Can Teleportation be a Reality?

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A Silly Introduction

Scotty. Star Trek. We all watched it, didn't we? At the very least, surely we all had mums who watched it (or in my case both). Even if you never really got into Star Trek you've probably considered this question anyway at some point.

What am I talking about?

Have you ever thought how great it would be to get to work and back every morning without the drudgery of the commute by simply "beaming" yourself over there? Think of the fortune you'd save on family holidays. And in life there are those sinking moments of embarrassment when you'd like to be immediately transported somewhere ……. *anywhere*.

Of course, we're talking here about the Star Trek Transporter machine aboard the *Starship Enterprise (NCC-1701)*, often operated by the trusty Scotty. It seemed to be that only those crew members wearing the *red* jumpers, the Engineers, were allowed to operate it, however. Although I seem to remember that Spock allowed himself the odd fling on the Transporter controls — this from a "man" who showed no emotions, allegedly. A bit like a Dad who's child absolutely *insists* that he go on the slide with them … "Oh, well if I *have* to …".

The tendency for Engineers to operate the Transporter might be a deliberate act on their part — the great Eddie Izzard has observed that if anyone wearing a red jumper (except Scotty) were to beam down to the surface of a planet they would end up being killed in some unusual way before the rest of the party could return to the *Enterprise*. Although this was obviously brushed-over in the TV series, the *Enterprise* obviously worked on the present-day football squad system approach in order to replace those red jumper wearers who would meet their inevitable demise each week. At the start of its mission, the *Enterprise* must have been completely *packed*. In the first few months of a mission the gold and blue jumper wearers must not have been able to move for naïve, fresh-faced red jumper wearers wandering around the ship bumping into each other.

But anyway, it would be fantastic, wouldn't it? To be beamed down, over, to, somewhere. Although, if it were to be a reality one day, you could bet that it would still be cheaper than a trip on the Channel Tunnel.

But seriously, could such a machine ever be a reality? More importantly, does contemporary knowledge of physics allow it in principle? As we shall see, it's an issue to which not just physicists can contribute.

Getting Serious: Current Discussions

Since the Star Trek TV shows of the 1960's, people have considered, even dreamed about, such *teleportation*, or *matter transference*. Rumours abound about secret experiments with military connections attempting to develop machines to transport inanimate objects across rooms, and an internet search on such issues would uncover all sorts of discussions and "reports". On the internet, you'll find serious scientific discussions, discussions which allege to be serious, hypothetical discussions related to games and "role playing", and weird stuff related to witchcraft "teleportation spells", and so forth. Even something supposedly unconnected with the teleportation debate as the Philadelphia Experiment[1] mentioned it as a sort of by-product.

However, the problem with such a subject as this, in keeping with other stories where science fiction might plausibly cross over into reality, is that we simply do not know what to believe and what not to believe. Moreover, the problem is often how to be objective about stuff that we actually *want* to believe to be true. This, indeed, is human nature in its most naked form.

Clues to the Physical Reality

By far the greatest topic in the serious teleportation debate is how the "teleportee" is conveyed from *A* to *B*, and the consequences of each method. The possible methods discussed are usually one of these two:

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1 The Philadelphia Experiment is beyond the scope of this article, and for details the reader is recommended to type it into a web search engine, hit <Search> and stand back. In summary, it's an alleged experiment allegedly involving the US military, Einstein (allegedly), grey aliens (equally allegedly), etc. and is rather bizarre! Although "eye witness" reports are sometimes convincing, and the story is so great to hear, I consider it to be the subject of complete and utter fabrication. Listen to the internet replays of the Art Bell interviews on this topic if you can.

(i) A stream of data conveys the information about how to reconstruct the teleportee at *B*; or

(ii) The actual atoms of the teleportee are being transmitted to *B*.

Straight away we start to see problems. Let's explore why.

This has received more attention from non-physicists than physicists. However, Roger Penrose considered item *(ii)* in his unique and excellent book *The Emperor's New Mind* [2].

