The Physical World as a Virtual Reality

Brian Whitworth
Massey University, Albany, Auckland, New Zealand
E-mail: bwhitworth@acm.org

Not only is the universe stranger than we imagine, it is stranger than we can imagine

Sir Arthur Eddington

Abstract

This paper explores the idea that the universe is a virtual reality created by information processing, and relates this strange idea to the findings of modern physics about the physical world. The virtual reality concept is familiar to us from online worlds, but our world as a virtual reality is usually a subject for science fiction rather than science. Yet the world could be an information simulation running on a multi-dimensional space-time screen. Indeed, if the essence of the universe is information, matter, charge, energy and movement could be aspects of information, and the many conservation laws could reduce to a single law of information conservation. If the universe were a virtual reality, its creation at the big bang would no longer be paradoxical, as every virtual system must be booted up. Ultimately, whether the world is an objective reality or a virtual reality is a matter for science to resolve. Modern information science can suggest how core physical properties like space, time, light, matter and movement could derive from information processing. Such an approach could reconcile relativity and quantum theories, with the former being how information processing creates space-time, and the latter how it creates energy and matter.

Key words: Digital physics, virtual reality, information theory

Modern online games show that information processing can create virtual "worlds", with their own time, space, entities and objects, e.g. Second Life (http://secondlife.com/). However that *our* physical world is a virtual reality (VR) is normally considered a topic of science fiction, religion or philosophy, not a theory of physics. Yet the reader is asked to keep an open mind, as one should at least consider a theory before rejecting it. This paper asks if a world that behaves just like the world we live in could arise from a VR simulation. It defines VR theory, asks if it is possible, considers how it relates to physics, and finally proposes how to evaluate the theory.

Strange Physics

While virtual reality theory seems strange, so do other current theories of physics, e.g. the many-worlds view of quantum physics proposes that each quantum choice divides the universe into parallel universes (Everett, 1957), so everything that can happen does in fact happen somewhere, in an inconceivable "multi-verse' of parallel universes. Even relatively main-stream physics theories are quite strange. Guth's inflationary model suggests that our universe is just one of many "bubble universes" produced by the big bang (Guth, 1998). String theory suggests the physical world could have 9 spatial dimensions, with six of them "curled up" from our perspective. M-theory puts our universe on a three dimensional "brane", floating in time along a fifth dimension we cannot see (Gribbin, 2000, p177-180). The cyclic-ekpyrotic model postulates that we exist in one of two 3D worlds that collide and retreat in an eternal cycle along a hidden extra connecting dimension (J. Khoury, 2001). Equally strange are the results of modern physics experiments, where time dilates, space curves, entities teleport and single objects multi-exist. At the cosmic level:

1. ***Gravity slows time***: An atomic clock on a tall building "ticks" faster than one on the ground.
2. ***Gravity curves space:*** Rays of light traveling around the sun are bent by curved space.
3. ***Speed slows time***. An atomic clock on a flying plane goes slower than one on the ground.
4. ***Speed increases mass***. As objects move faster, their mass increases.
5. ***The speed of light is absolute.*** Light shone from a torch on a spaceship moving at 9/10ths of the speed of light leaves the spaceship at the speed of light.

The above statements don't fit our normal reality concepts, yet they have been experimentally verified, e.g. in 1962 one of two synchronized atomic clocks was flown in an airplane for several days while the other stayed stationary on the ground. The result, as Einstein predicted, was that less time passed for the clock on the plane. The above are not theoretical possibilities but actual observable outcomes. Quantum physics introduces even more strangeness:

1. ***Teleportation***. Quantum particles can "tunnel", suddenly appearing beyond a barrier they cannot cross, like a coin in a sealed glass bottle suddenly appearing outside it.
2. ***Faster than light interaction***. If two quantum particles are "entangled", what happens to one *instantly* affects the other, even if they are light years apart.
3. ***Creation from nothing***. Given enough energy, matter can suddenly appear from an "empty" space (given no matter before).
4. ***Multiple existence***. Light passing through two slits creates a wave interference pattern. The interference continues even if the photons are shot through the slits *one at a time*, and *regardless of the time delay*. A single quantum entity, it seems, can interfere with itself.
5. ***Physical effects without causality***. Quantum events like gamma radiation occur randomly, and no physical cause for them has ever been identified.

The strange findings of physics experiments are driving the strange theories of physics.

Strange theories

Modern physics began when Maxwell presented his wave equations in 1900 and Einstein suggested special relativity in 1905 and general relativity in 1915. Despite considerable scientific skepticism, these theories met every experimental and logical test their critics could devise. Their predictive success surprised even their advocates, e.g. in 1933 Fermi's formulas pre-discovered the neutrino (a particle with no significant mass or charge) well before nuclear experiments verified it in 1953. Dirac's equations similarly predicted anti-matter before it too was later confirmed. These and other stunning successes have made the theories of quantum mechanics and relativity *the crown jewels of modern physics.* They have quite simply never been shown wrong. Yet, a century later, *they still just don't make sense*. As Kenneth Ford says of quantum theory:

"Its just that the theory lacks a rationale. "How come the quantum" John Wheeler likes to ask. "If your head doesn't swim when you think about the quantum," Niels Bohr reportedly said, "you haven't understood it." And Richard Feynman … who understood quantum mechanics as deeply as anyone, wrote: "My physics students don't understand it either. That is because I don't understand it."" (Ford, 2004, p98)

Similar statements could be made of relativity theory's claims that time and space are malleable. For perhaps the first time in the history of any science, the scholars of physics simply don't personally believe what the reigning theories of their discipline are saying. They accept them as mathematical statements that give correct answers, but not as literal world reality descriptions. This is, to say the least, an unusual state of affairs. The problem is not lack of use, as these theories permeate modern physics applications, from micro-computers to space exploration. By some estimates 40% of US productivity derives from technologies based on quantum theory, including cell phones, transistors, lasers, CD players and computers. Yet physicists use quantum theory because it works not because it makes sense:

