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On the Relation Between Psychology and Physics

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Garrison's recent article provides another analysis of the need for the inclusion of a relativistic theoretical structure for doing psychological work that adopts some notion related to complementarity for integrating distinct relativistic positions. Problems in his historical account of the introduction of this approach are addressed. Issues concerned with interpretation by psychologists, including Garrison, of modern physical theory are also discussed and point toward the unique contribution that psychologists can bring to understanding modern physical theory. The central significance of psychologists' exploration of modern physical theory is addressed through discussing evidence in this theory of an unavoidable link between the observing, thinking person and the physical world.

Though containing some errors and confusing statements, Garrison's (1988) recent article, "Relativity, Complementarity, Indeterminancy, and Psychological Theory," is important in a number of respects. First, it is the initial attempt to record how concepts from modern physics were introduced into psychological theory. Second, it is an elaboration of this previous theoretical work. Third, Garrison's work leads to, but does not explore in any depth, the key notion that special relativity and quantum mechanics, considered fundamentally different forms of physical theory by physicists, both provide an essential role for the observing and thinking person in the structure and function of the physical world.

This third point thus denotes a common basis to ground the theories of special and general relativity and quantum mechanics. Relativity theory and quantum mechanics are generally considered fundamentally different due to various issues. These issues center on:

1. The unavoidable uncertainty in the knowledge of particular quantities in quantum mechanics that can in principle be known precisely in classical physics (Newtonian mechanics and relativity theory).

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2. The probabilistic character of knowledge in quantum mechanics and the deterministic character of knowledge in classical physics.
3. The unavoidable effect of measurement on the structure of the physical world in quantum mechanics as opposed to the in principle independence of the physical world from the act of measurement in classical physics.

It is important to note that Garrison's explicit concern in his article is not with the essential interdependence of psychological and physical theory, but rather, in line with other psychologists studying modern physical theory, his concern is with how concepts from modern physics may be of use to psychology (Hyland, 1985; Kirsch and Hyland, 1987; Rothenberg, 1988). Yet the primary significance of the exploration by psychologists of modern physical theory is in detailing the contribution of the person to the structure and course of the physical world. This paper deals in part with showing the nature of this contribution.

Garrison's paper is also important because of its imprecise statements and because of his particular conception of modern physics. His imprecise statements reflect the recent attempt by psychologists to gain the background in physical science that many of the early contributors to the independent discipline of psychology thoroughly possessed (Snyder, 1989).

Further, Garrison's interpretation of the physical world as revealed in modern physical theory demonstrates the specific approach of a psychologist as opposed to that of a physicist. Garrison's discussion of observation in physics reveals an implicit assumption that physicists are concerned with human observation when they employ this term. Actually, when issues of observation arise in physics, physicists are by no means explicitly concerned just with human observation or measurement carried out "hands on" by a person. Indeed, as far as most physicists are concerned, one can dispense with any accentuation on the human aspect of these activities. The presumption by physicists is that observation and measurement can be carried out by machines at least just as well as, and in most cases much better than, by humans. The psychologist, on the other hand, is much more disposed to consider that the important role for observation in modern physical theory actually involves human observation and not a mechanical form of observation embedded in a materialist conception of the universe.

In addition to further discussion on the themes noted, my original discussion of the Einstein, Podolsky, and Rosen gedankenexperiment (i.e., thought experiment) and spacelike separated events (Snyder, 1983a) will be reviewed and shown to illustrate the particular approach of a psychologist to the formal structure of modern physical theory. Besides indicating this approach, this review will clarify the link in quantum mechanics between the concrete experimental apparatus used to make a measurement and the theoretical structure within which the apparatus is placed.

Garrison's History

Garrison's earliest citation for a discussion of modern physics in an academic social science context was in a paper by Lemert (1974) entitled "Sociological Theory and the Relativistic Paradigm." In this paper, various key concepts of relativity and quantum mechanics were briefly reviewed, and the manner in which these concepts had been applied in various social sciences, including psychology, was explored. Lemert did not find that there had been a systematic attempt to develop a framework for psychological theory in which the contributions of modern physics were explicitly noted. Rather, Lemert found that certain psychological work, limited in scope, had incorporated relativistic notions. Lemert's goal was to get sociologists to consider notions of relativity, complementarity, and indeterminancy in their discipline. Lemert's discussion of modern physics was useful in that important concepts were being presented to social scientists, primarily sociologists, but he did not propose a systematic program for sociological theory. He certainly did not propose one for psychological theory.

