mystical hypotheses can guide experimental parapsychology in the new realms it is mapping out for itself, e.g., animal psi. I do not deny that parts of Professor Whiteman's paper may be highly pertinent to the more complex spontaneous phenomena of parapsychology. Whether all the spaces and times hypothesized by him exist or not, they may describe the phenomenology of some ill-understood "out-of-the-body" experiences.

Professor Gerald Feinberg's paper is, in many ways, quite a counterblast to Professor Whiteman's mathematical and mystical disquisitions. Professor Feinberg is definitely of the opinion that we have to seek naturalistic, and even materialistic, solutions of parapsychological riddles. His theory boldly assumes "advanced effects" in the universe which are not confined to brains or living beings. Precognition as "memory of the future" is a natural phenomenon. I shall wait, of course, the outcome of the experiments to which Professor Feinberg refers. All major psi phenomena investigated over decades, so far as I know, are exclusively biocentered. There seems little promise of ESP or PK in the most sophisticated computers or androids.

Although I cannot object *a priori* to Feinberg's theory of "advanced effects," I have a suspicion that the theory is apt to run into the difficulties besetting the Wheeler-Feynman "absorber theory" of radiation in the cosmological context. Maxwell's electromagnetic equations are completely time-symmetric and the Wheeler-Feynman theory of interparticle action posits "advanced" (future) and "retarded" (past) fields. The two are inextricably mingled. The usual predominance of "retarded fields" (that is, the canceling out of "future absorbers"), Wheeler and Feynman attempted to explain by assuming that (a) time asymmetry is initially present and (b) persists on a purely statistical basis. J. E. Hogarth [Proc. Royal Soc., London, Ser. A, **267,** 365–383 (1962)] in advancing some "cosmological considerations of the absorber theory of radiation," showed that the second assumption made by Wheeler and Feynman was inconsistent with any realistic cosmological absorber theory of radiation. He found that the "absorber," as viewed along the *future* branch of a light cone, may be fundamentally different from the "absorber," as viewed along the *past* branch of the *same* cone. Hoyle and Narlikar [Proc. Royal Soc., London, Ser. A, **277,** 1–23 (1964)] derived the same result by generalizing the Schwarzschild-Tetrode-Fokker Action Principle for a Riemannian space. They insist that the electromagnetic arrow of time follows the thermodynamic and cosmological arrows. More recently, Hoyle and Narlikar [Nature **219** (1968)] reinforced their conclusion by constructing a generalized cosmological model of an expanding universe, with the Fokker interaction term, Hubble's constant, and Robertson-Walker elements, all in it. Can we be sure that Professor Feinberg's model of "advanced effects" will escape these cosmological consequences? He has little to say about the impact of cosmological models on his theory.

Perhaps Professor Firsoff should tell us more about these theories. There could be, I suppose, "time reversals" in a "Black Hole" or other cosmological curiosities. Their relevance to parapsychology is disputable. Nor, in my opinion, will multiply connected topologies of space-time, with "worm holes" and what not, crack the riddle of precognition. Baierlein, Sharp, and Wheeler showed, in the *Physical Review* in 1962, that "three dimensionality" could itself be a carrier of information about time. Lebedev and Levitin [Information and Control **9,** 1–22 (1966)] cogently extended Brillouin's negentropy concept to the problem of "information transmission" in an electromagnetic field involving both "wide-band" and "narrow-band" channels. Brillouin has pointed out that a corollary of the negentropic theory is that the *future* cannot be informationally *recorded*.

In the *Journal of Parapsychology* for March 1974, I have objected to tachyons or superliminal particles as carriers of information. To signal into the past, superliminal signals must be available. There has been some recent discussion [Nature: Physical Science **235** and **236** (1972)] of tachyons in relation to Čerenkov radiation. Quite a few authorities (among others, W. B. Polnick, G. A. Benford, and F. A. E. Pirani) maintain that superliminal signals lead to inevitable and irremovable contradictions in the present framework of physical theories. All this does not prove that Professor Feinberg's theories are mistaken. Parapsychologists can only watch for experimental demonstration of "advanced effects" in physical systems.

Professor O. Costa de Beauregard's work on time asymmetry is monumental and of the greatest significance for the philosophy of science. Unfortunately, we cannot go far with his concept of information as negentropy in parapsychology. I hope I have explained that the issues, according to me, are about the very foundations of information theory as well as of probability theory. Why *must* psi phenomena fit into the current edifice? Professor Beauregard's suggestion that "information can be organized" as a "sink of advanced waves" hinges, I think, on his other suggestion that the "collapse of the wave packet" is brought about by "an act of consciousness on the observer's part." I shall presently examine this theory which is propounded in a more systematic and thoroughgoing fashion by Professor E. H. Walker.