"*… physicists who work with the theory every day don't really know quite what to make of it. They fill blackboards with quantum calculations and acknowledge that it is probably the most powerful, accurate, and predictive scientific theory ever developed. But … the very suggestion that it may be literally true as a description of nature is still greeted with cynicism, incomprehension, and even anger*." (Vacca, 2005)

The need is not for more proofs or applications but for more understanding. Physicists know the mathematics, but cannot connect it to their understanding of the world, i.e. the theories are useful but not meaningful. Physics has theories that work but which make no sense, e.g. Feynman observed that an electron traveling from A to B acts like it simultaneously traverses all possible intervening paths. His "sum over histories" theory gives the mathematics to calculate that to correctly predict quantum outcomes. Yet while most scientific theories increase understanding, this theory seems to take understanding away. How can *one* electron simultaneously travel *all* possible paths between two points? Is the theory a mathematical device or a reality description?

It is ironic that relativity theory and quantum theory not only contradict much of what we know (or think we know) of the world, they also contradict each other. Each has its domain - relativity describes macro space-time events, and quantum theory describes micro sub-atomic events. Each theory works perfectly in its own domain, but when put together they contradict, e.g. relativity demands that nothing travels faster than light, but quantum entangled particles can instantly affect each other from anywhere in the universe. As Greene notes:

"*The problem … is that when the equations of general relativity commingle with those of quantum mechanics, the result is disastrous*." (Greene, 2004, p15)

A symptom of the semantic failure of modern physics is that even after a century of successful validation these theories are not taught routinely in high schools. Physics has quarantined the problem by putting an almost impenetrable "fence" of mathematics around it:

"*… we have locked up quantum physics in "black boxes", which we can handle and operate without knowing what is going on inside*. (Audretsch, 2004) (Preface, p x).

Physicists today use these black boxes like magic wands to predict the universe, but why the mathematical "spells" work is unknown. Some argue that pragmatically it doesn't matter - if the mathematics works what else is needed? Yet others think that since these formulae describe the essence of physical reality, an explanation is due: "*Many physicists believe that some reason for quantum mechanics awaits discovery."* (Ford, 2004, p98)

One cannot relegate quantum and relativity effects to the "odd" corner of physics, as in many ways these theories *are* modern physics. Quantum theory rules the atomic world, from which the visible world we see emerges, and special and general relativity rule the cosmic world of vast space which surrounds and contains us. These two poles encompass everything we see and know about the physical world. It is unacceptable that these theories, however mathematically precise, continue to remain opaque to human understanding. Traditional reality concepts have had over a century to explain modern physics, and have not done so. Given the Sherlock Holmes dictum: "*…when you have excluded the impossible, whatever remains, however improbable, must be the truth*", let us now think the unthinkable: *that the physical world is a virtual reality*.

The virtual reality axiom

While never commonly held, the idea that the world is a virtual reality has a long pedigree. Over two thousand years ago Pythagoras considered numbers the non-material essence behind the physical world. Buddhism says the world is an illusion, as does Hinduism, which considers it God's "play" or Lila. Plato's cave analogy suggests the world we see, like the shadows on a cave wall, reflects rather than embodies reality. Plato felt that "God geometrizes" and Gauss believed that "God computes" (Svozil, 2005), both seeing the divine mind in the mathematical laws of nature, e.g. in Blake's illustration "The Ancient of Days" Urizen wield a compass upon the world. Zuse first expressed the concept in modern scientific terms, suggesting that space calculates (Zuse, 1969), and since then other scientists have explored the idea (Fredkin, 1990, Schmidhuber, 1997, Rhodes, 2001, Wolfram, 2002, Tegmark, 2007, Svozil, 2005, Lloyd, 2006).

A *virtual reality* is here considered to be a reality created by information processing. By definition it does not exist independently in and of itself, as it depends upon processing to exist. If the processing stops then the virtual reality must also cease to exist. In contrast an *objective reality* simply *is*, and does not need anything else to sustain it. This suggests two hypotheses about our reality:

1. ***The objective reality (OR) hypothesis:*** *That our physical reality is an objective reality that exists in and of itself, and being self-contained needs nothing outside of itself to explain it.*
2. ***The virtual reality (VR) hypothesis***: *That our physical reality is a virtual reality that depends upon information processing to exist, which processing must occur outside of itself.*

Whatever one's personal opinion, these views clearly contradict. If a world is an objective reality it cannot be virtual, and if it is a virtual reality it cannot be objective. These hypothesis are mutually exclusive, and each has implications, e.g. objective reality suggests the universe as a whole is permanent as it has nowhere to come from or go to, i.e. it contradicts big bang theory. To illustrate the depth of the contrast, consider the primary axiom of Lee Smolin's recent book:

"***There is nothing outside the universe***" (Smolin, 2001 p17).

The edifice of science itself is often assumed to rest upon this apparently self-evident statement, yet it is precisely this statement that VR theory contradicts. Indeed reversing Smolin's axiom gives the virtual reality axiom:

There is nothing in our universe that exists of or by itself.

This axiom arises as a VR processor cannot itself exist within the virtual reality its processing creates. A processor cannot create itself, as the virtual world creation could not start if a processor did not initially exist outside it. Hence any VR world, by definition, *must* have existence dimensions outside itself. Many physics theories, like string theory, suggest that this world has additional dimensions, yet for some reason these are assumed to be in the world, just "curled up" to be invisible to us. In contrast VR theory's additional dimension(s) must be outside the VR world. Yet what is the difference between an unknowable dimension that is "in the world" and one that is "outside the world"? If the contrast is untestable, science favors neither view. To postulate the world is virtual does not contradict science, but rather engages its spirit of questioning. Science is a method of asking questions, not a set of reality assumptions (Whitworth, 2007). Scientists are entitled to ask if what could be so actually is so. The only constraint is that the question be decided by data from the world, gathered by an accepted research method. Science does not require an objective world, only information to test theories against, which a VR can easily provide. Not only can science accommodate the virtual world concept, a virtual world could also sustain science.