It should be noted that Lemert explicitly proposed that the fundamental categories of relativity, complementarity, and indeterminancy would be useful for sociological theory. In a very similar manner, Garrison adopted these terms explicitly for psychology (even including them in the title of his recent article) but did not note their previous use by Lemert. This similarity is particularly striking as the notions of indeterminancy and complementarity in physics are closely aligned and would not seem to require separate discussion as regards related notions for psychology. As noted later in the paper, the notions of indeterminancy, or uncertainty, and complementarity as applied to physical existents such as electrons stem essentially from the wave functions associated with these existents. It is from the wave functions that all knowledge of these existents is derived. The Planck and deBroglie relations in quantum mechanics relate the particle aspects of certain existents to their wave aspects. In conjunction with the Planck and deBroglie relations, certain paired characteristics of waves associated with the physical existents of concern are found to be mutually exclusive with regard to their precise determination. This mutual exclusivity is the fundamental notion underlying indeterminancy and complementarity in quantum mechanics.

Another article cited by Garrison, "Quantum Theory and Q-Methodology: Fictionalistic and Probabilistic Theories Conjoined" by Stephenson (1983), is a rambling work in which the author apparently maintained that Q-sorts provide the avenue for introducing quantum mechnical and relativistic concepts into psychology. The rambling quality of the work is exemplified by the following passage:

> Meanwhile, the answer to our question, as to how far quantum theory involves self-reference, whereas classical physics doesn't, is that in the final analysis there is self-reference

> in quantum mechanics, a conclusion corresponding to that of Wheeler (1975) in discussion on "The Universe as Home for Man," p. 575, and also corresponding to new developments in logic—self-reference—which enters logic at a profound level: I quote Wheeler. (p. 219)

Stephenson's paper, which touches on many different issues and disciplines, is hardly a systematic and rigorous approach to the relevance of modern physics to psychology.

Garrison indicated that the work of Kuhn (1962/1970) and others, such as Lakatos and Laudan (Gholson and Barker, 1985), has been the most influential to date in setting the agenda for integrating physical and psychological theory. First the work of Kuhn, Lakatos, and Laudan, does not, so far as I know, make explicit reference to modern physical theory as the source of their respective conceptual frameworks concerning the history of science, let alone for psychology. On the contrary, in *The Structure of Scientific Revolutions*, Kuhn (1962/1970) made repeated reference to psychological experiments to support his notions concerning the development of scientific knowledge. Kuhn's work, and what Gholson and Barker (1985) referred to as the popularized Kuhnian view, though, can be considered as relativistic in nature and adopting a form of complementarity. Roughly considered, the underlying scientific paradigm in a scientific discipline is composed of the shared commitments of the practitioners of this scientific discipline. If other commitments appear, they are generally considered mutually exclusive. Both the commitments of the established paradigm as well as the rival commitments are considered beyond confirmation or falsification by empirical evidence.

But Kuhn's work, and its popular interpretation, are concerned with the philosophy and history of science. It appears that Garrison is the first to appeal to views from this discipline as a basis for the development of theory in psychology. But this is far different than Garrison's implicit point regarding the influence of philosophers of science on psychological theory through their own reliance on modern physical theory. In the absence of scholars other than Garrison in psychology who have explicitly referred to work in the philosophy of science as the basis for integrating psychological and physical theory, Garrison's notion that philosophy of science has been the most influential source for integrating these areas of theory is incorrect. He is incorrect in attributing to philosophers of science that they are the conduits for the introduction of concepts from modern physical theory into psychology.

Perhaps Garrison meant to imply that the work of Kuhn, including its popularized interpretation, itself constitutes a form of psychological theorizing. This would be an interesting notion, but it would still not support Garrison's major contention that work in the philosophy of science has been the most influential to date in the integration of psychological and physical theory.

Also, in the work of Lakatos and Laudan, which Garrison implied has a relativistic character, the contributions of belief and value—or a certain psychological reference frame—to the development of scientific knowledge are severely constrained. For Lakatos, the development of scientific theory proceeds fundamentally on the basis of a weighing of empirical data in which the competing theories are tested against the data (Gholson and Barker, 1985). For Lakatos, there is an ultimate reliance on an objective world (i.e., a world fundamentally unaffected by an observing, thinking, or experiencing person) which somehow overcomes the various commitments maintained by the adherents of any particular theory.