With many of Professor Firsoff's admonitions I find myself in agreement. I grant cheerfully that cyberneticists limit themselves arbitrarily to propositions which can be handled with a binary yes-or-no rule. I think that the restriction is not in the mathematics. With an open-or-closed electrical circuit, we have a binary mechanism; its "yes-no" is homomorphic with the "true-false" (T-F) of a two-valued logic. There could be, I suppose, a generalization of a two-way switch into a many-way switch. The entire calculus of a many-valued logic can be generated by iterations of a simple operation yielding the basic "not," "and," "or." Professor Firsoff pleads for some emancipation from Aristotle's classical law of excluded middle (*tertium non datur*) dictating a rigid choice between two exclusive alternatives. I suspect that the muddles of quantum mechanics lie deeper. Neither Reichenbach's three-valued logic nor von Weizsäcker's many-valued logic suffices here. Material implication and strict implication in quantum mechanics both create difficulties. Professor Van Fraassen's "anti-Copenhagen" interpretation turns on a most involved modal logic. Suppose "necessarily A" is symbolized by $\Box A$, and "A strictly implies B" by $A \rightarrow B$, then Van Fraassen represents the latter formula as equivalent to $|\Box(A \supset B)|$, where the horseshoe sign is material implication. The interpretation of the modal system, however, turns out to be statistical. The "quantum state" is interpreted as an ensemble, in the fashion preferred by Margenau, Ballentine, and others.

Dr. E. H. Walker sets out from a "Copenhagen interpretation" of quantum mechanics and puts forward the hypothesis that the "collapse of the wave packet" is brought about by consciousness, a suggestion preferred also by Professor Beauregard. For Dr. Walker, the "hidden variable" of quantum mechanics is consciousness. In view of the Bell-Wigner criticism of "local" theories of "hidden variables," consciousness as a "hidden variable" is interpreted as "nonlocal." It may be remembered that Professor Bohm, in his 1952 version of the "hidden variable" theory, had changed the distribution of the "hidden variables" according to the kind of measurement. More recently, to circumvent criticism, he has proposed to introduce the concept of "wholeness" into quantum physics. "Wholeness" is the denial of disjunction. I do not know how far Professor Walker would draw upon such statements.

To turn to criticism. I subscribe to Professor Bub's recent contention [*Foundations of Physics*, Vol. 3, No. 1 (1973)] that all "hidden variables" theories are, in effect, attempts to "complete" quantum mechanics which would otherwise be an incomplete theory, according to the Einstein-Podolsky-Rosen paradox. All such attempts are implicitly committed to a Boolean framework regarded as adequate for microevents. For instance, tailoring the phase space probability measure to the relevant maximal Boolean algebra, in the logical space, is formally equivalent to introducing a fixed measure for each quantum statistical state and a different map associating phase space points with the truth-values of sentences for each maximal Boolean subspace. The Boolean interpretation sheds no light whatsoever on the partial algebra used in quantum mechanics. A phase space reconstruction, which seems to be entailed by "hidden variables," is, in principle, precluded if the logical space of microevents is non-Boolean. The nonexistence of dispersion-free probability measures on the statistical space of quantum physics means that it is impossible to embed the space in a Boolean algebra. It is, therefore, impossible to introduce a phase space and represent each physical magnitude by a real-valued Borel function on this space in such a way that each maximal compatible set of magnitudes is represented by a set of phase space functions which preserve the functional relations between the magnitudes.

The criticism is not obviated by Professor Walker's claim that his "hidden variable" is not a measurable magnitude, but consciousness. A phase space need not be a phase space in the sense that it is parametrized by generalized position and momentum. It can be a phase space in the sense that points of this space define two-valued probability measures. Professor Walker's "hidden variables" version of the "Copenhagen interpretation" is implicitly committed to the Boolean framework which, I maintain, fails to resolve the quantum anomalies, especially the accusation of incompleteness contained in the Einstein-Podolsky-Rosen paradox. Consciousness, as a "hidden variable" in the orthodox Copenhagen framework, is a *pis aller*.