Can a virtual reality be real?

Doesn't common sense deny that the world which appears so real to us is a virtual reality? Philosophers like Plato have long recognized that the reality of reality is not provable (Esfeld, 2004). Bishop Berkeley's solipsism argued that a tree falling in a wood will make no sound if no-one is there to hear it. Dr Johnson is said to have reacted to the idea that the world is created by the mind by stubbing his toe on a stone and saying "I disprove it thus". However VR theory does not claim that the world is unreal to its inhabitants, only that it is not objectively real.

To clarify the difference, suppose information processing in one world creates a second virtual world. To an observer in the first world, events within the virtual world are "unreal", but to an observer within the virtual world, virtual events are as real as it gets. If a virtual gun wounds a virtual man, to that virtual man the pain is "real". That a world is calculated does not mean it has no "reality", merely that its reality is local to itself. Even in a virtual reality, stubbed toes will still hurt and falling trees will still make sounds when no-one is around. Reality is relative to the observer, so by analogy, a table is "solid" because our hands are made of the same atoms as the table. To a neutrino, the table is just a ghostly insubstantiality through which it flies, as is the entire earth. Things constituted the same way are substantial to each other, so what is "real" depends upon what measures it. To say a world is a virtual doesn't mean it is unreal to its inhabitants, only that its reality is "local" to that world, i.e. it is not an objective reality.

The science-fiction movie The Matrix illustrated how a calculated reality could appear real to its inhabitants (as long as they remained within it). This was possible because people in the matrix only knew their world from the information they received, which is exactly how we know ours. Yet this movie does not illustrate VR theory, as its matrix was created by machines in a physical world, and matrix inhabitants could escape to this "real" world, i.e. the physical world was still presumed to be the "end of the line" for "realness". In contrast VR theory does not assume this. It merely argues that our reality is a local reality, i.e. dependent upon processing outside itself. Yet the Matrix movie did correctly show that any reality could in fact be virtual:

"*But maybe we are all linked in to a giant computer simulation that sends a signal of pain when we send a motor signal to swing an imaginary foot at an imaginary stone. Maybe we are characters in a computer game played by aliens.*" (Vacca, 2005, p131)

However Hawking's next sentence was "*Joking apart, …*" Though our world *could* be virtual, for some reason to imagine that it *is* must be presented as a joke involving aliens.

Approaching virtual reality

Current physics seems to approach VR theory in three ways:

1. **Calculable Universe Hypothesis**: That our physical reality can be simulated by information processing that is calculable.
2. **Calculating Universe Hypothesis**: That our physical reality uses information processing in its operation to some degree.
3. **Calculated Universe Hypothesis:** That our physical reality is created by information processing based outside the physical world we register.

The calculable universe hypothesis states that physical reality **can be simulated by information processing** (Tegmark, 2007). Calculable here does not mean deterministic, as processing can be probabilistic, nor does it mean mathematically definable, as not all definable mathematics is calculable, e.g. an infinite series. Many scientists accept that the universe is calculable in theory, as the Church-Turing thesis states that for any specifiable output there is a finite program capable of simulating it. If our universe is lawfully specifiable, even probabilistically, then in theory a program could simulate it (though this universal program might be bigger than the universe itself). This hypothesis does not say the universe *is* a computer, but that it could be simulated by one, i.e. it does not contradict objective reality.

The calculating universe hypothesis states that the universe **uses information processing** algorithms to create reality, e.g. quantum mechanical formulae. Supporters of this view are a minority, but include mainstream physicists like John Wheeler, whose phrase "*It from Bit*" suggests that objects ("it") somehow derive from information ("bit"). Now information processing does not just *model* the universe, it *explains* it (Piccinini, 2007). While a computer simulation *compares* its output to the physical world, in a computer explanation the information processing *creates* reality, i.e. the latter is a theory about how the world actually works. Now the world is not just *like* a computer, it *is* a computer.

The calculated universe hypothesis goes a step further, stating that physical reality **is created by external information processing**, which equates to the VR hypothesis presented earlier. Now the physical "real" world is the computer *output* rather the computer *process*. Supporters of this "strong" virtual reality theory are few (Fredkin, 1990), with none in the physics mainstream.

A common criticism of the calculated hypothesis is that we "…*have no means of understanding the hardware upon which that software is running. So we have no way of understanding the real physics of reality.*" (Deutsch, 2003). The argument is that virtuality implies an unfalsifiable reality, and so is unscientific and should be dismissed. However this misrepresents VR theory, which postulates no other dimensional "hardware". It is a theory about *this world*, not some other unknowable world, and its hypothetical contrast is that *this world* is an objective physical reality. Unprovable speculations about other virtual universes (Tegmark, 1997), or that the universe could be "saved" and "restored" (Schmidhuber, 1997), or that our virtual reality could be created by another VR (Bostrom, 2002), fall outside the scope of VR theory as proposed here.

The above three hypotheses cumulate, as each requires the previous to be true. If the universe is not calculable it cannot use calculating in its operations, and if it cannot operate by calculating it cannot be a calculated reality. They also constitute a slippery slope, as if one accepts that physical reality is *calculable* then perhaps it is also *calculating*, and if it is calculating, then perhaps it is also *calculated*, i.e. virtual. On the surface the calculating universe hypothesis seems to give the best balance, combining an objective universe with information processing, e.g. Deutsch says:

"*The universe is not a program running somewhere else. It is a universal computer, and there is nothing outside it.*" (Kelly, 2002)

Yet if the physical world is a universal computer with nothing outside it, *what is its output*? What is the "output" for example of the solar system? While the brain inputs and outputs information like a computer, most of the world does not (Piccinini, 2007). Or if the physical world is the computing output, *what is doing the processing?* That the universe computes the universe is a recursive paradox (Hofstadter, 1999), as physical processing (occurring in the physical world) creating that same physical world is an entity creating itself, but a universe can no more output itself than my computer can output itself. The physical universe cannot be both the universal computer and its output. If the physical world is produced by information processing, as modern physics computations imply, the processing cannot also be the same physical world, i.e. it must occur elsewhere. Hence under examination, the calculating universe hypothesis collapses to the calculated universe hypothesis, i.e. to VR theory. There are only two viable theory options– objective reality and virtual reality.

