Time's a one way ticket - Or is it?

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Q-bits and time

Alice and Bob are the good guys. They need to exchange information that can't be read by evil Eve. Actually this is impossible. Eve can always eavesdrop somehow, at least in principle if not in practise. But, if Alice and Bob are quantum cryptographers, they can ensure that they will always know whether Eve has been prying into their messages. How do they manage this?

One of them, Alice as the story is usually told, makes pairs of entangled particles. She keeps one particle from each pair and sends the other to Bob. Then she makes some measurement, chosen at random from a range of possibilities, and phones Bob with two pieces of information; first to let him know what she measured and second what the outcome was. Bob measures his particle in the same way, then compares his result with Alice's. Provided no-one has eavesdropped on Bob's particle, his measurement will always be perfectly anti-correlated with Alice's. If Eve did sneak a look at Bob's particle on its way to him, the measurements won't always agree. So Bob's particle can both carry a message from Alice and can help tell him and Alice whether anyone intercepted the message.

Entanglement can be useful, to be sure, but is also very weird. One of the weirdest aspects is the way it seems to ignore time. The Alice and Bob scenario would still work if Alice was an earthling and Bob lived in Andromeda. Suppose Bob were to receive a particle that had set out from earth a million years previously, and Alice happened to come into possession of its entangled partner, then Alice's measurement would still be perfectly related to Bob's provided nothing had interfered with either particle in the meantime. Probably the easiest way of envisaging what's going on is to think of information flows:-

1,000,000 BC
Creation of entangled particles.
1 AD
Bob (a long-lived Andromedan) receives and stores his particle.
1999 AD
Alice measures her particle and transmits outcome to Bob
201, 999 AD
Bob receive's Alice's message and can then gain information about whether his particle was untouched when he got it.

There's no problem with the classical information here, which flows in the usual orderly way. But something information-like can be pictured as connecting Alice's measurement with the creation of the entangled pair 1,002,000 years previously. This connection is what helps to fix the result Bob gets when he eventually measures the particle that he stored before Alice was born. There is a mysterious form of quantum information that poses no problem for our everyday world because it is inherently inaccessible to us. You can encode as many bits of classical information as you like into a single *q-bit,* but you can only ever retrieve one classical bit. The rest of the information may affect the probability of retrieving a '1', say, rather than a '0', but can never be experienced directly. Weird backward-in-time quantum information is also something that you can't see, only infer, so many people say. As it turns out, there's a good chance that what many people say is wrong.

Picturing these strange connections as real in some sense does help to make sense of quantum theory. Huw Price for instance has argued in his controversial book *(Time's Arrow and Archimedes' Point)* that quantum theory is just the whacky set of ideas you'ld expect if backward-in-time causal influences exist. Aristotle called them *final* causes. Another way to picture the situation, which may be philosophically sounder, is to envisage the inherently inaccessible foundations of reality (i.e. the world of quantum superpositions and *q-bits*) as atemporal. Basic reality is ordered, according to this view, but not in a fundamentally temporal manner. The time that we experience is no more than the usual outcome of projection of fundamental order into our perceived world. Since temporal order is not primary, so runs the argument, non-classical causalities may sometimes appear to be at odds with our understanding of everyday chains of cause and effect.

Q-bits and the brain

Ever since Roger Penrose published his best-seller, *The Emperor's New Mind,* there's been lots of interest in the possibility that our consciousness might make use of, or even be based on, quantum computation involving *q-bits* . A huge range of ideas suggest how this could come about. Whole conferences are devoted to the topic, for instance one held in Flagstaff, Arizona this August. Those involved in the discussions may be tempted to think that we need fewer speculations and more facts, but any such cynicism is unfair at this stage as the theories are both signs of ever-growing interest and also help to pinpoint which facts may be most important.

It seems reasonable to suppose that, if *q-bits* do have some essential role in brain function, we should sometimes come across causal anomalies in neurophysiology or conscious experience. Maybe free will itself could be an outcome of such an anomaly, but that's speculative. There are problems with this 'reasonable' supposition, however, quite apart from its conflict with everyday common-sense. Since there's no agreement on the precise role, if any, of *q-bits* , it is hard to know what sort of anomaly to look for. Physicists, too, are often reluctant to think along these lines because they entail accepting some modification of orthodox quantum theory. The Schrodinger equation evolves smoothly and linearly through time, and does not permit causal anomalies to manifest openly in the world that we experience. While no-one supposes that orthodox quantum theory is complete (witness the well-known incompatibility with general relativity, the interest in string theories, etc.), it is extraordinarily accurate and can be modified only for very good reasons and with great caution. All the same a causal anomaly does seem to exist, of just the sort that might have been expected.

