Title: Using humans to switch the settings in a Bell experiment

Date: Apr 09, 2018 10:00 AM

URL: http://pirsa.org/18040104

Abstract: I discuss how we might go about about performing a Bell experiment in which humans are used to decide the settings at each end. To get a sufficiently high rate of switching at both ends, I suggest an experiment over a distance of about 100km with 100 people at each end wearing EEG headsets, with the signals from these headsets being used to switch the settings. The radical possibility we wish to investigate is that, when humans are used to decide the settings (rather than various types of random number generators), we might then expect to see a violation of Quantum Theory in agreement with the relevant Bell inequality. Such a result, while very unlikely, would be tremendously significant for our understanding of the world (and I will discuss some interpretations). Possible radical implications aside, performing an experiment like this would push the development of new technologies. The biggest problem would be to get sufficiently high rates wherein there has been a human induced switch at each end before a signal as to the new value of the setting could be communicated to the other end and, at the same time, a photon pair is detected. It looks like an experiment like this, while challenging, is just about feasible with current technologies.

Proposal to use humans to switch the settings in a Bell experiment[1]

Lucien Hardy

Perimeter Institute, Waterloo, Ontario, Canada

[1] arXiv:1508.06900, arXiv:1705.04620

Consciousness and Turing-type tests

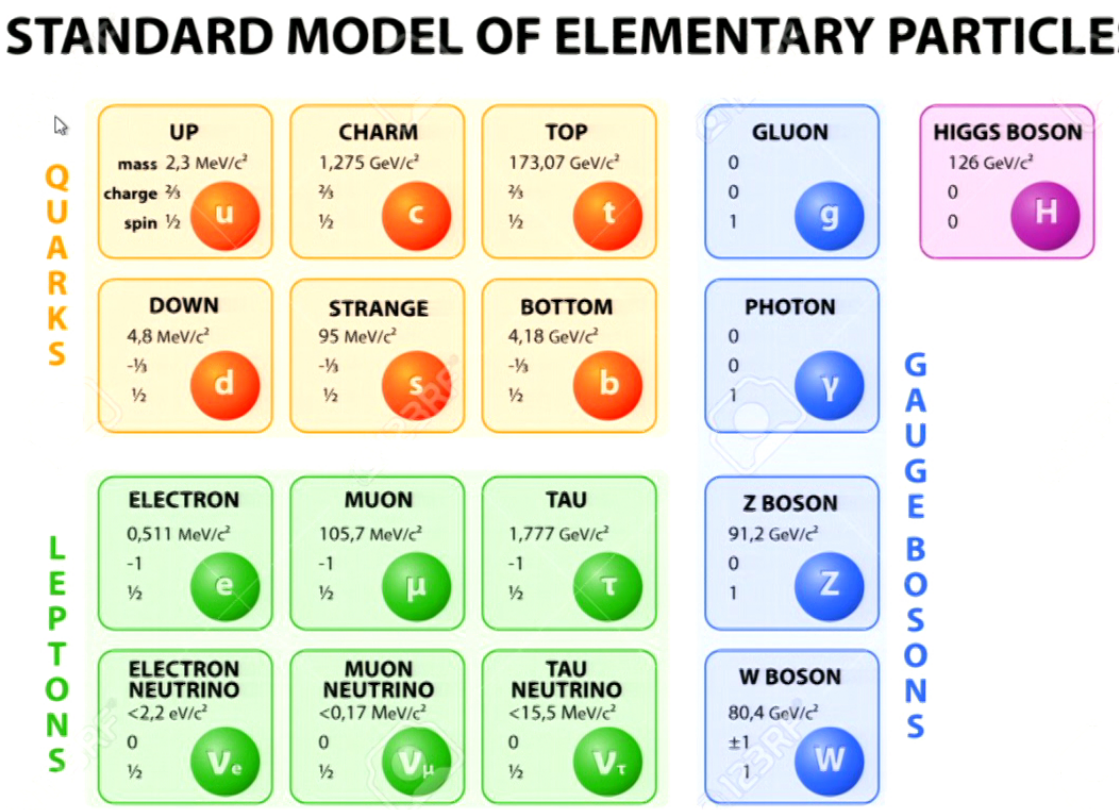
Prelude - accounting for consciousness

Three basic types of ontological account

	no fundamental consciousness property	fundamental consciousness property added
only matter	vanilla materialism (consciousness somehow emergent)	panpsychism (consciousness "glitter" everywhere)
mind added		mind-matter duality (ontologically distinct minds inhabit conscious systems)

(there is also idealism).

Vanilla materialism



Prelude - accounting for consciousness

Three basic types of ontological account

	no fundamental consciousness property	fundamental consciousness property added
only matter	vanilla materialism (consciousness somehow emergent)	panpsychism (consciousness "glitter" everywhere)
mind added		mind-matter duality (ontologically distinct minds inhabit conscious systems)

(there is also idealism).

Panpsychism

This is the doctrine or belief that everything material, however small, has an element of individual consciousness.

Panpsychism

This is the doctrine or belief that everything material, however small, has an element of individual consciousness.

Prelude - accounting for consciousness

Three basic types of ontological account

	no fundamental consciousness property	fundamental consciousness property added
only matter	vanilla materialism (consciousness somehow emergent)	panpsychism (consciousness "glitter" everywhere)
mind added		mind-matter duality (ontologically distinct minds inhabit conscious systems)

(there is also idealism).

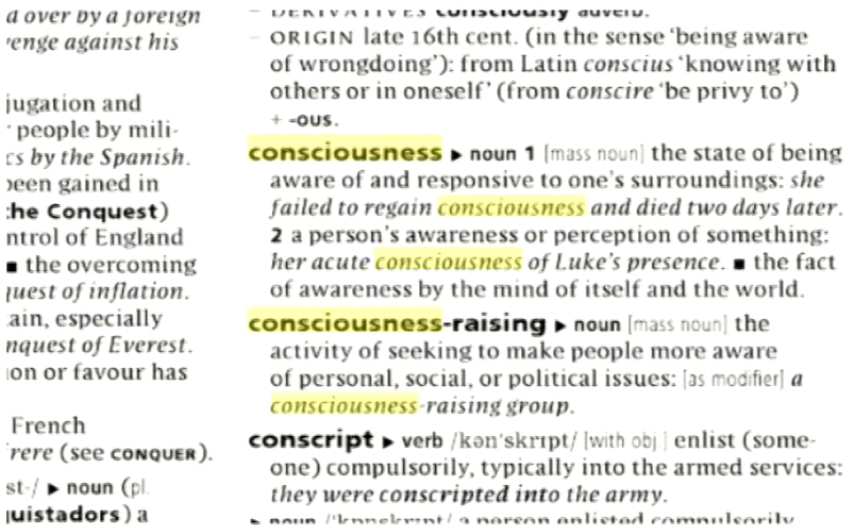
Cartesian mind matter duality

1641 - Rene Descartes

Squires's dictionary

Argument against epiphenomenalism (from Euan Squires).

The word "consciousness" is in the dictionary in black ink



a over by a foreign
'enge against his

jugation and
' people by mili-
cs by the Spanish.
been gained in
he Conquest)
ntrol of England
■ the overcoming
uest of inflation.
ain, especially
nquest of Everest.
ion or favour has

French
'rere (see **CONQUER**).
st-/ ▸ **noun** (pl.
uistadors) a

– DERIVATIVES **consciously** adverb.
– ORIGIN late 16th cent. (in the sense 'being aware of wrongdoing'): from Latin *conscius* 'knowing with others or in oneself' (from *conscire* 'be privy to') + **-OUS**.