Virtual reality requirements

What would be necessary to create a VR that behaves like our world? First one must assume *information processing constancy, that the properties of information processing are constant*, e.g. information processing in our world involves discrete data and calculable algorithms. It is reasonable to assume that a virtual reality's processing works the same way. The requirements include:

1. ***Finite processing allocations***. *That the processing that creates a VR that behaves like our world allocates it's processing in finite amounts*. Apart from the fact that we have no concept of what "infinite" processing means, finite processing allocation suggests that every quanta of matter, time, energy and space has a finite information capacity: "*…recent observations favor cosmological models in which there are fundamental upper bounds on both the information content and information processing rate.*" (Davies, 2004 ,p13) While the processing power needed to run a universe is enormous it is not inconceivable, e.g. Bostrom argues that all human history would require less than 10^{36} calculations to simulate, and a planet sized computer could provide 10^{42} operations per second (Bostrom, 2002).
2. ***Autonomy***. *Once started, a VR that behaves like our world must run itself without further information input.* Most human computer simulations require regular data input to run. In a virtual world that behaves like ours, such external data input would constitute a "miracle", and in our world miracles are at best rare. This VR simulation must run itself without miracles, i.e. without ongoing data input.
3. ***Consistent self-registration***. *A VR that behaves like our world must register itself consistently to internal "observers"*. Most human computer simulations output data to an outside viewer, but we see our world from within. We register "reality" when light from the world interacts with our eyes (also in the world). For a virtual reality to "register itself" internal interactions must be consistent with respect to each local "observer".
4. ***Calculability***. *A VR that behaves like our world must at all times be calculable*. If processing is allocated in finite amounts, local calculations must not tend to infinity. While many mathematical calculations can do just this, a calculable VR is guaranteed to avoid that.

These requirements constrain any VR model of our world. A prima facie case is now presented that a VR model could help explain some of the strange results of modern physics.

A prima facie case that the physical world is a virtual reality

One of the mysteries of our world is how every photon of light, every electron and quark, and indeed every point of space itself, seems to just "know" what to do at each moment. The mystery is that these tiniest parts of the universe have no mechanisms or structures by which to make such decisions. Yet if the world is a virtual reality, this problem disappears. Other examples of how a VR approach could illuminate current physics issues include:

1. ***Virtual reality creation***. A virtual reality usually arises from "nothing", which matches how the big bang theory proposes our universe did arise (see next section).
2. ***Maximum processing rate***. The maximum speed a pixel in a virtual reality game can cross a screen is limited by the refresh rate of the screen. In general, a virtual world's maximum event rate is fixed by the allocated processing capacity, so the speed of light maximum could reflect a maximum VR information processing rate (see next section).
3. ***Digital processing***. Everything in a calculated world must be digitized, i.e. discrete at the lowest level. Plank's discovery that light is quantized (as photons) could then generalize not only to charge, spin and matter, but also to space-time. Discrete space-time avoids the

mathematical infinities of continuous space-time, e.g. loop quantum gravity theory (Smolin, 2001).

4. ***Non-local effects***. The processing that creates a virtual space is not limited by that space, e.g. a CPU drawing a screen is no "further" from any one screen point than any other. All screen points are equidistant with respect to the CPU, so VR processor effects can ignore screen distance, i.e. be non-local. The non-local collapse of the quantum wave function could be such an effect, explainable as common processing that is equidistant to all points of the multi-dimensional "screen" that is our universe.

5. ***Processing load effects***. On a distributed network, nodes with a high local workload will slow down, e.g. a video may download and play slower than usual if the local server has many demands. A high matter concentration may constitute a high processing demand, so a massive body could slow down the processing of space-time, causing space to "curve" and time to slow. Likewise, if faster movement requires more processing, high speeds could cause time to "dilate" and space to extend. Relativity effects could arise from local processing overloads.

6. ***Information conservation***. If a system inputs no new information after it starts, it must also not lose the information it has, or it will "run down". Our universe has not run down after an inconceivable number of micro-interactions over 14+ billion years. So if it is made of information. it must conserve it. If matter, energy, charge, momentum and spin are all information, all the conservation laws could reduce to one. Einstein's matter/energy equation ($e = mc^2$) would then simply describe information going from one form to another. The only conservation law VR theory requires is the conservation of information.

7. ***Algorithmic simplicity***. If the world arises from finite information processing, it is necessary to keep frequent calculations simple. Indeed the core mathematical laws that describe our world are surprisingly simple: "*The enormous usefulness of mathematics in the natural sciences is something bordering on the mysterious and there is no rational explanation for it*." (Wigner, 1960) In VR theory physical laws are simple because they must actually be calculated.

8. ***Choice creation***. Information requires a choice between options (Shannon and Weaver, 1949), so a predictable choice is not really a choice in this sense, and so has no information. Our reality however does create choices by quantum randomness. Einstein never accepted that quantum events were truly random, i.e. no prior world events could predict them. That a radioactive atom decays by pure chance, whenever "it decides" was to him unacceptable, as he felt every physical event must be predicted by another physical event, so one day as yet unknown "hidden properties" would predict quantum randomness. Yet if quantum randomness creates choice, and the source is VR processing outside this world, no hidden variables will ever be found.

