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On the Quantum Physical Theory of Subjective Antedating

FRED ALAN WOLF

~~*7777 Fay Avenue, Suite K-166, La Jolla, California 92037, U.S.A.*~~

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This paper explores the question of mental events causing neural events through the actions of the quantum physical probability field. After showing how quantum mechanical descriptions pertain to the influence that mental events have upon neural events, the question of Libet's "delay-and-antedating" observation is examined in the light of quantum mechanical description, specifically in the action of the probability field. The probability field is the product of two quantum wave functions. According to the transactional interpretation (TI) of quantum physics these wave functions can be pictured as offer and echo waves--the offer wave passing from an initial event to a future event and the echo wave passing from the future event back in time towards the initial event. I propose that two events so correlated are experienced as one and the same event; that is, any two quantum physically correlated events separated in time or space will constitute a single experience-an event in "consciousness." Using the *TI* then suggests a quantum physical resolution of the "delay-and-antedating" hypothesis/paradox put forward by Libet, B., Wright, E. W., Feinstein, B., & Pearl, D. K. (Brain, 1979, **102**, 193). It also offers a first step towards the development of a quantum physical theory of subjective antedating based on the transactional interpretation of quantum mechanics.

Introduction

In a recent paper Honderich (1984) criticized the apparent "delay-and-antedating" hypothesis put forward by Libet et al. (1979) to explain the apparent paradox in the timing of the events associated with peripheral sensation and neuronal adequacy. In a later paper Libet (1984) defended his hypothesis, pointing out that "this phenomenon, though conceptually strange, must be encompassed by any mind-brain theory".

Following this, Snyder (submitted) offered a proposal based on relativistic consideration of the relative time interval between the events. Snyder's idea was to consider the events from two different reference frames. The apparent difference between the relative time intervals as observed in these reference frames was postulated to account for the discrepancy. Namely, simultaneous events in one reference frame would appear as a time interval between the two events in another reference frame. However, because of the relativistic timelike connection between the events reported, Snyder's proposal failed to resolve the paradox.

After examining the delay and antedating hypothesis, I offer a plausible argument suggesting that mental events do control neural events through the actions of the probability field of the quantum wave function. Specifically, I show that the uncertainty in velocity of a presynaptic vesicle as predicted by the Heisenberg uncertainty principle compares favorably with the required magnitude for vesicle emission. This

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suggests that a sudden change in probability as predicted by the change in the quantum wave function known as the collapse of the wave function is enough to modify vesicle emission.

The paper concludes with a new hypothesis offering a quantum physical resolution of the above paradox and a first step towards the development of a quantum physical theory of subjective antedating.

The Delay and Antedating Paradox

The “delay-and-antedating” paradox/hypothesis refers to the delay in time of cerebral production resulting in a conscious sensory experience following a peripheral sensation, combined with a subjective antedating of that experience. The subject’s brain showed that neuronal adequacy was not achieved until after a full 500 msec following the sensation. Yet the subject stated that he was aware of the sensation within a few msec (10 msec) following the stimulation. Put briefly, how can a subject be aware of a sensation, that is, be conscious of it, if the subject’s brain has not registered that “awareness”?

The resolution of the paradox and the first step towards a full fledged quantum theory of the mind-brain interaction is based on the transactional interpretation (TI) of quantum physics (Cramer, 1983). This step in turn supports the theoretical idea underlying the TI and indicates that Libet’s data constitutes experimental evidence for that interpretation.

It was widely believed before this that no experimental evidence favoring one interpretation of quantum physics over another was possible. However, it has been recognized that the action- of observing any quantum system can alter the physical property under scrutiny. While this has been widely recognized, no one to date has any idea how this happens. Up to now research has been occupied with investigations of physical systems. Libet’s data may suggest that a biological foundation for quantum physics may exist and that the question of which interpretation of quantum physics is correct can only be answered biologically. This step may also provide a theoretical basis for a quantum physical model of the mind-brain.

To understand how the TI provides the link between mental and neural events, we need next to consider the question of the relevancy of quantum mechanical descriptions to the nervous system.

Are Quantum Mechanical Descriptions Relevant to the Nervous System?

While it may have long been suspected, it is only recently that the question of the mind-brain problem having a solution based on quantum physical considerations has taken on a new look. Current interest in macroscopic quantum systems as well as interest in molecular biology suggests that quantum physical principles do operate in the nervous system.

In a recent paper, Eccles (1986) offered plausible arguments for mental events causing neural events analogously to the manner in which probability fields of quantum mechanics are causatively responsible for physical events. His arguments were based on the idea that the conventional operations of the synapses depended on the manner of operation of “ultimate synaptic units”. As he put it, “these units are the synaptic boutons that, when excited by an all-or-nothing nerve impulse, deliver the total content of a single synaptic vesicle, not regularly, but probabilistically”. Eccles went on to point out that refined physiological analysis of the ultrastructure of the synapse shows that the effective structure of each bouton is a paracrystalline pre-synaptic vesicular grid with about 50 vesicles. The existence of such a crystalline structure is suggestive of quantum physical laws in operation.