Converting a Person to Data Bits

Penrose points out that in order to reduce someone to a data stream we must have in place a combination of extremely complex detections and computations, a way of focussing and receiving the data stream, and murder! The process would run as follows. A teleportee stands in the Transporter at *A* and the machine is activated. The machine then scans the teleportee to map, with incredible accuracy, the precise locations and nature of every atom (including all subatomic elements) of every molecule of every organ in the teleportee's body. This, I would hope, should also include the teleportee's clothes, equipment, etc. Then, this tremendous amount of information must be transmitted to the receiving station at *B* before a similarly monstrous computer decodes the data stream and recreates the atoms exactly as described and, as if that wasn't impressive enough, place each atom in the correct molecules at the exact (perhaps relative) locations specified in the data stream. Think of it a bit like an instant, digital genetic cloning.

It already sounds a bit far-fetched, doesn't it? But there's more to consider. Now, if this works, we have an exact copy of the teleportee at *B*, but we still have our teleportee standing in the machine at *A*. Remember, we scanned him, so just as a scanned photo in your flatbed scanner at home remains under the lid after the scan is complete, so our teleportee remains standing in the Transporter machine at *A*. So we now have *two* copies of the teleportee. What do we do now? It's obvious — when the machine at *A* receives confirmation from the receiver at *B* that the teleportee has been reconstructed without problems, we simply kill the original! An ethical issue if ever there was one.

Now, seldom has more weird stuff been crammed into two paragraphs of text since James Joyce said to one of his mates "You know, I feel a book coming on". So let's explore some of these issues more closely.

Firstly, notice that we spoke of a receiving station with a computer to allow the reconstruction to take place. In Star Trek, however, the characters are often beamed down to the surface of a planet[3] and so do not, apparently, require the use of a receiving station of any sort. So quite how each member of the landing party is reconstructed is best left to Trekkies who own copies of the *STTNG Technical Manual* [4].

Not only that, but as Lawrence M. Krauss[5] points out, the human body contains in the order of 10^{28} atoms (that's a 1 followed by 28 zeros). Even if we take the simplistic approach of assuming that we need 1 kilobit (Kb) of data to store the nature and location of each atom, these 10^{28} atoms translate to 10^{28} Kb. Now let's be really annoying and consider this in a present-day framework. First of all you would need a 10^{21} GB hard disk to hold the scan of just one person. Then that data would have to be transmitted to our receiving station. Even taking a fast present-day data link, such as a $1Mbs^{-1}$ DSL connection, we would require about 3×10^{14} years to transmit that data. Current estimates suggest that the age of the Universe is 1.37×10^{10} years, therefore the length of time required to make such a transfer would be a factor of around 20,000 times the present age of the Universe. Clearly, we must await vast leaps in technology!

But even *with* such a receiving station, and the appropriate technology in place to store and transmit such huge quantities of data, we will have problems when scanning and reconstructing the teleportee's atoms as a result of the constraints placed on us by *quantum theory*. Atoms consist of fundamental particles: a nucleus of protons and neutrons held together by the strong and weak nuclear forces (involving the continuous exchange, loss and gain of a host of particles, including W and Z bosons, gluons, etc.) and electrons (held in "orbit" around the nucleus by the exchange of virtual photons, the carriers of the electromagnetic force). So, rather than a simple little entity, an atom is actually a hive of very complex activity. Not only that, but there is a limit to the extent to which we can measure the exact state of any component of an atom due to the *Heisenberg Uncertainty Principle*

[2] Roger Penrose, 1989 (reprinted 1999), *The Emperor's New Mind*, Oxford University Press. [ISBN 0-19-286198-0].

[3] *"… and it's always an oval of gravel with three rocks behind it … every week!"* — Eddie Izzard.

[4] Rick Sternbach & Michael Okuda, 1991, *Star Trek: The Next Generation — Technical Manual*, New York: Pocket Books. [ISBN 1-85-283340-8.]

[5] Lawrence M. Krauss, 1995, *The Physics of Star Trek*, Flamingo. [ISBN 0-00-655042-8].

(HUP). HUP essentially says that we cannot measure the position of a fundamental particle if we also know its momentum (i.e. velocity); and conversely, we cannot measure the momentum if we already know the position. The upshot of all this is that we have natural inaccuracies placed on our measurements, by Nature herself, which prevents us from knowing the precise states of individual particles within atoms, and therefore the exact nature of the atoms themselves. Imagine the mess that would be caused at the receiving end if the teleportee's atoms were not put back together in quite the right place and with slightly different (perhaps "guessed") states. The teleportee would suddenly find they were affected by neurological or physiological disorders.