9. ***Complementary uncertainty***. In Newtonian mechanics one can know both an object's position and momentum, but Heisenberg's uncertainty principle means one cannot know both at once for quantum objects. Knowing one property with 100% certainty makes the other entirely uncertain. This is not measurement "noise", but seems a property of reality, as if measuring position displaces momentum information, and vice-versa. If complementary object properties use the same memory location, an object can *appear* (in the VR interface) as having either position *or* momentum, but not both at once (Rhodes, 2001).

10. ***Digital equivalence***. Every digital symbol calculated by the same program is identical to every other, e.g. every "a" on this page identical to every other one, because all arise from the same computer code. In computing terms, the objects are "instances" of a general class. Likewise every photon in the universe is exactly identical to every other photon, as is every

electron, quark, etc. While the objects we see have individual properties, quantum objects like photons seem all pressed from identical moulds. VR theory suggests that this is so because each is created by the same digital calculation.

11. ***Digital transitions***. When one views a digital animation it looks continuous, but it is in fact a series of state transitions, e.g. a movie is a series of still frames run together fast enough to look like a continuous event. Only if the projector is slowed down does one see a series of still pictures. Quantum mechanics describes quantum interactions in similar terms, as state transitions. These transitions could explain quantum tunneling, where an electron at A suddenly appears at C without moving through the intervening area B which is impenetrable to it. While this is strange for an objective reality, in a VR all object movement is expected to involve state transitions.

Individually none of the above points is convincing, but together they offer what a court might call circumstantial evidence. When coincidences mount they argue that a case is worth investigating. This plausibility argument is bolstered by cases where OR theory struggles but VR theory does not. Two such cases are now given in more detail.

Where did the universe come from?

The traditional view of our universe was that as an objective reality it “just is”, and so has always existed. While its parts may transform, its total is in a “steady state” that always was and always will be. The alternative view is that the universe did not always exist, but arose at some specific point, which also created space and time. During the last century these two theories battled it out for supremacy on the stage of science. Steady-state theory proponents included respected physicists, who felt the idea that the entire universe expanded from a single point was highly unlikely. However Hubble’s finding that the galaxies around us are all red-shifted suggested that the universe is indeed expanding. Since an expanding universe has to expand from somewhere, scientists could run the expansion backwards to a source “big bang” that began the universe about 15 billion years ago. The discovery of cosmic background radiation, left over from the big bang, has largely confirmed the theory today in the minds of most physicists.

Big bang theory sidesteps questions like: “What existed before the big bang?” by saying “There was no time or space before the big bang”. Yet if time and space suddenly “appeared” for no apparent reason at the big bang, could they equally suddenly disappear tomorrow? Big bang theory implies a dependent universe, so “What is it dependent upon?” is a valid question, even without time and space. If nothing in our universe is created from nothing, how can the entire universe come from nothing? That this universe arose from nothing is not just incredible, it is inconceivable. One can state the problems simply:

1. What caused the big bang?
2. What caused space to start?
3. What caused time to start?
4. How can a big bang arise when there is no time or space?
5. How can space be caused if there is no “there” for a cause to exist within?
6. How can time be started if there is no time flow for the starting to occur within?

The big bang contradicts the theory that the universe is objectively real and complete in itself. How can an objective reality, existing in and of itself, be created out of nothing? The failure of the steady state theory of the universe removes a cornerstone of support for the OR hypothesis. In contrast virtual reality theory meshes well with a big bang. No virtual reality can have existed forever, since it needs a processor to start it up. All virtual realities “start up” at a specific moment of time, typically with a sudden influx of information. Every time one starts a computer game or boots up a computer, such a “big bang” occurs. From the virtual world perspective its creation is always from “nothing”, as before the virtual world startup there was indeed no time or space *as defined by that world*. There was nothing relative to that world because the world itself did not exist. It is a hallmark of virtual realities that they come into existence at a specific event in their space and time, which also initiates their space-time fabric. In VR theory the big bang was simply when our universe was “booted up”.

The big bang is an accepted aspect of modern physics that VR theory accommodates but OR theory does not. It illustrates that VR/OR arguments can be resolved by appeal to experimental data *from this world*. Just as the steady state versus big bang theories were resolved by research, so the more general virtual vs. objective theory contrast can be resolved by research. To decide if the world is objective or virtual we simply need to consider what the physical data is telling us.

Why does our universe have a maximum speed?

This paper began with the question: *“Why does the universe have a maximum speed?”* Einstein *deduced* that nothing travels faster than light because the world works the way it does, but did not explain why it had to be that way. Why cannot an object’s speed simply keep increasing? Why must there be a maximum speed? If light is like a classical wave, its speed should depend upon the elasticity and inertia of the medium it travels through. As light travels through space, its speed should depend upon the elasticity and inertia of space, but how can empty space have properties? Once space was considered a luminiferous “ether” through which objects move as a fish swims through water, but such a space gave movement a fixed frame of reference, and in 1887 Michelson and Morley showed that space didn’t work that way. Einstein discovered the speed of light was the real absolute, which discredited the spatial “ether” idea, but left the problem that empty space, the medium of light, was “nothing”. Mathematical properties like length, breadth and depth give no basis for elasticity or inertia. To say the speed of light defines the elasticity of space argues backwards, that an outcome determines a cause. The speed of light should conclude the argument, not begin it, i.e. the nature of space should define the rate of transmission through it. How can “empty space”, devoid of object properties, be a “medium” that not only transmits light but also limits its speed?

This paradox, like many others, arises from assuming objective reality. If one assumes objects exist in and of themselves one needs a context for them to exist within. The ether’s proponents thought the context space was like the objects it contained, as fish and water are. Space, which contains objects, cannot itself also be an object, else it would have to exist in itself. Yet Newton’s space and time contexts were replaced by an equally absolute space-time context:

“…*absolute space-time is as absolute for special relativity as absolute space and absolute time were for Newton* …” (Greene, 2004, p51)

Einstein replaced space and time with space-time, but a context is still a context. Like Newton, he believed that *objects exist of themselves*, which put him at odds with quantum theory’s non-local equations. Any theory that assumes objects exist independently must also *assume* a reality context for them to exist within, e.g. string theory assumes strings exist in a space-time context. Such an assumed context, whether space or space-time, cannot have properties like the objects it contains. Yet the speed of light limit suggests that space as a transmission medium does have properties.