In the case of Laudan (1977), characteristics of theory such as elegance are also relevant in arriving at scientific truth. But this consideration of theory is not unique to Laudan. Prior to Laudan, Einstein (1949/1969) noted the importance of evaluating "the 'naturalness' or 'logical simplicity' of the premises [of physical theory]"(p. 23). This evaluation "has played an important role in the selection and evaluation of theories since time immemorial" (p. 23). But Einstein acknowledged that in weighing empirical evidence against theoretical elegance, empirical evidence is the final arbiter. "Pure logical thinking cannot yield us any knowledge of the physical world; all knowledge of reality starts from empirical experience and ends in it. Propositions arrived at by purely logical means are completely empty as regards reality" (Einstein, 1954, p. 271). Laudan's position is close to mainstream scientific thought on the role of theory in science. Though Laudan noted the importance of conceptual problems in science, these conceptual problems are themselves driven by empirical results which are considered to be fundamentally independent of theoretical issues and thus able to test them. Thus, the implication of Laudan's position, in accordance with mainstream scientific thought, is that the ultimate reliance for the development of scientific knowledge remains with empirical data.

Garrison (1988) noted that in "The Relativity of Psychological Phenomena" (Snyder, 1983b) I adopted a philosophical view, a view which is apparently also found in a subsequent article entitled "On the Nature of Relationships Involving the Observer and the Observed Phenomenon in Psychology and Physics" (Snyder, 1983a). Garrison's characterization of "The Relativity of Psychological Phenomena" as philosophical allowed him the opportunity to implicitly claim his own article as deserving of consideration for being the first to present an explicit systematic elucidation of a relativistic position for psychology using the theories of special relativity and quantum mechanics as sources for this model. Essentially, he distinguished his "critical assessment of issues of complementarity, indeterminancy and relativity" (Garrison, 1988, p. 119) from my "philosophical position" (p. 114). Garrison wrote, "Basically, they [including Snyder] have attempted to merely graft the concepts of relativity (primarily), indeterminancy, and/or complementarity. Had these efforts been aimed at critical revision, they would have led to an altered view of psychological theory on the whole" (p. 114). All of this allowed Garrison to propose "a preliminary version of a psychological relativity paradigm" (p. 113) without giving a full account of my earlier work on this topic.

Even a cursory review of my two papers shows the intent to develop a systematic program for psychology incorporating the notion of relativity and an extended notion of complementarity. In "The Relativity of Psychological Phenomena," certain key features of Einstein's special theory of relativity are first reviewed and then a principle of relativity for psychological phenomena is presented. The relativistic structure proposed for psychology is distinguished from other major models in psychology, and an example of the use of this relativistic model is given.

In "On the Nature of Relationships Involving the Observer and the Observed Phenomenon in Psychology and Physics," certain fundamental features of quantum mechanics are introduced, including the notion of complementarity, and an extended notion of complementarity is discussed for both physics and psychology. The extended notion of complementarity for psychology is presented after showing how traditional theories of personality and psychotherapy manifest a Newtonian-type conceptual framework and after noting that the subsequent change with regard to these theories implicit in the work of Szasz and others reflected the complementarity Bohr proposed for quantum mechanics.

In that article, the notion of perspectival reference frames is integrated with the idea that these reference frames, including particular characterizations of the experiencing individual as well as the world in which he or she exists, are mutually exclusive but nonetheless exist simultaneously. Situation is the term used to denote a particular stance of the person in conjunction with a particular characterization of the physical world. Thus, it was proposed that there exist mutually exclusive simultaneous situations. This is very close to Garrison's own proposal for a relativistic consideration of psychological theory, one that incorporates forms of complementarity and indeterminancy. A major difference between Garrison's proposal and my work is that Garrison does not seem to allow that the various mutually exclusive perspectives concerning psychological phenomena can be maintained simultaneously by an individual, a position at odds with various authors (Hyland, 1985; Kirsch and Hyland, 1987; Rothenberg, 1988; Snyder, 1983a, 1983b).