Radin and Bierman

Dean Radin, working in the U.S., discovered the anomaly. His experiment involved the use of Galvanic Skin Responses (GSRs). These are changes in the electrical conductivity of the skin due to sweat gland activity. The GSR is constantly fluctuating, but particularly large changes tend to occur a few seconds after emotional or other stresses. Measuring the GSR is therefore often used as one of the components of lie detector testing. Radin showed to people a series of calm or emotionally disturbing pictures, presented in random order, while recording their GSRs. When he looked at the recordings later he of course saw GSR responses following each picture, bigger on average if the picture had been upsetting. But he also sometimes saw small GSR swings a second or two *before* each picture had been shown. These too were larger on average if the picture was going to be a disturbing one.

Some part of the brain, it seemed, could anticipate whether an upsetting picture was about to be shown. He was unable to explain his findings in terms of sensory leakage, statistical artefact or other understandable source of causation. It looked as if his 'pre-sponse' was a genuine causal anomaly.

Dick Bierman, based in Amsterdam, got to hear of Radin's work and decided to see if he could replicate it. He has done so and has also been able to find no 'ordinary' explanation for the findings, though he is careful to point out that this cannot yet be taken to mean that no such explanation exists. New work that he has done indicates, for instance, that men tend to show the biggest pre-sponse in anticipation of sexy pictures while women pre-spond best to scary ones. At the Flagstaff conference, he announced some further results. He had been wondering whether some subtle error in his own and Radin's methodology was producing the pre-sponses. "I don't even trust my own results.", he said. So he looked for other people who had happened to reproduce essentially the same experimental conditions but in quite different contexts. He came up with three groups all of whom had both used GSRs as measures of emotional arousal, in a way that could have allowed appearance of pre-sponses, and were willing to make their raw data available. None of these groups had themselves observed any pre-sponse because they had used the pre-picture GSR as a baseline from which to measure the post-stimulus response that they got. Nevertheless, when Bierman re-examined their raw data, small pre-sponses to upsetting pictures could be found in each set.

Explaining the pre-sponse

On the evidence so far, pre-sponses are genuine causal anomalies that appear to be readily reproducible. If these characteristics turn out to be robust, they'll have to be explained. Major questions centre on whether orthodox quantum theory can be modified to accomodate them and, if so, what sort of modification is needed. Some quite intensive discussions on this topic were held on-line (in the 'quantum mind' forum) at the end of last year. Two front runners emerged from the discussions, one due to Henry Stapp and the other to Jack Sarfatti, both of whom are physicists based in California.

Stapp's idea is to push the Copenhagen interpretation of quantum theory as far as it will go. This leads him to a view similar to that of Alfred North Whitehead who held that reality is a series of 'knowings' (Whitehead sometimes called them 'actual occasions of experience'). In particular, until an event has registered in someone's mind, its nature is not necessarily fixed. So the apparent pre-sponse could be an outcome of the unfixed nature of reality prior to observation by someone (note that the GSRs were recorded and were not seen by anyone until long after each experimental session).

Sarfatti's suggestion is quite different. He builds on David Bohm's picture of the quantum world which divides reality into 'particles' and the 'quantum potential'. According to Bohm the 'quantum potential' has no sources and thus cannot be influenced by the 'particles', despite being responsible for guiding their motions. Sarfatti however suggests that the 'particles' of certain systems, including brains, can feed back to influence the 'quantum potential' in a manner which essentially involves loops in state space (i.e. imaginary space) but can sometimes manifest as temporal loops in the perceived world.

Where next?

We obviously need a lot more evidence that the pre-sponse is robust and genuine before it can be taken too seriously. Ideally, dozens of researchers in different places will try to replicate the findings. A particularly interesting possibility arises because the experiment lends itself to being controlled by hard-nosed skeptics such as those involved in CSICOP (the Committee for Scientific Investigation of Claims of the Paranormal). Some people are cautious about involving them for fear that CSICOP might shift the goalposts in such a way that no confirmatory findings, however strong, could ever meet their changing criteria for proof. Such fears could probably be negotiated away. If CSICOP-certified confirmation of the pre-sponse were to become available, it's likely that research in this area would 'take off' in a big way.

In the meantime smallish steps can be taken. For instance, both Stapp's and Sarfatti's accounts suggest that the pre-sponse is dependent on conscious perception of the pictures. Unconscious, subliminal perception should not suffice. Dick Bierman says he already has preliminary evidence that conscious perception is indeed necessary for a pre-sponse to occur. Another useful suggestion concerns modification of the experiment to distinguish between Stapp's and Sarfatti's explanations. If an observer, an 'experimenter's friend', were introduced to watch the GSR measurements as they were made in real time, this should abolish any pre-sponse according to Stapp. According to Sarfatti an observer would have no effect on the pre-sponse. Whatever the merits of rival theories, they will almost certainly need modification as evidence accumulates. The wonderful thing is that a relatively simple experiment stands a good chance of teaching us much about time, quantum theory and consciousness.

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