In contrast, virtual reality theory assumes nothing except that everything is information. While objective reality must assume a space-time context different from its object constituents, virtual reality theory is not constrained this way. Information, as a universal constituent, avoids the problem that a substance cannot exist within itself as information processing can “stack”, i.e.

processing can create processing. That VR objects arise from information processing does not conflict with space itself arising the same way. That a virtual space is empty of "objects" need not make it empty of structure, e.g. an idle computer network, with no messages to send, still has protocols and connections to maintain. Space as a virtual processing network supports the modern view that empty space is not "empty", and implies a maximum network processing rate. The Lorentz transformations suggest the maximum rate objects move through space-time trades off between space and time, e.g. for a photon moving at the speed of light (maximum) the time rate of change is zero, i.e. time stands still. If both space and time arise from a fixed processing allocation, that their sum total adds up to a fixed amount is reasonable. That our universe has maximum speed is a fact of physics that VR theory explains well but objective reality theory does not.

Evaluating virtual reality theory

Possible responses to this prima facie case for the world as a virtual reality include:

1. *Spurious*. One can satisfy any world requirements by appropriate assumptions, so a VR model can always be found to match our world. This response is less likely if the assumptions are few and reasonable.
2. *Coincidence*. The matches between VR theory and modern physics are fortunate coincidences. This response is less likely if the matches found are many and detailed.
3. *Useful*. Seeing the world in information processing terms may open up new perspectives in physics. This response is more likely if VR theory explains new things.
4. *Veridical*. Our world is in all likelihood a virtual reality. This option is more likely if VR theory explains what other theories cannot.

While it the reader can decide their own response, it is suggested that virtual reality theory deserves consideration alongside physic's other strange theories. That the essence of the universe is information may not be correct, but it is an approach worth exploring. Can science evaluate if a world is a virtual reality from within it? Suppose one day that the computer code that creates "The Sims", a virtual online world, became so complex that some Sims within the simulation began to "think". Could they deduce that their world was a virtual world, or at least that it was likely to be so? If simulated beings in a simulated world acquired thought would they see their world as we see ours now? A virtual entity could not *perceive* the processing that creates its world, but it could *conceive* it, as we do now.

One response might be to try to "hack" into the universal program, to use its operation for their benefit, and our scientists currently developing quantum computers may be doing just that (Lloyd, 1999). Another is to contrast how a virtual reality would behave with how our world actually behaves. The scientific contrast is the VR vs OR hypotheses presented earlier. Data from the world can be used to compare them, and while one can never "know" entirely, one can deduce a likelihood, which is all our science does anyway.

However in testing a theory one must not select data to support it. The data must be unbiased, not chosen by the researcher (to fit their case). It is not enough to find that *selected* computer programs, like cellular automata, mimic *selected* world properties (Wolfram, 2002), as then the researcher chooses the explanation. There is no need for "a new kind of science" if the old kind still works, i.e. one must not select the parts of reality a VR theory explains. One way to avoid this trap is to *derive the core of physics from first principles*, i.e. begin with information properties and derive physical properties like space, time, light, energy, electrons, quarks and movement. This would then explain not just selected world events, but its operational core. The approach is to assume that VR theory is true, then "follow the logic" until it fails. If the world is not a virtual reality, this should soon generate outcomes inconsistent with observations. Conversely if the world is a virtual reality, this should explain facts that objective reality theories cannot. Ultimately, the success or failure of VR theory depends upon how well it explains our world.

Confusion arises if one imagines objective reality is proven by science. It is not. Objective reality theory is as unprovable by science as virtual reality theory is, and for the same reason, e.g. if everyone else assumed the world was a virtual reality, one would have difficulty proving it was not. It is inconsistent to dismiss a new theory as unprovable when the accepted theory is in the same boat. Both theories are falsifiable, e.g. one could disprove VR theory by showing some incomputable physics, as if reality does what information processing cannot then the world cannot be virtual. Yet currently, while mathematics has many incomputable algorithms, all known physics seems to be computable. Equally OR theory is falsifiable, as if the physical world does what an objective reality could not, the world cannot be objectively real. Currentlmodern physics is challenging *physical realism* assumptions in exactly this way, e.g. (Groblacher et al., 2007):

1. *Object locality*: That objects exist in a locality that limits their event interactions.
2. *Object reality*: That objects have inherent properties that their existence carries forward from one moment to the next, which determine their behavior independent of measurements.

Evaluating virtual reality theory challenges a core physics axiom. Chaitin has shown (following Gödel) that physics and mathematics depend upon an infinite number of irreducible facts or axioms, that are not “proven” (in the usual sense) (Chaitin, 2006). Such axioms, Chaitin argues, are normal for science, but should be distinguished from typical “facts” in evaluation. Since their value is that they explain more than they assume, they are assessed not by “proof” but by fruitfulness, e.g. changing Euclid’s parallel postulate gave rise to the new field of hyper-geometry. Axioms then must be tried out to assess them, as has been proposed for VR theory – to try it out to see where it leads.

Discussion

Almost a century ago Bertrand Russell dismissed the idea that life is a dream using Occam’s razor (prefer the simpler theory):

"*There is no logical impossibility in the supposition that the whole of life is a dream, in which we ourselves create all the objects that come before us. But although this is not logically impossible, there is no reason whatever to suppose that it is true; and it is, in fact, a less simple hypothesis, viewed as a means of accounting for the facts of our own life, than the common-sense hypothesis that there really are objects independent of us, whose action on us causes our sensations*." (Russell, 1912)

However in VR theory objects could be independent of us but still not objectively real. All physical entities, events and the space-time context itself could arise from information processing. That information is the basic underlying “quintessence” of the universe is today not so easily dismissed. Given the big bang, what is simpler, that an objective universe was created out of nothing, or that a virtual reality was booted up? Given a maximum speed of light, what is simpler, that it depends upon properties of featureless space or that it reflects a maximum network processing rate? Similar questions can be asked for each of the points of Table 1. Modern physics increasingly suggests that virtual reality is a simpler theory, i.e. Occam’s razor now favors virtual reality theory.