Biologically speaking, Eccles focused attention on these paracrystalline grids as the targets for non-material events.

Physically speaking, he showed how the probability field of quantum mechanics which carries neither mass nor energy, can nevertheless exert effective action at these microsites. In the event of a change in the probability field brought on by the observation of a complementary observable, there would be a change in the probability of emission of one or more of the vesicles.

The action of altering the probability field without changing the energy of the physical system involved can be found in the equation governing the Heisenberg principle of uncertainty,

$$\Delta v \, \Delta x >= h/m,$$

where Δv is the tolerance set for determining the velocity of the object, Δx is the tolerance set for determining the position of the object, and h is Planck’s reduced constant $1{\cdot}06 \text{x} 10^{-27}$ erg-sec. Accordingly, when the tolerances are minimal, the inequality becomes an eqn.

In an earlier paper (Wolf, 1985), I presented similar lines of reasoning showing that protein gate molecules in the neural wall could also be candidates for micro-objects subject to quantum physical probability fields. I also explained how the sudden change in the probability field brought on when an observation occurs, could be the mechanism by which mental events trigger neural events.

A key argument for the plausibility of Eccles’ and my argument comes from a simple inquiry based on the mass of a typical synaptic vesicle, m, 40 nm in diameter. It can be calculated to be $3 \text{ x } 10^{-17}$ g. If the uncertainty of the position of the vesicle in the presynaptic grid, Δx, is taken to be 1 nm, it is possible to determine, according to the uncertainty principle, the uncertainty of the velocity, Δv, to be 3·5 nm in 1 msec. This number compares favorably with the fact that the presynaptic membrane is about 5 nm across and the emission time for a vesicle is about 1-10 msec.

These arguments support the idea that the uncertainty in velocity as shown by the uncertainty principle is well within the range necessary to modify the vesicle emission through mental intention in the manner known as the “collapse of the wave function (Bohm, 1950)”.

Thus, Eccles concludes that calculations based on the Heisenberg uncertainty principle show that the probabilistic emission of a vesicle from the paracrystalline presynaptic grid could conceivably be modified by mental intention in the same manner that mental intention modifies a quantum wave function. Although my conclusions were based on the operations of protein gating molecules in the neural wall, I came to a similar conclusion: mental events stimulate neural events through sudden changes in the quantum physical probability field.

For experimental evidence showing how mental events influence neutral events, Eccles pointed to that put forward by Roland *et al*. (1980) who recorded, using a radio-Xenon technique, the regional blood flow (rCBF) over a cerebral hemisphere while the subject was making a complex pattern of finger-thumb movements. They discovered that any regional increase in rCBF is a reliable signal of an increased neuronal activity in that area. Other evidence, using the same technique of monitoring rCBF, showing that silent thinking has an action on the cerebral cortex was also offered by Eccles. For example, merely placing one's attention on a finger that was about to be touched, showed that there was an increase in rCBF over the postcentral gyrus of the cerebral cortex as well as the mid-prefontal area.

Eccles concluded from his research that the essential locus of the action of non-material mental events on the brain is at individual microsites, the presynaptic vesicular grids of the boutons. Each bouton operates in a probabilistic manner in the release of single vesicle in response to a presynaptic impulse. It is this probability field that Eccles believes is influenced by mental action that is governed in the same way as a quantum probability field undergoing sudden change when as a result of observation the quantum wave function collapses.

However, the question of what causes the probability field to change in this manner remains. A new interpretation of quantum physics, the *TI*, may shed some light and Libet's data may indeed be showing how mental events influence neural events and indeed just what is necessary for a conscious (knowing) event to occur.

A New Hypothesis

Assuming that neuronal adequacy and experience were one and the same, Libet (1985) pointed out the obvious discrepancy between the time of the experience of an event--the subjective referral--and the time of neuronal adequacy required to experience the event. I would like to suggest an alternative proposal. Neuronal adequacy and subjective experience are not one and the same events. Neither are peripheral stimulation and subjective experience one and the same events, even though they seem to be. The truth actually lies somewhere in-between. Both the stimulation and neuronal adequacy (two events) are needed for the conscious (one event) experience, even though the time of that experience is referred back to the peripheral sensation.

This proposal is based on ideas put forward in my book (Wolf, 1984) and upon the new *TI* of quantum mechanics stated by Cramer (1983, 1986). According to the *TI*, a future event and a present event are involved in a transaction wherein a real quantum wave of probability (retarded wave), u, called the "offer" wave, issues from the present event to the future event. The future event is then stimulated to send back through time an "echo" wave (advanced wave), u^*, towards the present event. The echo wave is the complex conjugate of the offer wave.