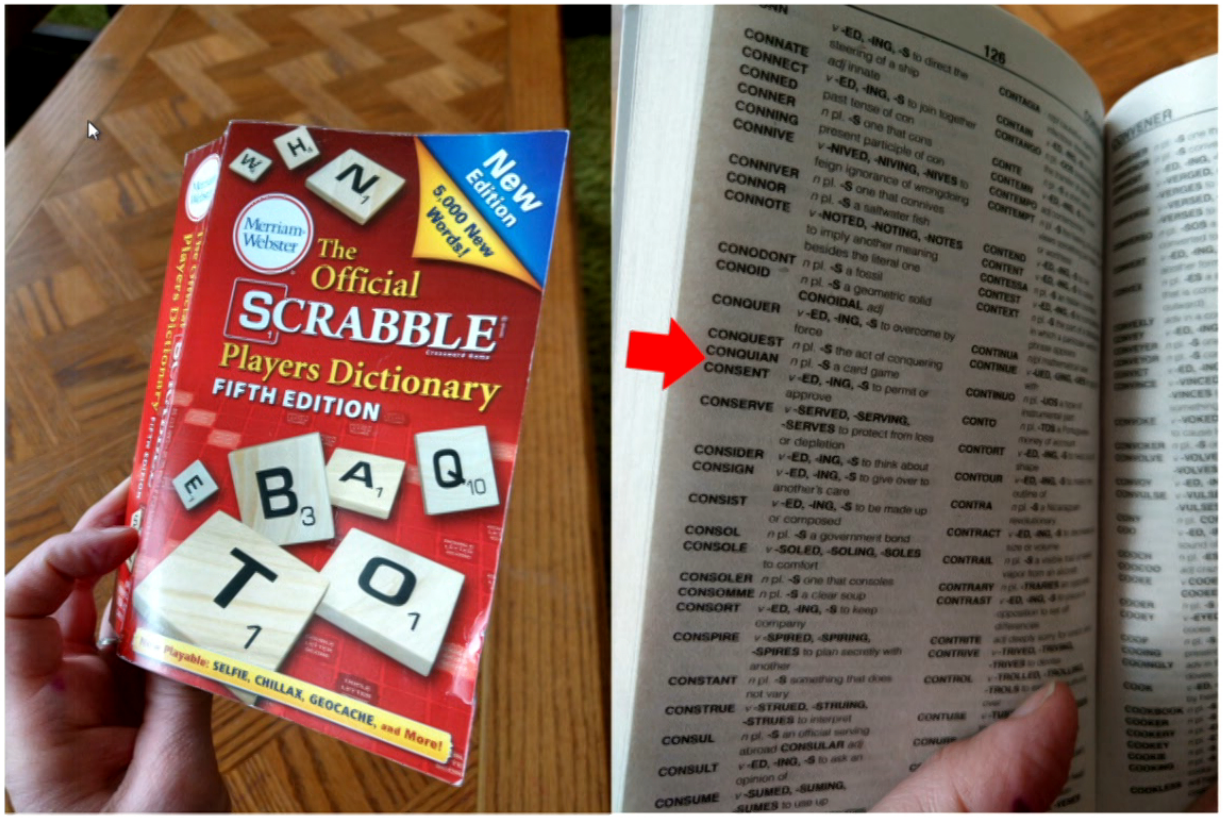
consciousness ▸ **noun 1** [mass noun] the state of being aware of and responsive to one's surroundings: *she failed to regain consciousness and died two days later.* **2** a person's awareness or perception of something: *her acute consciousness of Luke's presence.* ■ the fact of awareness by the mind of itself and the world.

consciousness-raising ▸ **noun** [mass noun] the activity of seeking to make people more aware of personal, social, or political issues: [as modifier] *a consciousness-raising group.*

conscript ▸ **verb** /kən'skrɪpt/ [with obj.] enlist (someone) compulsorily, typically into the armed services: *they were conscripted into the army.*
▸ **noun** /'kɒnskrɪpt/ a person enlisted compulsorily

The ink atoms must have been influenced (presumably indirectly) by whatever is responsible in the ontology for consciousness.

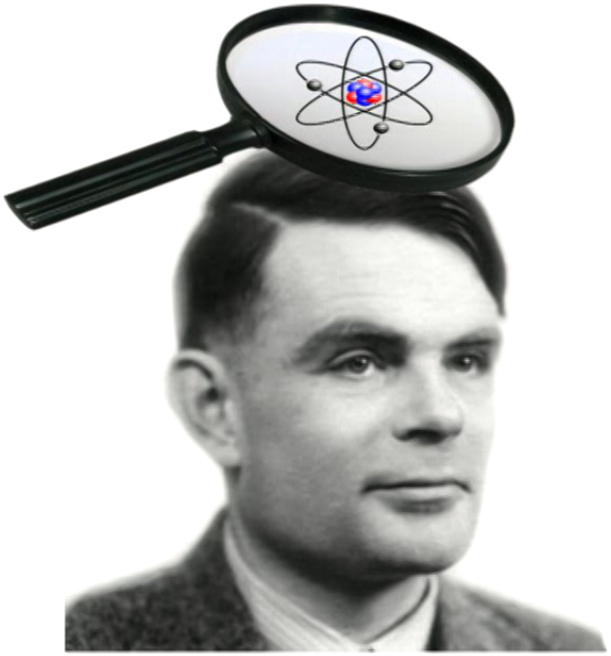
From Conquian to Consent: Scrabble players are zombies



From Conquian to Consent: Scrabble players are zombies

Since the word consciousness does appear (in good dictionaries) we conclude that the behaviour of matter can effected by ontological elements responsible for consciousness.

From the Cartesian dualist viewpoint we can tell a story in which the mind acts on the brain and thereby imparts information into the physical world (that, somewhere down the line, can lead to certain configurations of ink in a dictionary) . . .

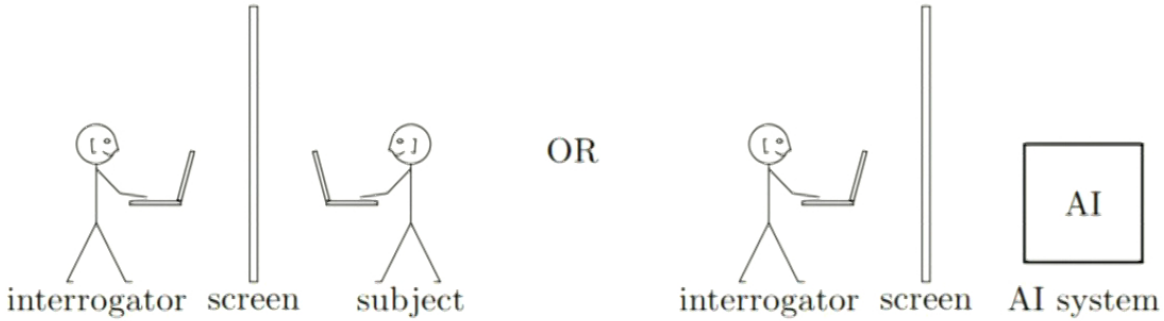


. . . atoms inside the brain would have to violate the laws of physics.

Could attempt to look inside mind to see this.