The Intrinsic Relation Between a Person and the Physical World

More was accomplished in these two papers, as well as in subsequent papers (Snyder, 1984, 1985, 1986, 1987, 1989, in press), than just the development of a general structure for psychological theory. The theoretical results obtained in this work have centered on the notion that physics is itself affected by a relativistic position in psychology and by the introduction of an extended notion of complementarity into psychology. This work has in general indicated that there exists an irreducible tie between psychological and physical phenomena. The implication has been that the observing, thinking, and in general experiencing person is central not only to the object of psychological investigation, but that this individual is central to the structure and course of the physical world as well.

There is a good deal of evidence that can be cited to support the significance of psychological phenomena to the structure and function of the physical world (Snyder, 1984, 1985, 1986, 1987, 1989, in press). In the present paper, a few new considerations from special relativity and quantum mechanics will be discussed, considerations which bear on Garrison's article.

Special Relativity

In physics, an inertial frame of reference is a set of spatial coordinate axes attached to a physical body for which Newton's law of inertia holds. It can be shown, for example, that Einstein's fundamental result on the relativity of the spatial lengths of objects and the temporal duration of occurrences in inertial reference frames in uniform, translational motion (i.e., with constant velocity and direction and without rotation) relative to one another is dependent on cognition, or imagination. A popular statement of Einstein's result is: moving rods measure shorter, and moving clocks run slower. In transforming the spatial length of a rod from one inertial frame to another, it is assumed that the rod is at rest in one of the frames and that in the other frame it is moving at the same uniform, translational velocity that the former frame has relative to the latter. Essentially, the observer in the inertial reference frame in which the rod is moving in a uniform, translational manner relies on the fundamental assumption of special relativity that a rod at rest in one inertial reference frame will have the same length as a similarly constructed rod at rest in another inertial reference frame. This observer, of course, cannot measure the rest length of the rod (termed the proper length) while it is moving. In a related fashion, the observer in the reference frame in which a clock is moving in a uniform, translational manner relies on the fundamental assumption of special relativity that a clock at rest in one inertial frame will run at the same rate as a similarly constructed clock at rest in another inertial frame. This observer, of course, cannot measure the proper time interval (or what might be called the rest time interval) of the moving clock. Thus, the observer in the inertial reference frame for which the rod or clock is moving relies on a cognitive, or imaginative, act concerning the proper length of the rod or the proper time interval determined with the clock that cannot in principle be directly empirically verified by the observer.

It should be noted that Garrison's discussion of temporal dimensions in special relativity is imprecise. Strictly speaking, in special relativity, physicists consider that temporality is linked to causality and causality is limited by the empirically determined invariant velocity of light in any inertial reference frame. A physical event has space and time coordinates. In special relativity, physical events which can either be caused by other physical events (i.e., in the past) or cause other physical events (i.e., in the future) maintain these relations in inertial reference frames in uniform, translational motion relative to one another. (Physical events for which light originating at one event can affect the other are called either timelike or lightlike separated events.) Thus, past and future, considered within the framework of possible causal relations among physical events, are the same in different inertial reference frames in uniform, translational motion relative to one another. In special relativity, temporal dimensionality can be different among such inertial reference frames for physical events which in principle cannot affect or be affected by other physical events in an inertial reference frame. These events are known as spacelike separated events. (Specifically, spacelike separated events are generally defined in physics as events for which a light ray originating at one event cannot reach the other event). Events which are spacelike separated in one inertial reference frame are spacelike separated in inertial reference frames in uniform, translational motion relative to the former frame.

It is accepted by many physicists that if physical events cannot in principle be causally related (i.e., be related by a physical influence with a velocity no greater than that of light), then their temporal relation is ambiguous. For most physicists, the clear temporal relations across inertial reference frames of physical events which can be causally related lends additional significance to these relations as opposed to those characterizing spacelike separated events. This is a position which psychologists are not apt to maintain. Issues concerning the nature of spacelike separated events (Snyder, 1984, 1986) have led me as a psychologist, and perhaps have led Garrison, to suppose that these events are very significant in terms of their temporal structure.