While VR theory changes the mathematics of physics little, it drastically changes its meaning, as if the universe is virtual then our physical bodies are pixilated avatars in a digital world. This hardly flatters the human ego, but then again, science has done this before:

"*Since our earliest ancestors admired the stars, our human egos have suffered a series of blows*." (Tegmark, 2007)

Copernicus discovered that the Earth is not the center of the universe, and we now know that our tiny planet circles a mediocre star two-thirds of the way out of an average million, million star galaxy, itself within a million, million galaxy universe. Darwin discovered that we are not the biological center of things either, and over 99.9% of every species that ever lived are now extinct. Even the matter we are made of is only about 4% of the universe, with the rest being dark matter (23%) and dark energy (73%) (Ford, 2004, p246). Freud found that the sub-conscious affects our life more than the conscious, and neuroscientists find the brain "split" at the highest (cortical) level (Sperry and Gazzaniga, 1967), suggesting our unitary "self" is also an illusion (Whitworth, 1975). Science may offer further disillusionments in areas like dreams, genetics and consciousness. The trend is clear: science finds us to actually be less than we imagine, and we imagine ourselves to actually be more than science finds we are. Would one more ego blow, say that our reality didn't exist objectively at all, be a surprise?

For a century physicists have tried unsuccessfully to interpret quantum and relativity theories with traditional objective reality concepts. Yet quantum experiments on Bell's theorem flatly contradict both the locality and reality assumptions of physical realism (Groblacher et al., 2007). Isn't it is time to try something new?

Physicists today commonly talk of the "multi-verse" (Deutsch, 1997, Lloyd, 2006) , where our universe is just one of many, following Hugh Everett's many worlds theory that at every atomic event choice the entire universe splits into separate universes that explore each choice. Yet imagine how many universes that means, if every photon, electron and atom in the universe creates a new universe at every throw of the quantum dice. VRT at least it just involves one universe, albeit a virtual one. Yet physicists who call for radical new views of reality still balk at the idea of virtual reality. Modern physics implies a calculated world, so why not consider it? That we cannot imagine something is so, or that we would wish it were not so, are not reasons for it to actually be not so. Ultimately, that the world is virtual or real is not our choice. One must accept reality whatever form it takes.

Theoretical physics is currently in a bind. On the one hand, mathematical speculations about unknowable dimensions, branes and strings seem increasingly pointless and untestable (Woit, 2007). On the other hand, objective realism seems to be facing paradoxes it can never, ever, solve. This paper suggests virtual reality theory is *a real hypothesis about the knowable world.* It could reconcile the contradiction between relativity and quantum theory, with the former how processing creates space-time, and the latter how it creates energy, matter and charge. A virtual approach could open up new ideas, as virtual objects need no inherent properties beyond those embodied in the calculations that create them. VRT could solve the quantum measurement problem, as if reality is in effect a processing interface, an observer viewing an object does indeed "create" it. Online virtual worlds do not calculate the entire world onscreen at once. The computer only calculates what the viewer chooses to view, after they choose to view it. The calculations are done as required, a process called "culling". If what we call reality is a multi-dimensional graphical user interface (MDGUI), one expects it to be calculated on demand. The VR viewer would be no more aware of this than a virtual game player is, as everywhere one looks, the world "exists". That our reality is only calculated when we "measure" or interact with it would well explain the measurement problem of physics. Yet there is a twist, as if our world is a virtual reality, our physical bodies are within it, not outside it. In a computer game, the player exists outside the screen interface, but in the case of our world, we are physically the avatar, viewing the world from within. This makes this world a recursive interface, that both sends to and receives from itself. If so, it is like no other information interface that we know.

Table 1. Virtual properties and physical outcomes

Virtual Property	Physical Outcome
Virtual reality creation. Virtual worlds must begin with an information influx from "nothing", that also begins VR time/ space.	*The big bang.* The universe was created out of nothing by a "big bang" in a single event that also created time and space.
Digital processing. All events/objects that arise from digital processing must have a minimum quantity or quanta.	*Quantum minima.* Light is quantized, as photons. Matter, energy, time, and space may be the same, i.e. have a minimum amount.
Maximum processing rate. Events in a VR world must have a maximum rate, limited by a finite processor.	*Light speed.* The speed of light is a fixed maximum for our universe, and nothing in our space-time can move faster.
Non-local effects. A computer processor is equidistance to all screen "pixels", so its effects can be "non-local" with respect to its screen.	*Wave function collapse.* The quantum wave function collapse is non-local - entangled photons on opposite sides of the universe may instantly conform to its requirements.
Processing load effects. If a virtual processing network is overloaded, its processing outputs must be reduced.	*Matter and speed effects.* Space curves near a massive body and time dilates at high speeds.
Information conservation. If a stable VR is not to gain or lose information it must conserve it.	*Physical conservation.* Physical existence properties like matter, energy, charge, spin etc are either conserved or equivalently transform.
Algorithmic simplicity. Calculations repeated at every point of a huge VR universe must be simple and easily calculated.	*Physical law simplicity.* Core physical processes are describable by relatively simple mathematical formulae, e.g. gravity.
Choice creation. A random number function in the VR processor could provide the choices needed to create information.	*Quantum randomness.* The quantum "dice throw" is to the best of our knowledge truly random, and unpredictable by *any* world event.
Complementary uncertainty. Calculating one property of a self-registering interface may displace complementary data.	*Heisenberg's uncertainty principle.* One cannot know both a quantum object's position and momentum, as knowing either fully makes the other entirely unknown.
Digital equivalence. Every digital object created by the same code is identical.	*Quantum equivalence.* All quantum objects, like photons or electrons, are identical to each other.
Digital transitions. Digital processes simulate event continuity as a series of state transitions, like the frames of a film.	*Quantum transitions.* Quantum mechanics suggests that reality is a series of state transitions at the quantum level.