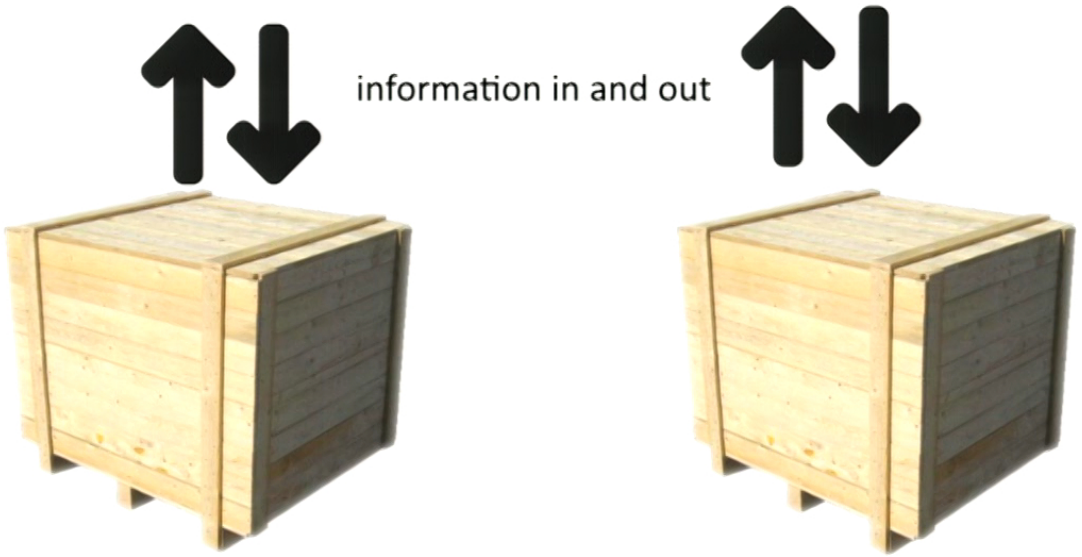
Difficult to do such an experiment - very messy environment.

The Turing Test



Turing-type tests

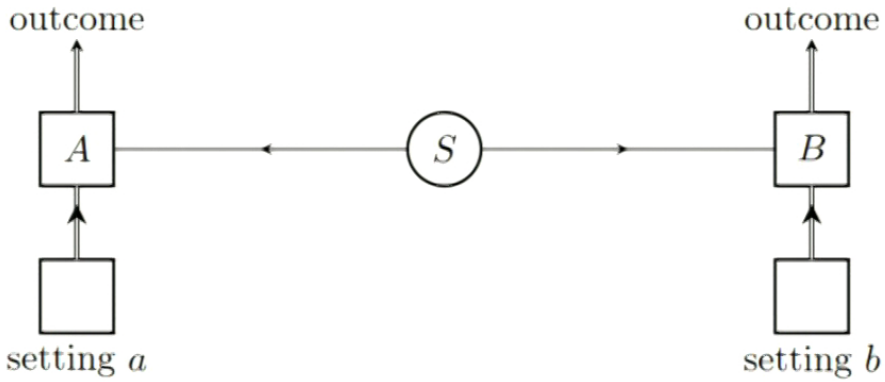
Put people or artificial devices in (figurative) boxes and only allow classical information to flow in and out of box



If real people can do something that artificial devices cannot then have evidence for mind matter duality.

Quantum Entanglement and Bell-type tests

Bell Experiments



Assume locality:

- outcome at end B does not depend on setting a.
- outcome at end A does not depend on setting b.

Can show

$$\text{correlation} \leq 2$$

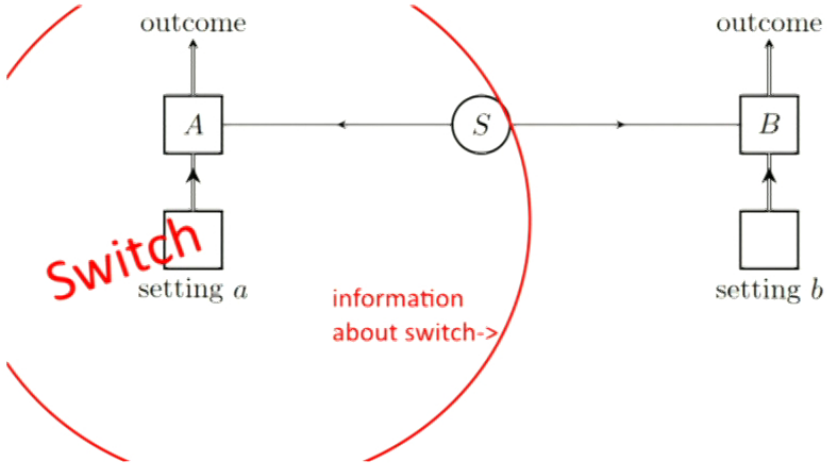
But Quantum Theory predicts

$$\text{correlation} = 2.8$$

One end seems to know what the setting at the other end is.

Imposing locality conditions

To be sure that we impose locality conditions we need to switch the setting at each end so there is no time for the information about the new setting to reach the other end.



In actual experiments switching is usually done by random number generators.

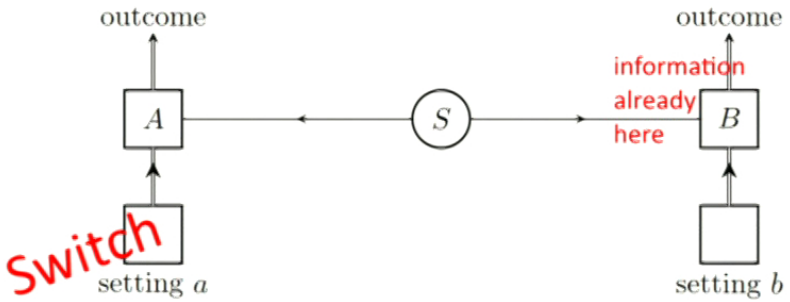
Random number generators?

But what if the random number generator is really a deterministic machine?

It has a hidden state that can be used to predict the future state.

Then the earlier hidden state could be broadcast to reach the other end in time . . .

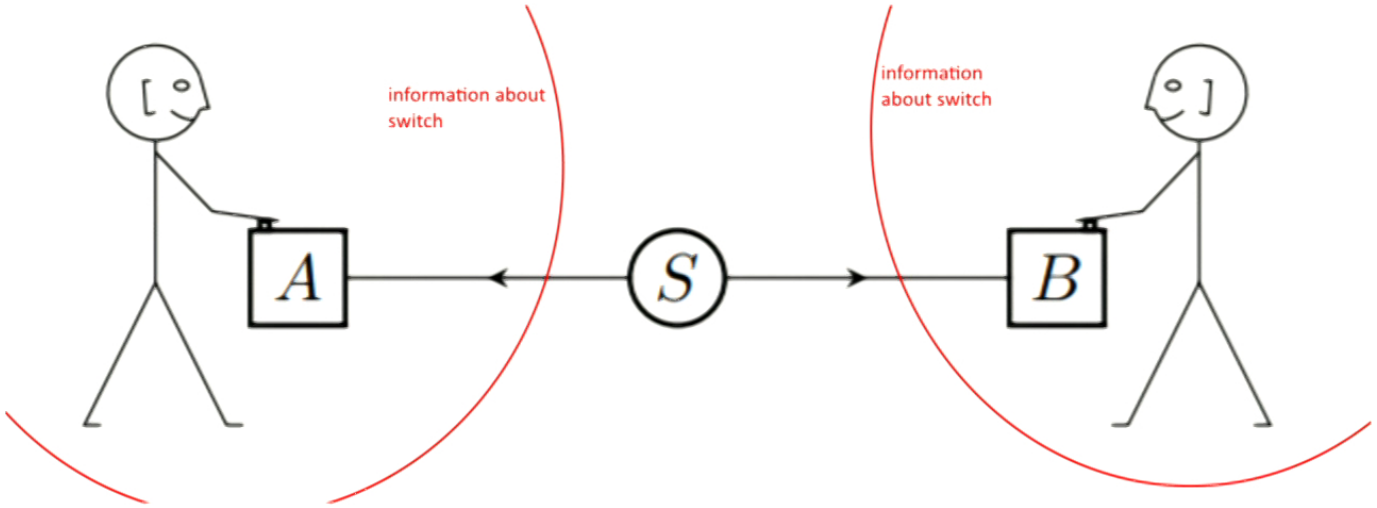
. . . thereby allowing the information about the actual setting to be available at the other end