Another example of the fundamental connection between the individual and the physical world is found in the different ways in which Einstein developed concepts of time for an inertial frame of reference in his original argument concerning the relativity of simultaneity. The results obtained in the special theory of relativity are dependent on Einstein's consideration of time, most significantly the relativity of simultaneity for inertial reference frames in uniform, translational motion relative to one another. In beginning his development of the idea of time, Einstein (1905/1952) wrote:

> If we wish to describe the *motion* of a material point, we give the values of its co-ordinates as functions of the time. Now we must bear carefully in mind that a mathematical description of this kind has no physical meaning unless we are quite clear as to what we understand by "time." We have to take into account that all our judgments in which time plays a part are always judgments of *simultaneous events*. If, for instance, I say, "That train arrives here at 7 o'clock," I mean something like this: "The pointing of the small hand of my watch to 7 and the arrival of the train are simultaneous events." (pp. 38–39)

Einstein found that this characterization of simultaneous events is limited when one is concerned with physical events that are not spatially close to one another. He went on to develop the special theory of relativity relying on a concept of simultaneity dependent on the invariant velocity of light in any inertial reference frame. Many physicists maintain that this concept of simultaneity requires only mechanical observers in inertial reference frames.

The simple beginning of Einstein's development of the concept of time for inertial reference frames encompasses two points relevant to the importance of psychology for physics. The first point is that knowledge, whether of the physical or psychological world, depends on measurement, on the spatiotemporal coincidence of two events, one of which involves the measuring instrument and the other of which involves that which is measured (Einstein, 1916/1952). The second is that the person is ultimately involved in the measurement process and ultimately relates the measuring instrument to that which is measured.

These links between measuring instrument and existent measured, and between person and world, are emphasized by considering the footnote to the above quote concerning the arrival of the train (Einstein, 1905/1952):

> * We shall not here discuss the inexactitude which lurks in the concept of simultaneity of two events at approximately the same place, which can only be removed by an abstraction. (p. 39)

Here Einstein allows that an exact determination of the simultaneity of two events requires an abstraction (i.e., a cognitive act). In the above example, the abstraction is that whatever distance separates Einstein's watch from the train arriving in the station is considered to be 0. The abstraction is necessary because in classical physics (i.e., Newtonian mechanics and the special and general theories of relativity) no two discrete existents (e.g., electrons) can occupy the same place at the same time. Einstein's abstraction amounts to an immediate reduction of the spatial distance between such existents such that they are considered in principle to occupy the same place at the same time. This reduction is the ideal of measurement in classical physics, one that is carried over into quantum mechanics with some modification. Exact measurement in classical physics, and in a modified sense in quantum mechanics, in principle requires an abstraction, a cognitive act.

Quantum Mechanics

In addition, the significance of human observation and cognition to the structure and function of the physical world is indicated by the fundamentally probabilistic notion of the physical world incorporated in the theory of quantum mechanics (Snyder, 1986, 1989). According to quantum mechanics, there is no deterministically functioning physical world behind the probabilistic predictions derived with this theory. In the theory of quantum mechanics, as these predictions are generally altered when a human observation of a physical existent is made, the course of the physical world in general depends on whether or not a human observation is made of some physical event. In "Is the Moon There When Nobody Looks? Reality and Quantum Theory," Mermin (1985) noted Einstein's special concern with this point. In commenting on his conversations with Einstein while at the Institute for Advanced Study, Pais (1979) wrote, "We often discussed his notions of objective reality. I recall that during one walk Einstein suddenly stopped, turned to me and asked whether I really believed that the moon exists only when I look at it" (p. 907).

In quantum mechanics, the physical world is intrinsically tied to the observing, thinking person. Moreover, as this tie involves the particular stance of a person (i.e., whether this observing, thinking individual knows the results of some measurement procedure), it is the experiencing person that is intrinsically tied to the physical world. If a measurement in the physical world does not occur until an individual knows that it occurs (including its results), and if the measurement process is particular to the knowing individual (inasmuch as whether a measurement occurs depends on the knowledge possessed by an individual regarding whether a measurement occurred and the results of that measurement), then this knowing individual must be aware of his or her knowledge. An individual cannot depend on anyone else for his or her knowledge concerning a measurement. A similar case exists in relativity theory where the particular stance of the human observer, specifically as regards his or her frame of reference, is also central to the structure of the physical world (Snyder, 1989). As noted, in special relativity an observer at rest in his or her inertial reference frame cannot directly measure the length of a measuring rod at rest, or the duration measured with a clock at rest, in another inertial reference frame in uniform, translational motion relative to the former frame.