Aside from the logical inadequacy, I find that the particular construction which Professor Walker puts on "consciousness" receives no unambiguous support from quantum mechanics. Unless I am mistaken, Dr. Walker seems to favor a monism and naturalism as thoroughgoing as that of Dr. Feinberg. We hear that the theory of "hidden variables" propounded "identifies consciousness with an ongoing quantum process in the brain." We are told later that there are no psi processes without a physical basis. Dr. Walker finds the current theory of information (reckoned in bits or nits) sufficient for his purposes. All this, in my opinion, fails to meet the paradox of "Wigner's friend." A little piece of crudely simplified symbolism, for which I claim no originality, will serve to bring out the point of the paradox. Wigner's view, it seems to me, can be formulated in two specific claims. First, the so-called quantum mechanical measurement is not complete until consciousness accomplishes the reduction of the wave packet. Second, consciousness plays a role vastly different from that of any inanimate apparatus.

Suppose a quantum physicist learns from his friend about a quantum mechanical measurement the friend has performed. The system of *friend + object* is *not* described by the classical wave function but only by an odd mixture. As Professor Jagdish Mehra, paraphrasing Wigner, remarks, the composite resulting state, *friend + object,* is given, say, either by the wave function $\psi_1 \times \phi_1$ with the probability $|\alpha|^2$, or by the wave function $\psi_2 \times \phi_2$ with the probability $|\beta|^2$. As a result of the interaction, quantum mechanics, in its present form, ceases to apply to a system with a conscious observer, because the final state requires a nonlinear description. It is, nevertheless, curious (as Professor Mehra notes) that there exists a transition from the state described by the classical quantum mechanical wave function,

$$\alpha(\psi_1 \times \phi_1) + \beta(\psi_2 \times \phi_2), \tag{1}$$

to the non-quantum-mechanical state described by the system of *friend + object*

$$(\psi_1 \times \phi_1) \text{ with probability } |\alpha|^2$$

and

$$(\psi_2 \times \phi_2) \text{ with probability } |\beta|^2. \tag{2}$$

The transition can be represented by a 2 × 2 matrix

$$\begin{pmatrix} |\alpha|^2 & \alpha\beta^* \cos\delta \\ \alpha^*\beta \cos\delta & |\beta|^2 \end{pmatrix}, \tag{3}$$

where the special parameter δ has been introduced. If one takes $\delta = 0$, then the orthodox quantum mechanical situation is obtained and the "statistical matrix" of Eq. (3) becomes singular. For $\delta = \frac{1}{2}\pi$, one obtains the non-quantum-mechanical mixture of Eq. (2). For intermediate values of δ, one has mixtures of the two states given by both Eqs. (1) and (2) with the probabilities

$$\tfrac{1}{2} \pm (\tfrac{1}{4} - |\alpha\beta| \sin^2 \delta)^{\frac{1}{2}}. \qquad (4)$$

Now the parameter δ does look like a new "hidden variable." Nonetheless, it is quite different from *all* the usual "hidden variables" discussed under that caption from von Neumann onwards. The new parameter δ relates *two quite different levels of description*, the quantum mechanical wave and the complete state including an observer regarded as a conscious being. Professor Whiteman's criticism of one-level reductionism would seem to apply to Dr. Walker's theory of consciousness as a "hidden variable," conceived entirely in the framework of orthodox quantum mechanics. The argument calculated to show that superposition is resolved by conscious or subconscious states in this framework fails to bring conviction. Wigner's theory of the role of consciousness in quantum mechanical measurement deserves to be considered as a valid alternative to Dr. Walker's version of the "hidden variable" theory. In his essay on "The Place of Consciousness in Modern Physics," in *Consciousness and Reality*, edited by C. Muses and A. M. Young (Outerbridge and Lazard, New York, 1972), Wigner claims that "from the point of view of quantum mechanics, the faculty [of self-awareness] is completely unexplained." In *Contemporary Physics*, Vol. II (International Atomic Energy Agency, Vienna, 1969), Wigner concludes that "quantum mechanics does not describe reality but only gives statistical correlations between subsequent observations. It does not even commit itself to a 'reality' that may be behind these observations in the way classical theory implies this. I am afraid this cannot be helped and only the future will tell us whether our fellow physicists will get used to this as they got used to the idea that there is no absolute time. The jump is much greater." I have drawn an analogous conclusion in my paper on quantum logical grounds.