Using humans to switch the settings

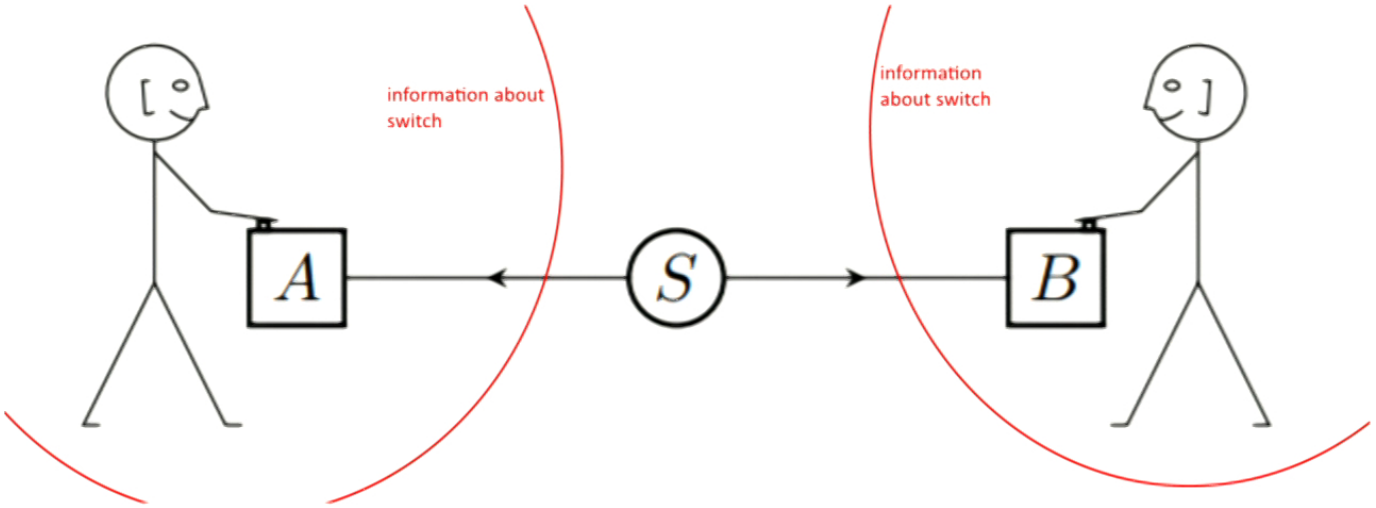
Mind interventions on matter

If the interventions of mind on matter cannot be "anticipated" by the laws at the physical level then the locality conditions can be imposed in a Bell experiment if we use humans to switch the settings.



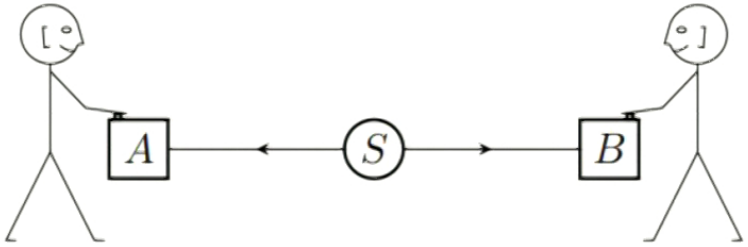
Mind interventions on matter

If the interventions of mind on matter cannot be "anticipated" by the laws at the physical level then the locality conditions can be imposed in a Bell experiment if we use humans to switch the settings.



So far no experiments have been done with humans.

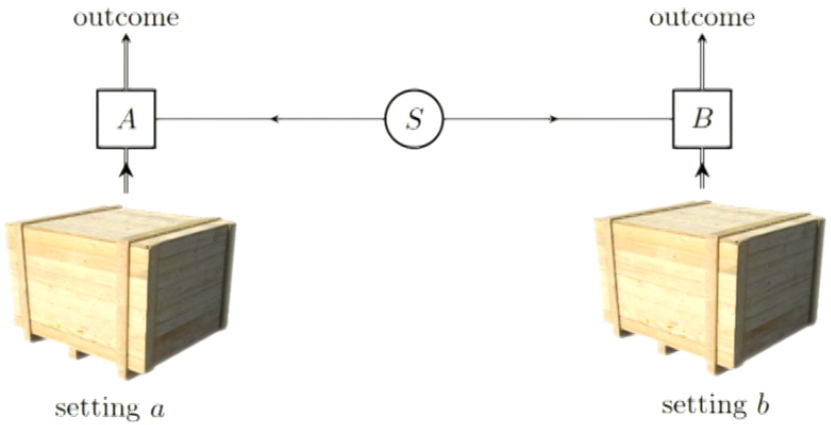
Humans or AI



OR

AI stands for "artificial interventions" such as random number generators.

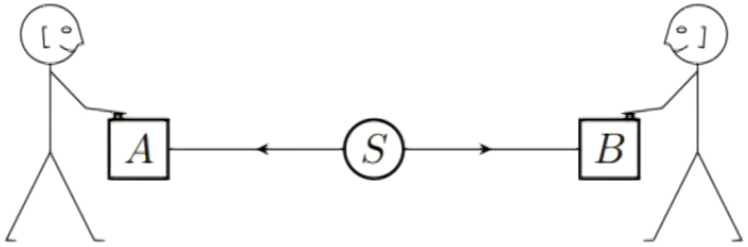
This is a Turing-type test



Put humans or artificial devices (such as random number generators) in each box.

Proposed experiment

Humans or AI



OR

AI stands for "artificial interventions" such as random number generators.

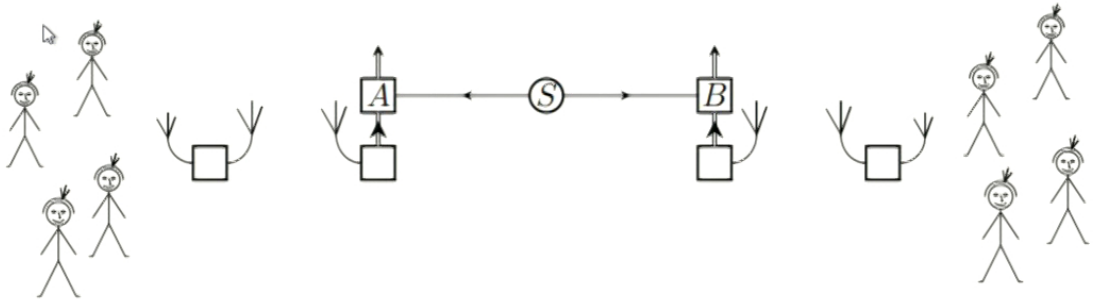
Human inputs

Could imagine humans pushing buttons to choose setting. However, can predict from EEG signals $\frac{1}{10}$s earlier what choice will be. In this time a light speed signal could carry information about the setting could be several times the radius of the earth away.