The probabilistic basis of quantum mechanics, incorporating a significant role for human observation and cognition, is dependent on the notion that the quantum mechanical wave function associated with a particle will, when its absolute square is taken, provide the basis for a probability density function for this particle. The probability density function is a function providing the probability of each particle being found within a certain spatial range (Eisberg and Resnick, 1974). Knowledge of all other observable quantities for the particle is also derived from the particular wave function characterizing the existent.

In developing a localized wave packet in space, which in quantum mechanics would be associated with specifying the position of a particle such as an electron within a small range, one uses sinusoidal waves of varying wavelength. In quantum mechanics, the momentum of a particle is associated with the wavelength of the wave packet from which knowledge of the particle is derived. Thus, the very structure of quantum mechanics precludes precise knowledge of both the position and momentum of the electron. The in-principle-lack of precise knowledge concerning certain paired quantities, such as the position and momentum of a particle, is at the heart of the uncertainty principle in quantum mechanics. When a measurement of some existent is taken, the wave function characterizing the existent is generally changed and, thus, so are the uncertainties concerning the values of those observable quantities tied to the wave function. According to Bohr (1935), one of the originators of quantum mechanics, in precisely measuring the position of a particle, there is a "renunciation" (p. 698) of knowledge of its momentum. Similarly, measuring precisely the momentum of the particle constitutes a renunciation of knowledge of its position. In this circumstance, Bohr (1935) coined the term "complementarity" (p. 700) to denote that in this theory there is a choice between mutually exclusive concrete measurement possibilities for certain paired quantities, quantities which in classical physics could in principle be simultaneously known with arbitrary precision.

Similarly, greater specification of the temporal duration at some spatial location of the wave packet associated with a particle requires sinusoidal wave components of increasingly varying frequencies. As the energy of a particle is associated with the frequency of its wave function, the very nature of the wave function precludes a precise knowledge of the duration of the wave packet at a spatial location, described by the wave function, and the particle's energy. And as the wave function associated with a particle is generally altered in a measurement, the uncertainties characterizing the time of measurement and the particle's energy are also generally changed in a measurement.

Garrison's implication that uncertainty and complementarity are fundamentally different concepts on a par with the difference between each of them and relativity does not hold in physics or psychology. Uncertainty and complementarity are closely aligned concepts, the foundation of both of which is the mutually exclusive description of certain aspects of psychological or physical phenomena.

The issue arises as to the nature of the waves described by the quantum mechanical wave function associated with a particular existent. The wave function is in principle complex. This means that, mathematically speaking, it has a real and imaginary component. The wave function thus does not describe the motion of a wave in real space, but it is relevant to the physical world. Eisberg and Resnick (1974) stated:

> The fact that wave functions are complex functions should be not considered a weak point of the quantum mechanical theory. Actually, it is a desirable feature because it makes it immediately apparent that we should not attempt to give to wave functions a physical existence in the same sense that water waves have a physical existence. The reason is that a complex quantity cannot be measured by any actual physical instrument. The "real" world (using the term in its nonmathematical sense) is the world of "real" quantities (using the term in its mathematical sense) . . . . It is apparent from the outset that *the wave functions are computational devices* which have a significance only in the context of the Schroedinger theory of which they are a part . . . . These comments should not be taken to imply that the wave functions have no physical interest . . . . A wave function actually contains all the information which the uncertainty principle allows us to know about the associated particle. (p. 147)

In the context of their noting that a "real" world is reflected in mathematics by real quantities, Eisberg and Resnick's statement that the wave function is basically a computational device is close to a statement that the wave function has a significant cognitive component. It is proposed here that the wave function indeed has a significant cognitive component, specifically that the use of "computational devices" (Eisberg and Resnick, 1974, p. 147) reflects physicists' cognitive function and their knowledge of the physical world. It is to be emphasized that quantum mechanics does not posit any world other than that revealed by the wave function. Thus a wave function with a significant cognitive component would indicate a fundamental link between the theorist involved in quantum mechanical computation and the physical world for which the results of the computation have consistently provided correct predictions.