I have taken quite some space discussing the logical and epistemological issues raised by Professor Walker's paper; for I feel that these issues are crucial for the Conference. Parapsychologists must meet the challenge of Professor Walker's naturalism constructed with quantum theoretical premises. The interpretation, in my judgment, does not unambiguously follow from the formalism of quantum theory. The issue is not merely one of empirical adequacy; it is one of logical adequacy. It is also one of adequacy in parapsychological theory. Whatever the plausibility of Dr. Walker's calculation of the physical forces involved in PK (parapsychologists must test his empirical constructs), I am afraid that he gets nowhere with precognition. If consciousness or subconsciousness is the "hidden variable" of quantum mechanics, how do we account for precognition in rodents? I addressed the question to Professor Whiteman, too. Dr. Walker's assertion that "hidden variables" are "space- and time-independent" does nothing to enlighten us about precognition in the framework of quantum mechanics. Time in quantum mechanics plays a dual role. It is represented by the topology of *c* numbers and also by a time-operator. If we demand that time be an observable, corresponding to a hypermaximal time-operator in a Hilbert space, then, for systems having a continuous energy spectrum with a lower limit, in the framework of the nonrelativistic theory, there must exist an upper limit of the energy, too. Moreover, the time-operator is not defined on the whole Hilbert space, but only on state functions satisfying a certain condition. Y. Aharonov and Bohm [Phys. Rev. **122,** No. 2, 1649–1658 (1961)], challenged the time-energy uncertainty relationship, $\Delta E \Delta t \gtrsim h$, of the Copenhagen interpretation. They argued that time, as a parameter in Schrödinger's equation, must commute with every operator of the observed system. They devised a *Gedankenexperiment* to show that energy can be measured in arbitrarily small times. The argument was criticized by V. A. Fock, but Aharonov and Bohm gave a rejoinder.

I have only appreciation for Dr. Helmut Schmidt's models. It is not a complete theory of psi that he is offering but a framework for the experimental work. I suggest that the stochastic model should be followed up by a construction of probability spaces appropriate to the experimental work, with an eye on entropic and information-theoretic concepts.

I cannot anticipate what Professor Bastin may have to say in his paper on combinatorial mathematics; I have not received a copy of it. I expect that his paper will supplement in a fruitful way some quantum-logical considerations. Can combinatorial methods establish a set of states sufficient for quantum mechanics but not strongly ordered? The axiom of sufficiency may not follow from the other quantum axioms.

I have read only popular accounts of the experiments at Stanford carried out by Dr. Harold Puthoff and Dr. Russell Targ, among others, with Uri Geller, the "man with electric power."

Their papers will be highly significant, I am sure, for a discussion of PK in relation to entropic concepts.

As participants in the Conference, we perhaps differ in our approaches to the foundations of quantum mechanics and parapsychology. But in such vexed and contentious domains, I think that agreement would be fatal to further research. Only criticism will make us aware of the limits of the hypotheses we are proposing. The mere admission of problems goes a long way. It required great courage and enterprise on the part of the Parapsychology Foundation to arrange this Conference.

POSTSCRIPT

I should like to add, in view of the emphasis laid by Professors Beauregard and Walker on information-theoretic concepts, that there is no known uncontroverted and linear extension of the current informational formulas to a generalized "uncertainty principle" applicable to *any* set of observables not simultaneously measurable with any arbitrarily desired degree of precision. In Information and Control **2,** 64–79 (1959), Roy Leipnik sets out from the sum of the entropies of two distributions related as the absolute squares of a Fourier transform pair, the minimum value of the sum being attainable for a Gaussian pair. Taking the Hirschman inequality in the form $L(\psi) \geq \log h$, Leipnik conjectures that

$$L(\psi) = -\int |\psi(x)|^2 \log |\psi(x)|^2 dx - \int |\phi(p)|^2 \log |\phi(p)|^2 dp,$$

where $\psi(x)$ and $\phi(p)$ are the wave functions in coordinate space and momentum space respectively. But the "joint entropy" in the derivation has a lower bound determined by a *nonlinear* minimal condition. A. S. Rubanov's attempt [Dokl. Akad. Nauk., USSR **7,** 594–597 (1963)] to extend Leipnik's result to the uncertainty $\Delta E \Delta t \geq h$ is most controversial, especially in view of the criticism of Aharonov and Bohm. Rubanov considers the standard deviation dE of the energy distribution $w(E)$ in relation to the decay half-time of a quasistationary state changing in time according to Schrödinger's equation satisfying the uncertainty formula $\Delta E\tau > \frac{1}{4}\pi h$. Rubanov, in fact, finds that ΔE is not at all a suitable measure of uncertainty and substitutes for it the entropy-like expressions

$$H_E = -\int w(E)\,\ln w(E)\;dE;$$

$$H_t = -\int \hat{w}(t)\,\ln \hat{w}(t)\;dt;$$

and

$$\hat{w}(t) = \left|\int w(E)e^{-iEt/\hbar}\;dE\right|^2.$$

It is courting an illusion to suppose that these controversial information-theoretic formulas can be extended to the resolution of a "wave packet" by a "conscious act," in a situation in which the Schrödinger equation cannot be linear.

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