Propose, instead, to use EEG signals directly. Electrical signals travel through brain at near light speed so little delay incurred.

Proposed Experiment

I wrote up an explicit proposal in May 2017 (arxiv:1705.04620)



For example, could have

- Free space transmission of entangled photons over about 100km at altitude between remote locations.
- About 100 people wearing EEG headsets at each end in towns one either side of Bell experiment for two hours.

Assuming 10Hz intervention rate per person we could see a 1% effect.

Beginning of collaboration on actual experiment

Then, in July 2017, there was this:

Satellite-Based Entanglement Distribution Over 1200 kilometers

Juan Yin[1,2], Yuan Cao[1,2], Yu-Huai Li[1,2], Sheng-Kai Liao[1,2], Liang Zhang[2,3], Ji-Gang Ren[1,2], Wen-Qi Cai[1,2], Wei-Yue Liu[1,2], Bo Li[1,2], Hui Dai[1,2], Guang-Bing Li[1,2], Qi-Ming Lu[1,2], Yun-Hong Gong[1,2], Yu Xu[1,2], Shuang-Lin Li[1,2], Feng-Zhi Li[1,2], Ya-Yun Yin[1,2], Zi-Qing Jiang[3], Ming Li[3], Jian-Jun Jia[3], Ge Ren[4], Dong He[4], Yi-Lin Zhou[5], Xiao-Xiang Zhang[6], Na Wang[7], Xiang Chang[8], Zhen-Cai Zhu[5], Nai-Le Liu[1,2], Yu-Ao Chen[1,2], Chao-Yang Lu[1,2], Rong Shu[2,3], Cheng-Zhi Peng[1,2], Jian-Yu Wang[2,3], Jian-Wei Pan[1,2]

[1]Shanghai Branch, Department of Modern Physics and National Laboratory for Physical Sciences at the Microscale, University of Science and Technology of China, Shanghai 201315, China
[2]CAS Center for Excellence and Synergetic Innovation Center in Quantum Information and Quantum Physics, University of Science and Technology of China, Shanghai 201315, China
[3]Key Laboratory of Space Active Opto-Electronic Technology, Shanghai Institute of Technical Physics, Chinese Academy of Sciences, Shanghai 200083, China
[4]The Institute of Optics and Electronics, Chinese Academy of Sciences, Chengdu 610209, China
[5]Shanghai Engineering Center for Microsatellites, Shanghai 201203, China
[6]Key Laboratory of Space Object and Debris Observation, Purple Mountain Observatory, Chinese Academy of Sciences, Nanjing 210008, China
[7]Xinjiang Astronomical Observatory, 150, Science-1 Street, Urumqi 830011, China
[8]Yunnan Observatories, Chinese Academy of Sciences, Kunming 650011, China

Abstract:

Team

Jian-Wei Pan

Chief scientist

Quantum Science Satellite & National Quantum Communication Backbone Project

Excellence Center for Quantum Information and Quantum Physics

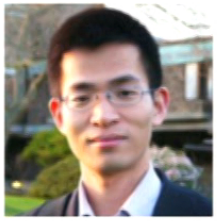
University of Science and Technology of China

National Laboratory for Physical Sciences at Microscale

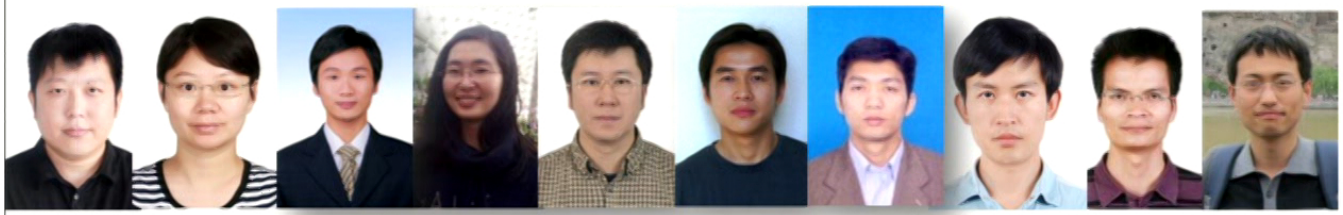
Cheng-Zhi Peng

Yu-Ao Chen

Qiang-Zhang



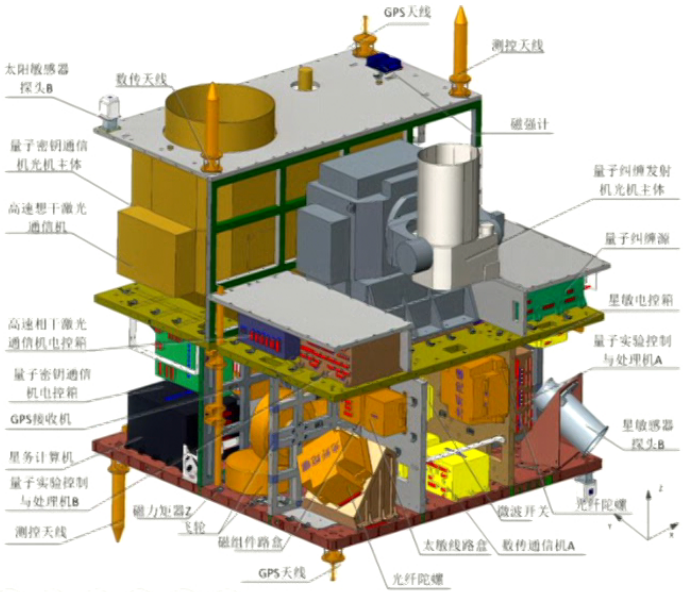
Chao-Yang Lu



Ji-Gang Ren, Juan Yin, Sheng-Kai Liao, Ping Xu, Yuan Cao, Jun Zhang, Teng-Yun Chen, Hai-Lin Yong, Xiao Jiang, Yang Liu