The Einstein-Podolsky-Rosen Gedankenexperiment

Greater depth in understanding the cognitive link with the physical world found in quantum mechanics can be gained in exploring the gedankenexperiment of Einstein, Podolsky, and Rosen (1935) noted in Snyder's (1983a) "On the Nature of Relationships Involving the Observer and the Observed Phenomenon in Psychology and Physics." As previously discussed, Einstein appreciated the apparent lack of objective reality in quantum mechanics. In their gedankenexperiment, Einstein et al. attempted to demonstrate the incompleteness of quantum mechanics as a physical theory. In this attempt, they did not just rely on the generally accepted notion that quantum mechanics involves fundamentally probabilistic knowledge that is tied to the unavoidable interaction between the measuring system and the existent measured. Einstein et al. also demonstrated that in quantum mechanics the concrete experimental apparatus does not require that the experimenter choose a particular experiment with its attendant results. Rather, the choice of experiment and the accompanying different predictions, which are supported by empirical evidence, are limited by the thought of the experimenter. This flexibility in the choice of experiment in quantum mechanics led Einstein et al. to conclude that quantum mechanics is incomplete. The results are also the basis for Einstein's comment regarding the possibility in quantum mechanics of "telepathically" (Einstein, 1949/1969, p. 85) changing the physical world.

The generally accepted notion in quantum mechanics is that a measurement event is linked to a particular concrete experimental arrangement utilized in the measurement. But as Einstein et al. showed, quantum mechanics provides different empirically verifiable predictions for different choices of experiments, involving certain pairs of spacelike separated events, which are not limited by any known physical restriction. The choice between experimental procedures can occur essentially instantaneously, and the implementation of this choice can preclude the possibility that any known physical existent is the basis for explaining the results obtained in the different experiments. In quantum mechanics, the concrete experimental arrangement ought not to be accepted as the sole determining factor in measurement of the physical world. It is the *chosen* experiment that is the determining factor in the measurement of the physical world. The experiment with its attendant results, which are predicted in quantum mechanics, exist on a cognitive, or theoretical, level that requires some concrete apparatus that is not uniquely determinative of any particular empirical result.

These considerations led to the seemingly odd notion presented in "On the Nature of Relationships Involving the Observer and the Observed Phenomenon in Psychology and Physics" concerning concrete experimental arrangements in quantum mechanical measurement. In this paper, it was proposed that in quantum mechanics concrete experimental circumstances are inadequate to account for physical measurement, specifically as regards measuring certain paired quantities such as the position and momentum of an electron. It was proposed that there are also encompassing theoretical considerations that affect whether the concrete experimental arrangement is involved in measuring an electron's position or momentum. Thus, where a scaffold with a diaphragm with a slit was used to determine the position of an electron, it was proposed that this arrangement itself could be part of a theoretical arrangement in which the scaffold was hinged by a spring to another scaffold. In this latter circumstance, the concrete scaffold would actually be suited for measuring the momentum of the electron and not its position.

As Bohr (1935) himself noted, a concrete measuring apparatus can be set up so that even during what appears to be a measurement of a particle's momentum, the concrete measuring apparatus can be used instead to measure the position of the particle. Bohr originally proposed using the scaffold from which a diaphragm with a single slit hangs by a spring to determine the particle's momentum. But as Bohr noted:

> In an arrangement suited for measurements of the momentum of the . . . diaphragm, it is further clear that even if we have measured this momentum before the passage of the particle through the slit, we are after this passage still left with a *free choice* whether we wish to know the momentum of the particle or its initial position relative to the rest of the apparatus. In the first eventuality, we need only to made a second determination of the momentum of the diaphragm, leaving forever unknown its exact position when the particle passed. In the second eventuality we need only to determine its position relative to the space frame with the inevitable loss of the knowledge of the momentum exchanged between the diaphragm and the particle. If the diaphragm is sufficiently massive in comparison with the particle, we may even arrange the procedure of measurements in such a way that the diaphragm after the first determination of its momentum will remain at rest in some unknown position relative to the other parts of the apparatus, and the subsequent fixation of this position may therefore simply consist in establishing a rigid connection between the diaphragm and the common support. (Bohr, 1935, pp. 698–699)

Bohr's (1935) reaction to Einstein et al.'s gedankenexperiment was to point out that in choosing an experimental arrangement in quantum mechanics, one renounces an aspect of the description of some physical entity. Bohr essentially considered the physical descriptions that were attained with different choices of experiment fundamentally distinct and resulting directly from the interaction of the physical existent measured and the concrete experimental arrangement used. Notwithstanding the above quote from Bohr, Bohr attempted to limit the role of the observer in quantum mechanical measurement to selection of a concrete experimental arrangement, and thus he did not maintain that the possibility of essentially instantaneously selecting one of numerous experiments using the same concrete experimental apparatus could present problems for quantum mechanics. Bohr's stance did not allow for a theoretical overlay for the concrete experimental circumstances.