According to the rules of quantum mechanics, the probability distribution (probability per unit volume) for an event to occur, is given by *u*u*. However, no other interpretation explains how this product arises physically. Following the *TI*, the echo wave modulates the offer wave thus producing the required *u*u* probability pattern. Thus, it is necessary for future events to influence present or past events by sending back into time a corresponding echo wave, *u**, following an offer wave, *u*, from the present or past. Specifically, the echo wave contains the complex conjugate reflection of the offer wave multiplying the offer wave in much the same manner as a radio wave modulates a carrier signal in radio broadcasting. The probability, *u*u*, which then results in a probability for a transaction--a correlation between the two events--arises as a probability field at the initial event.

The events in question (stimulation and neuronal adequacy) are time-like separated. Thus, according to the theory of relativity, there is no way that these two events could be ever be simultaneously observable so Snyder's resolution of the paradox is not tenable. However, the fact that the observer of those events sees them as simultaneous means that his mind acts as a kind of "time machine". That is, the experience of the event is "projected" back in time towards the occurrence of the sensation.

Libet suggests that this may be an illusion, that the real "recognition" of the event only occurred later at the time of neuronal adequacy and that the subject "subjectively" and mistakenly remembered the event as having occurred earlier. Whether or not this is an illusion is at present not experimentally testable. In any case, one must wonder why subjects believe that their knowledge or recognition of an event is a simultaneous occurrence with the event if indeed the knowing and the stimulation are time-like separated.

This backwards-in-time projection between a neural event and a stimulus can be consistently accounted for using the *TI* of quantum mechanics. In this case, the present event (the peripheral sensation), *S*, sends a forward-through-time probability offer wave to a future event (neuronal adequacy), *N*. Most likely, *N* lies on the area of the cortex normally associated with the sensation. The future event, *N*, sends a backwards-through-time probability echo wave to the present event, *S*.

According to the *TI*, the *S* to *N* offer wave stimulates the *N* to *S* echo wave. The *N* to *S* echo wave then carries a replica of the *S* to *N* offer wave back towards the original stimulation. The *N* to *S* echo wave arriving at the location of the source, S, is the probability for the correlation of the events. If the two waves "resonate," meaning that the probability for the S to N correlation is large, then a significant probability for the two events is achieved. In this manner, that which is significantly measurable--has the largest probability--is also that which is brought to conscious awareness. In my view, all possible future events are in contact with a present event, however, the most probable future events are those that produce the largest value of *u*u*, and consequently constitute an event in consciousness.

I offer the hypothesis that whenever two events are so correlated, i.e., the probability for the events is not *a priori* zero, they will be experienced as one and the same event. I suggest that this means, in general, that any two quantum physically correlated events separated in time or space will constitute a single experience.

Thus, I suggest that "consciousness" can only occur when two or more events are so quantum correlated. A single sensory event, without a neuronal correlate will not be a conscious event.

This sheds light on both "subjective referral in time" as well as "subjective referral in space". Libet (1984) suggests that, in the same manner that neuronal adequacy following a peripheral sensation is projected "out there" on the peripheral site and not felt to occur at the cortex, visual experience is "projected" out there onto the external world and not referred to the retinal net.

In my hypothesis, the time and the location of the experience are projected back to the original stimulus. It would be hard to explain how appropriate present behavior could occur, if this projection from the future did not occur. This hypothesis also fits with certain experiments performed by physiologist von Békésy and phantom limb experiences reported to Pribram which I described in my earlier book (Wolf, 1984).

If the echo and offer waves fail to resonate a much smaller probability for the connection of the two events occurs. Thus, for example, suppose that the offer event, *S*, is received by two separate areas of the brain, *N* (the normal sensorial cortex region) and *M* (a remote cortical area not usually connected with peripheral sensation). Nevertheless, the events *S* and *M* will also appear to be simultaneous with, however, a much smaller probability.

Suppose for example, that *S* is a forearm skin prick and *M* lies within the aural (sense of small) cortex. The events to be correlated, the actions of smelling and skin pricking, would have a small probability of correlation. If these events were the more probable, because of damage to the skin sensory cortex, for example, the subject would refer to the skin prick as an odor of piercing skin rather than a feeling of the prick.

Normally the probability for associating a smell with a skin prick would be small. The correlation would be ignored and the events would be interpreted as unmeaningful. Meaningfulness in this regard simply means of significant probability. Thus considering the relative meaningfulness of two correlated event sequences as merely being the relative probabilities of the sequences, the correlation would be ignored. Of course in certain abnormal situations, possibly involving drug intoxication or schizophrenia, such sequences may be the normal.

If my hypothesis is correct, the quantum interpretation appears to offer a better explanation of the paradox of subjective antedating as well as suggest a necessary first step towards a quantum physical mind-brain theory. It is the realization of this *TI* transaction that finally becomes a conscious experience.

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