“Micius” Quantum Science Satellite

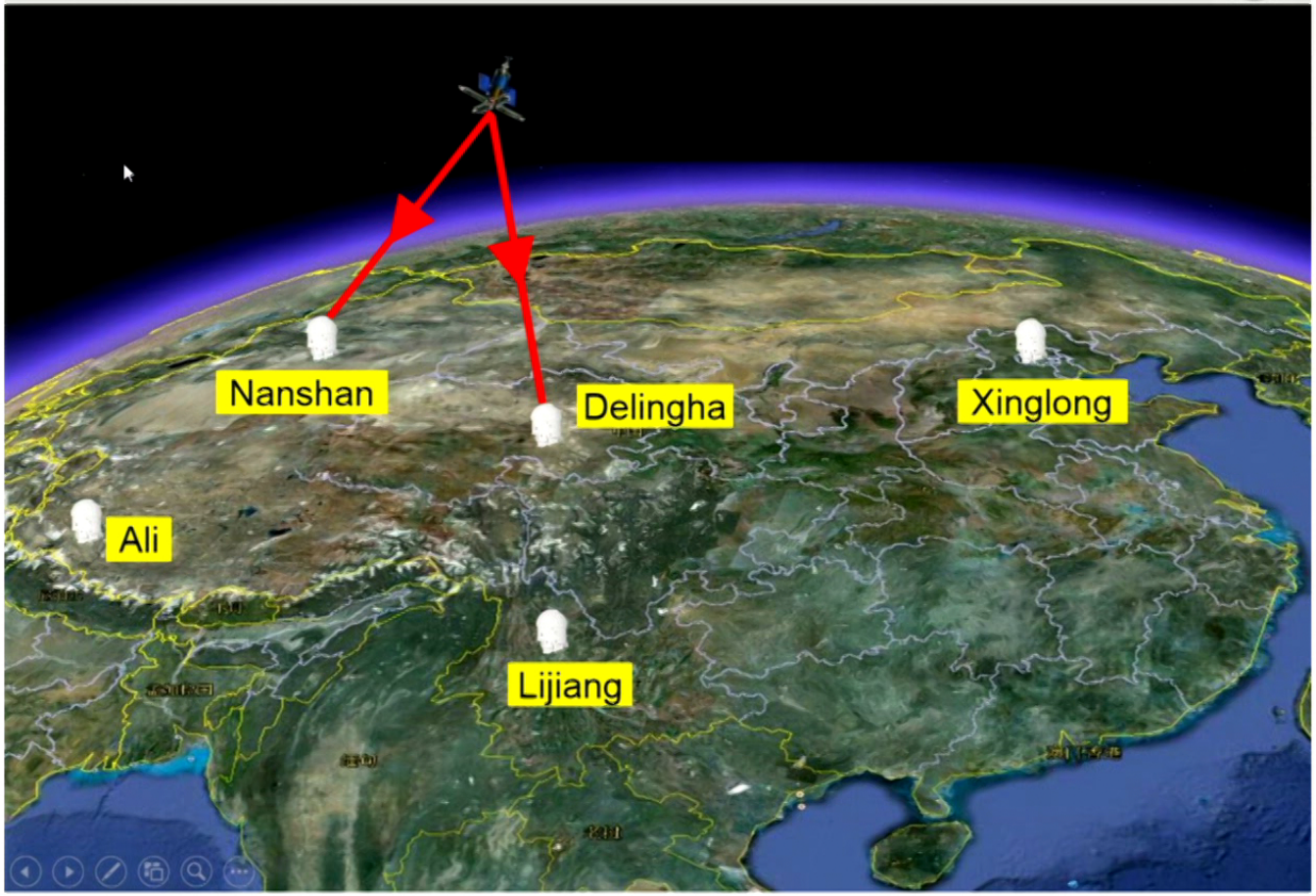
- Total weight of the satellite:631kg
- Average power:560W
- 500km sun synchronous orbit
- With the ability of pointing station



Launched on 16th Aug. 2016

- ✓ Tracking error is about 1urad
- ✓ Polarization visibility is over 100:1
- ✓ Satellite divergence angle is 10urad
- ✓ Channel loss is roughly 30 dB

Experiments of “Micius” Quantum Satellite



Prospects

With the distance 1200km, 100 people at each end, and a 10Hz per person switching rate we can expect to see close to a 100% effect.

What if?

What if QT were violated in this experiment. . .

Consequences for Quantum Foundations would be significant

- Locality
- Super-determinism

But, this would pale into insignificance compared with the importance would be for the study of mind . . .

I think this would provide strong evidence for Cartesian duality . . .

. . . though we can think about other explanations.

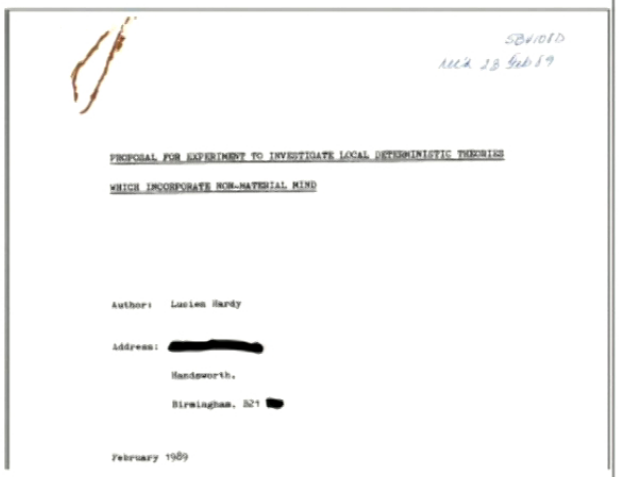
We are not invoking consciousness to solve the measurement problem

History of thinking about duality in Quantum Foundations (Wigner, Many Minds Interpretation, Copenhagen(?), . . .).

Here have a different flavour (not about solving the measurement problem).

Beginnings

I had the idea to use humans to switch the settings in a Bell experiment thirty years ago



PROPOSAL FOR EXPERIMENT TO INVESTIGATE LOCAL DETERMINISTIC THEORIES

WHICH INCORPORATE NON-MATERIAL MIND

Author: Lucien Hardy

Address: [redacted]

Handsworth,

Birmingham, B21 [redacted]

February 1989

Locality Determinism and Mind-matter Duality

Lucien Hardy

Department of Mathematical Sciences, University of Durham, Durham DH1 3LE, UK

It is shown that the class of theories that exhibit locality, physical determinism and interactive mind-matter duality must violate quantum mechanics in some situations.

1. Introduction

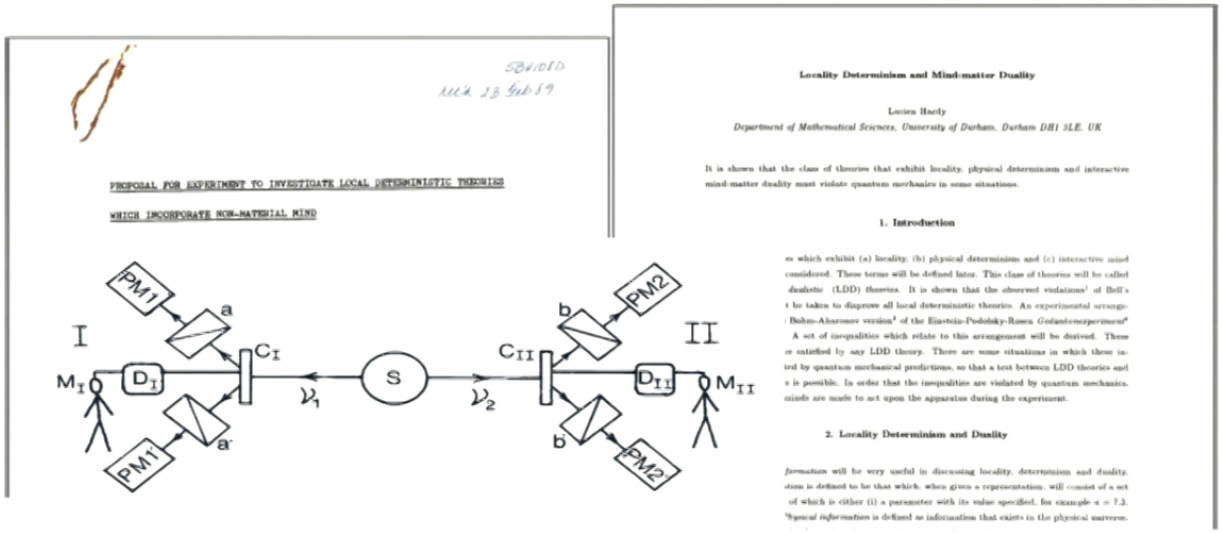
The class of theories which exhibit (a) locality, (b) physical determinism and (c) interactive mind matter duality are considered. These terms will be defined later. This class of theories will be called *local deterministic dualistic* (LDD) theories. It is shown that the observed violations[1] of Bell's inequalities[2] cannot be taken to disprove all local deterministic theories. An experimental arrangement similar to the Bohm-Aharonov version[3] of the Einstein-Podolsky-Rosen *Gedankenexperiment*[4] will be considered. A set of inequalities which relate to this arrangement will be derived. These inequalities must be satisfied by any LDD theory. There are some situations in which these inequalities are violated by quantum mechanical predictions, so that a test between LDD theories and quantum mechanics is possible. In order that the inequalities are violated by quantum mechanics, it is required that minds are made to act upon the apparatus during the experiment.