Acknowledgements

Thanks to Professor Onofrio L. Russo, NJIT, for arousing my interest in the subject, to Professor Ken Hawick, Massey University, for listening to my ramblings, and to Professor Cris Calude, Auckland University, for a valuable critique.

References

AUDRETSCH, J. (Ed.) (2004) *Entangled World: The fascination of quantum information and computation*, Verlag, Wiley.

BOSTROM, N. (2002) Are you Living in a Computer Simulation? *Philosophical Quarterly*, 53**,** 243-255.

CHAITIN, G. (2006) The limits of reason. *Scientific American*, 294**,** 74-81.

DAVIES, P. (2004) Emergent Biological Principles and the Computational Properties of the Universe. *Complexity* 10 11-15.

DEUTSCH, D. (1997) *The Fabric of Reality*, Penguin Press, Allen lane.

DEUTSCH, D. (2003) Physics, Philosophy and Quantum Technology. IN SHAPIRO, J. H. A. H., O. (Ed.) *Proceedings of the Sixth International Conference on Quantum Communication, Measurement and Computing.* Princeton, NJ, Rinton Press

ESFELD, M. (2004) Quantum Theory: A Challenge for Philosophy! IN AUDRETSCH, J. (Ed.) *Entangled World.* Weinheim, Wiley-VCH.

EVERETT, H. (1957) 'Relative state' formulation of quantum mechanics. *Rev. of Mod. Phys.*, 29**,** 454-462.

FORD, K. W. (2004) *The Quantum World: Quantum Physics for Everyone*, Cambridge, Ma., Harvard University Press.

FREDKIN, E. (1990) Digital Mechanics. *Physica D***,** 254-270.

GREENE, B. (2004) *The Fabric of the Cosmos*, New York, Vintage Books.

GRIBBIN, J. (2000) *The Search for Superstrings, Symmetry, and the Theory of Everything*, Little, Brown & Company.

GROBLACHER, S., PATEREK, T., KALTENBAEK, R., BRUKNER, C., ZUKOWSKI, M., ASPELMEYER, M. & ZEILINGER, A. (2007) An experimental test of non-local realism. *arXiv:0704.2529v2 [quant-ph] 6 Aug 2007.*

GUTH, A. (1998) *The Inflationary Universe: The Quest for a New Theory of Cosmic Origins* Perseus Books.

HOFSTADTER, D. R. (1999) *Godel, Escher, Bach: An eternal golden braid*, New York, Basic Books.

J. KHOURY, B. A. O., P.J. STEINHARDT AND N. TUROK (2001) Ekpyrotic universe: Colliding branes and the origin of the hot big bang. *Phys. Rev. D64*.

KELLY, K. (2002) God is the Machine. *Wired*, 10.

LLOYD, S. (1999) Universe as Quantum Computer. *arXiv:quant-ph/9912088v1* 17 Dec.

LLOYD, S. (2006) *Programming the Universe. A Quantum Computer Scientist Takes On the Cosmos* Alfred A. Knopf.

PICCININI, G. (2007) Computational modelling vs computational explanation: Is everything a Turing machine and does it matter to a philosophy of mind? *The Australasian Journal of Philosophy,* 85**,** 93 - 115.

RHODES, R. (2001) A Cybernetic Interpretation of Quantum Mechanics. *http://www.bottomlayer.com/bottom/Argument4.PDF*.

RUSSELL, B. (1912) *The Problems of Philosophy,* London, Williams and Norgate.

SCHMIDHUBER, J. (1997) A Computer Scientist's View of Life, the Universe and Everything. IN FREKSA, C. (Ed.) *Foundations of Computer Science: Potential-Theory-Cognition Lecture Notes in Computer Science.* Springer.

SHANNON, C. E. & WEAVER, W. (1949) *The Mathematical Theory of Communication,* Urbana, University of Illinois Press.

SMOLIN, L. (2001) *Three Roads to Quantum Gravity,* New York, Basic Books.

SPERRY, R. W. & GAZZANIGA, M. S. (1967) Language following surgical disconnexion of the hemispheres. IN MILLIKAN, C. H. & DARLEY, F. L. (Eds.) *Brain Mechanisms Underlying Speech and Language.* USA, Grune & Stratton.

SVOZIL, K. (2005) Computational Universes. *Chaos, Solitons & Fractals,* 25**,** 845-859.

TEGMARK, M. (1997) The interpretation of Quantum Mechanics: Many Worlds or Many Words. *arXiv:quant-ph/9709032v1*

TEGMARK, M. (2007) The Mathematical Universe. IN CHIAO, R. (Ed.) *Visions of Discovery: Shedding New Light on Physics and Cosmology.* Cambridge, Cambridge Univ. Press.

VACCA, J. (2005) *The World's 20 Greatest Unsolved Problems,* Upper Saddle River, NJ, Prentice-Hall.

WHITWORTH, B. (1975) Brain Systems and the Concept of Self. *Psychology Department.* Auckland, University of Auckland, New Zealand.

WHITWORTH, B. (2007) A Research Publishing Checklist For New Authors. *18th Australasian Conference on Information Systems (ACIS).* Toowoomba, USQ.

WIGNER, E. (1960) The Unreasonable Effectiveness of Mathematics in the Natural Sciences. *Communications in Pure and Applied Mathematics, vol. 13, No. I* New York, John Wiley & Sons, Inc.

WOIT, P. (2007) The problem with physics. *Cosmos,* 16.

WOLFRAM, S. (2002) *A New Kind of Science,* Wolfram Media

ZUSE, K. (1969) *Calculating Space,* Cambridge Mass., MIT.