Bohr allowed that Einstein et al.'s gedankenexperiment applied to the simpler circumstance involving a single particle passing through a diaphragm with a single slit, specifically as regards choosing the concrete experimental arrangement to measure either its position or momentum. Bohr used this similarity in circumstances to argue for the applicability of complementarity to Einstein et al.'s gedankenexperiment. Einstein et al.'s concerns, though, apply to the simpler circumstance and not the reverse. If, in their gedankenexperiment, the concrete experimental arrangement is subject to theoretical, or cognitive, parameters, these parameters are germane to the simpler concrete experimental setup noted by Bohr. There is nothing in quantum mechanics that precludes the relevance of these theoretical parameters to physical events measured in Bohr's simpler experimental arrangements. Indeed, Bohr's own quote above allows for an in principle instantaneous choice of experiment, not constrained by the velocity limitation of special relativity, for which correct predictions can be made.

A Psychologist's Approach to the Concept of Spacelike Separated Events

In "On the Nature of Relationships Involving the Observer and the Observed Phenomenon in Psychology and Physics," spacelike separated events were discussed in the context of Einstein et al.'s gedankenexperiment. Einstein et al.'s work demonstrated that in quantum mechanics, there is no known physical existent that can provide the basis for the correlations of certain pairs of spacelike separated events. It was in this context that the notion of spacelike separated events took on meaning because I had been considering the notion of how spacelike separated events could exist in view of Einstein's reliance on the velocity of light for determining simultaneity, or the synchronization of clocks, in an inertial reference frame (Einstein, 1905/1952).

It seemed that Einstein et al.'s gedankenexperiment, based on well verified quantum mechanical principles and which has been subjected to empirical scrutiny (Aspect, Dalibard, and Roger, 1982), indicated the fundamental nature of spacelike separated events. The fundamental nature of spacelike separated events seemed to be that they are events for which a light ray originating at one event cannot reach the other event *and* which nonetheless are subject to being correlated in the mind of the physicist or person considering or observing these events. (The latter part of this description of spacelike separated events is not generally part of the physicists' description of this term.) That is, given the lack of a way for spacelike separated events to be defined only in apparently physical terms (i.e., in terms of the motion of light), Einstein et al. demonstrated in their gedankenexperiment that certain spacelike separated events depend on a mental correlation for their very existence. It seemed that even without the Einstein-Podolsky-Rosen gedankenexperiment spacelike separated events had to involve a cognitive correlation even if there was no physically based correlation for them. Just to conceive of these events in the particular relation that is defined as spacelike separated requires a cognitive correlation, one that in special relativity could have no physical underpinning. Einstein et al. thus gave a demonstration in terms of modern physical theory for what a psychologist thought was necessary on psychological grounds, specifically the cognitive component of spacelike separated events.

Conclusion

There has been a focus in recent work on what modern physical theory offers psychology, particularly in the applicability of concepts of relativity and complementarity to psychological phenomena. Garrison, in his inaccurate but nevertheless important recent article, discussed only the relevance of modern physical theory for psychology. But relativity theory and quantum mechanics, well supported by empirical data, indicate the significance of the observing and thinking person to the structure and course of the physical world. The relevance of psychology to physics forms part of the core of the relationship between these disciplines of study. Psychology's relevance to physics centers on the person's intrinsic relation to the physical world, a relation that is likely to be missed if the focus is only on what physics has to offer psychology. Psychology's relevance to physics depends in part on the emphasis in psychologists' training on psychological, as opposed to physical, characteristics of phenomena. A case in point is the role of the human observer in scientific observation. Others are the significance of a theoretical, or cognitive, overlay in the Einstein-Podolsky-Rosen gedankenexperiment and the importance of a mental correlation in understanding the nature of space-like separated events.

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