2. Locality Determinism and Duality

The concept of *information* will be very useful in discussing locality, determinism and duality. Abstractly, information is defined to be that which, when given a representation, will consist of a set with elements each of which is either (i) a parameter with its value specified, for example $a = 7.3$, or (ii) a function. *Physical information* is defined as information that exists in the physical universe.

Beginnings

I had the idea to use humans to switch the settings in a Bell experiment thirty years ago



PROPOSAL FOR EXPERIMENT TO INVESTIGATE LOCAL DETERMINISTIC THEORIES

WHICH INCORPORATE NON-MATERIAL MIND

Locality Determinism and Mind-matter Duality

Lucien Hardy
Department of Mathematical Sciences, University of Durham, Durham DH1 3LE, UK

It is shown that the class of theories that exhibit locality, physical determinism and interactive mind-matter duality must violate quantum mechanics in some situations.

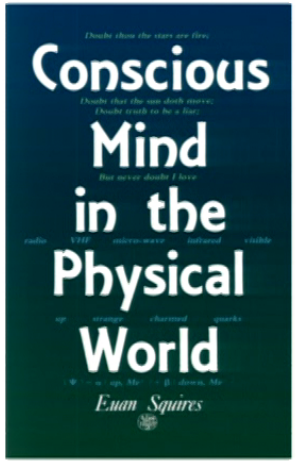
1. Introduction

es which exhibit (a) locality, (b) physical determinism and (c) interactive mind considered. These terms will be defined later. This class of theories will be called dualistic (LDD) theories. It is shown that the observed violations[1] of Bell's t be taken to disprove all local deterministic theories. An experimental arrange- Bohm-Aharonov version[2] of the Einstein-Podolsky-Rosen *Gedankenexperiment*[3] A set of inequalities which relate to this arrangement will be derived. These re satisfied by any LDD theory. There are some situations in which these in- ted by quantum mechanical predictions, so that a test between LDD theories and s is possible. In order that the inequalities are violated by quantum mechanics, minds are made to act upon the apparatus during the experiment.

2. Locality Determinism and Duality

formation will be very useful in discussing locality, determinism and duality. tion is defined to be that which, when given a representation, will consist of a set of which is either (i) a parameter with its value specified, for example $a = 7.3$. *Physical information* is defined as information that exists in the physical universe.

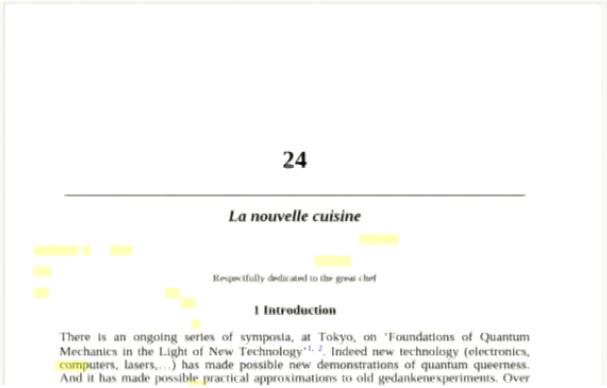
Euan Squires mentioned the idea in his 1990 book



measuring devices. If such an experiment were possible, would it give disagreement with quantum theory? An alternative idea, being studied by a research student here in Durham, L Hardy, is that there might exist genuine free agents which are outside the physically determined world. Such free agents could be responsible for "mind-acts" affecting the settings in the EPR experiment. Assuming these are constrained by the Bell inequality, they would give rise to violations of quantum theory. (Experiments along these lines would be precise tests of a well defined type of dualism. Unfortunately, the time scales involved suggest that they would be very difficult to perform.)

John Bell on using humans

In his 1990 paper, La Nouvelle Cuisine, John Bell suggested using "experimental physicists, or some other random devices" to choose settings.



24

La nouvelle cuisine

Respectfully dedicated to the great chef

1 Introduction

There is an ongoing series of symposia, at Tokyo, on 'Foundations of Quantum Mechanics in the Light of New Technology'[1, 2]. Indeed new technology (electronics, computers, lasers,...) has made possible new demonstrations of quantum queerness. And it has made possible practical approximations to old gedankenexperiments. Over

In the application to the Einstein–Podolsky–Rosen–Bohm two-photon experiment, a and b are the polarizer settings. Then we may imagine the experiment done on such a scale, with the two sides of the experiment separated by a distance of order light minutes, that we can imagine these settings being freely chosen at the last second by two different experimental physicists, or some other random devices. If these last second choices are truly free or random, they are not influenced by the variables λ.

John Bell did not, however, discuss issue of mind (more concerned with imposing locality).

Three things have changed in last thirty years:

1. Attitudes have changed.
2. Experiment is just about feasible.
3. I have tenure.

Back then I was very confident a positive result would be seen. By now I am think it is far less likely.

However, the probability $\times$ payoff is, I think, very big.

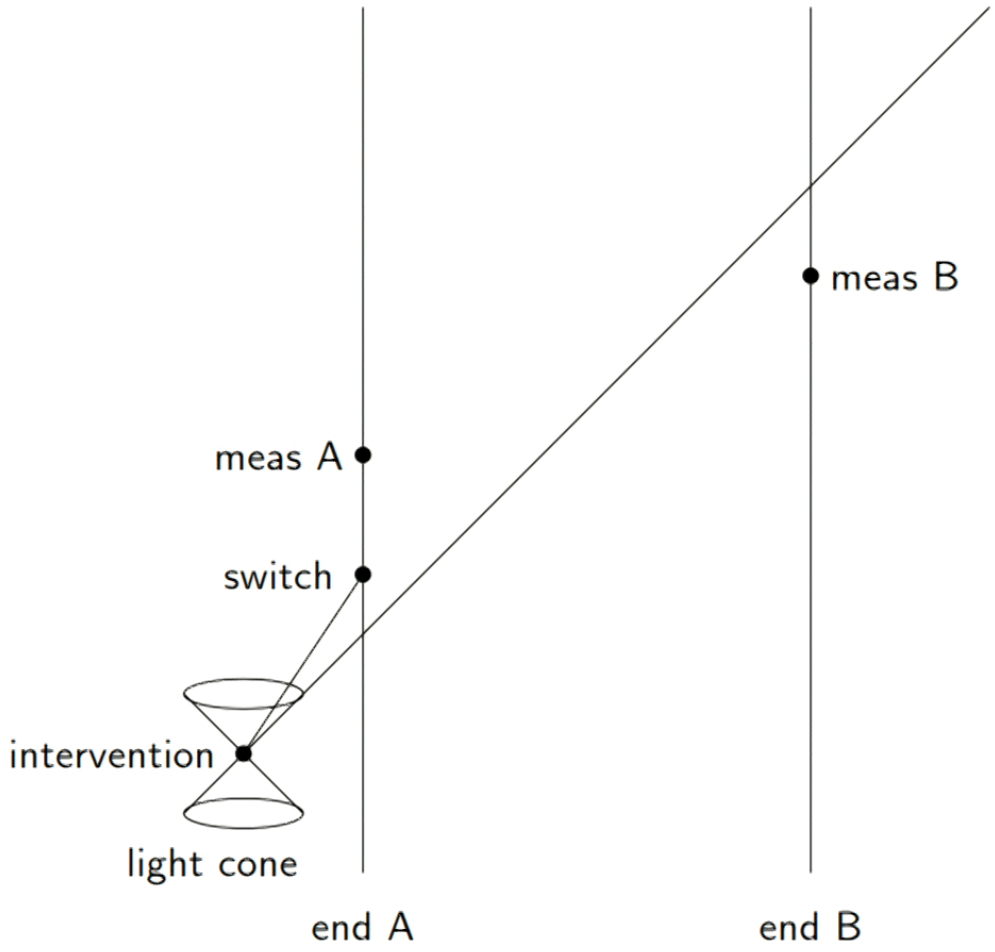
Often people say that Cartesian dualism is not a valid scientific point of view

However, this experiment shows we can address issue of dualism scientifically.

Even as a thought experiment this is valuable.

Retarded settings

What are retarded settings?



Let the state of switch box at end A at time t be

$$\alpha_t$$

This state may consist of hidden variables that appear in the fundamental theory (that are not directly accessible to experimentalists). Further, this state can describe any physical systems that can locally influence the setting at end A (so the term "switch box" is potentially broader than just referring to the box in the laboratory that appears to determine the setting).

According to our assumptions, in the absence of interventions, this state is given by some deterministic rules from the state at time 0

$$\alpha_t = f_t(\alpha_0)$$

We chose time $t = 0$ to be the last time that a light speed signal can communicate the state of machine at end A to the measurement event at end B.

If an intervention happens at a time $t' > 0$ then

$$\alpha(t') \neq f_{t'}(\alpha_0)$$

This is, simply, what we mean by an intervention.

We can write the *retarded setting* as

$$a_r = a(\alpha_0)$$

This is the prediction as to what value the setting would take according to the last information available at end B.

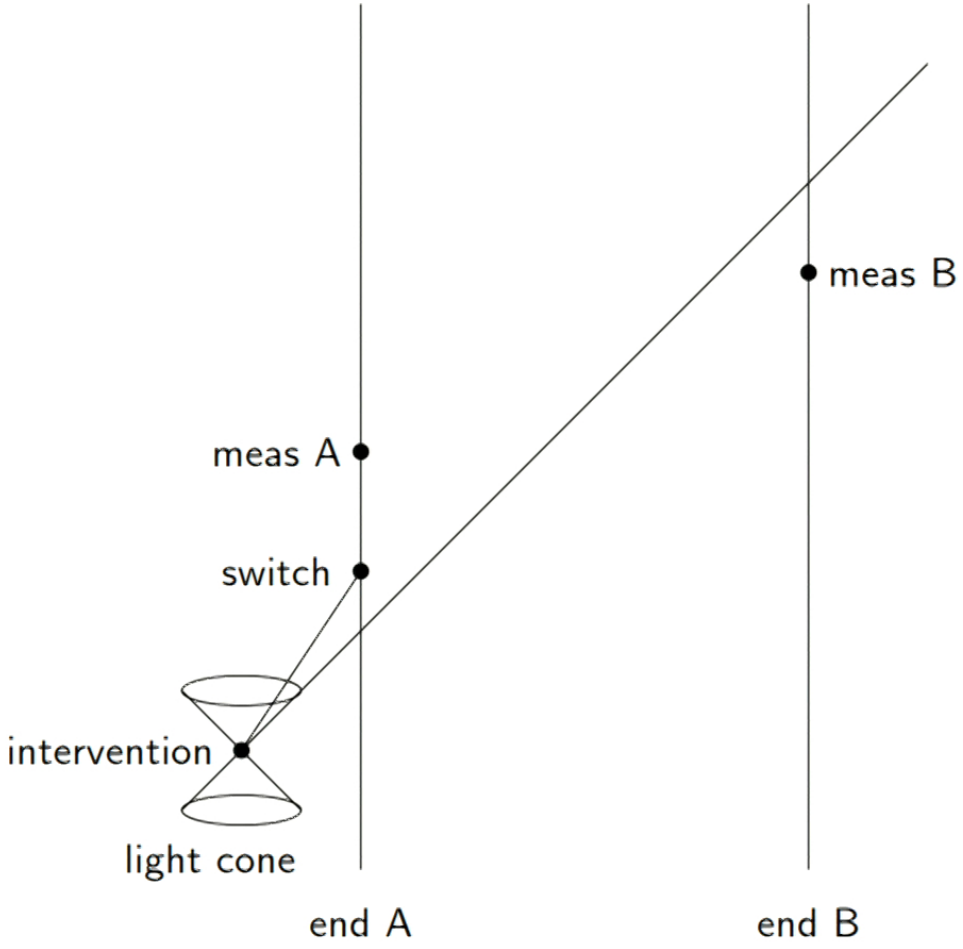
Bell inequalities with retarded settings

Outcome at end B can depend on b, b_r, a_r, and some local hidden variables.

$$B(b, b_r, a_r, \lambda)$$

Similarly we have

$$A(a, a_r, b_r, \lambda)$$



We use the mathematical result

$$X'Y' + X'Y + XY' - XY = \pm 2$$

where $X, X', Y, Y' = \pm 1$. We put

$$\begin{aligned} X &= A(a, a_r, b_r, \lambda) \\ X' &= A(a', a_r, b_r, \lambda) \\ Y &= B(b, b_r, a_r, \lambda) \\ Y' &= B(b', b_r, a_r, \lambda) \end{aligned}$$

Substitute integrate over λ

$$-2 \leq E(a', b'|a_r, b_r) + E(a', b|a_r, b_r) + E(a, b'|a_r, b_r) - E(a, b|a_r, b_r) \leq +2$$

These are the retarded Bell inequalities.

A model

Let

$$0 \leq \lambda < 2\pi \qquad \Gamma = \frac{1}{2\pi}$$

Define

$$A(a, b_r, \lambda) = \left\{ \begin{array}{ll} +1 & \text{for } \theta_L \leq \lambda < \theta_L + \pi \\ -1 & \text{for } \theta_L + \pi \leq \lambda < \theta_L + 2\pi \end{array} \right\}$$

and

$$B(b, a_r, \lambda) = \left\{ \begin{array}{ll} +1 & \text{for } \theta_R \leq \lambda < \theta_R + \pi \\ -1 & \text{for } \theta_R + \pi \leq \lambda < \theta_R + 2\pi \end{array} \right\}$$

It is easy to prove that

$$E(a, b|a_r, b_r) = 1 - \frac{2|\theta_R - \theta_L|}{\pi}$$

If we set

$$\theta_L = -\frac{\pi}{4}(1 + \cos(a - b_r)) \qquad \theta_R = \frac{\pi}{4}(1 + \cos(a_r - b))$$

we obtain

$$E(a, b|a_r, b_r) = -\frac{1}{2}(\cos(a - b_r) + \cos(a_r - b))$$

When the retarded settings are equal to the actual settings we get

$$E(a, b|a, b) = -\cos(a - b)$$

in agreement with Quantum Theory.

With this model we get a violation of Quantum Theory even when the actual and retarded settings are di?erent for only one end.

Discussion

- Experiment is difficult, but just feasible. Would act as a stretch goal.
- Open up field of BQI (Brain Quantum Interface) experiments.
- Unlikely QT would be violated. For me it is the super-determinism that is hardest to believe.
- If QT were violated, this would be a tremendously significant result (especially because of relationship with issue of mind).
- Would then need to perform future experiments using more and more complex inanimate systems, as well as other types of animate system.
- What are the odds?

Do we need to use humans, or will penguins do?