Recent experiments have demonstrated the possibility of *Quantum Teleportation* [6]. These experiments were carried out in 1998, principally by physicists at the California Institute of Technology, and followed on from theoretical work by Charles Bennett and his team at IBM five years earlier. The quantum state (i.e. the "information") of one photon (a particle which carries the energy of light) is transferred via the use of a cable to create a replica photon 1 metre away. However, in order to allow this the quantum state of the "original" photon is destroyed, and therefore the original photon itself ceases to exist once the replica is created. This is because quantum theory tells us that we cannot copy the quantum state of a particle without affecting the initial quantum state. Essentially, when we copy a quantum state, we kill the original and the copy survives. But this is a far cry from the transmission of the vast quantities of data required to teleport an everyday object, or a person.

More recently, a team at the Australian National University have managed to teleport an actual laser beam[7], making the beam disappear from one location and reappear in another location 1 metre away.

These teleportation experiments have utilised a totally weird property of particles called *entanglement* or *non-locality*. The details are best left to a (possible future?) article on the bizarre aspects of quantum theory, but in a nutshell, fundamental particles which are "born" together will always stay "connected" even if separated by huge distances. For example, take two entangled particles with equal and opposite "spins". If you now take one of those particles to, say, the edge of the Universe and get its spin to "flip", the particle back on earth will also flip … and the flip will take place instantaneously! Therefore, the "information" is transmitted between the particles at infinite speed. Einstein referred to this as a "spooky interaction" and cited it as a reason why quantum theory must be fundamentally flawed, but experiments have since proved him to be wrong.

It is also worth mentioning that it might be conceivable that one would require some sort of "scanning beam" to allow us to probe the position of the teleportee's atoms, both on the initial scanning and during the reconstruction. However, to probe the distances involved (i.e. the size of individual atoms and the spaces between them) would require electromagnetic waves with a wavelength comparable to, or less then, this distance. That leaves us only with x-rays and the more energetic waves (e.g. gamma rays). These would severely damage the very tissue they were intended to reconstruct.

Can We Send the Actual Atoms?

Perhaps one of the biggest issues associated with sending the actual atoms of the teleportee from *A* to *B* is how to strip them away from the teleportee's body in the first place. The atoms are held in molecules and in order to strip them away from the molecules represents a physical and chemical headache. Firstly, how do we trick the atom into coming away from the molecule, and secondly what happens to what's left of the molecule before we get around to taking other atoms from it?

I'm not a chemist, so I won't begin to speculate about the second issue, except to say that it should be considered whether or not the remaining parts of the molecule would itself constitute a new molecule which might react chemically with the other molecules around it, or whether these remains will somehow reconfigure themselves after the first atom is (or even subsequent atoms are) removed.

As regards the first issue, namely how to prise the atom away from the molecule in the first place, we have to overcome the fact that the atom is held in a chemical bond with the rest of that molecule. To break this bond requires the input of a certain amount of energy. You may or may not remember from school that most of the atom is in fact empty space. The nucleus is a tiny entity in the very centre of the atom with a cloud of electrons orbiting relatively (for an atom) large distances from it.

[6] Bennett, C.H., *et al.*, 1993, *Teleporting an Unknown Quantum State via Dual Classical and Einstein-Podolsky-Rosen Channels*, Phys. Rev. Lett., **70**, pp. 1895-1899; and
Furusawa, A., *et al.*, 1998, *Unconditional Quantum Teleportation*, Science, **282** (no. 5389), pp. 706-709.

[7] Bowen, W.P. *et al.*, 2003, *Experimental Investigation of Continuous Variable Quantum Teleportation*, Phys. Rev. A, **67**.

(Ernest Rutherford, whose team pioneered the splitting of the atomic nucleus in the 1930's, described it as "the fly in the cathedral".) The fact that the mostly-empty-space atoms at the ends of my fingers don't pass through the mostly-empty-space atoms of the keys on my keyboard while I'm typing this article is due to the electromagnetic force which holds the electrons around the nucleus. This force not only holds the electrons firmly[8] in place, thus preventing my fingers mixing with the keys, but also binds atoms to other atoms. This "binding energy" must be overcome if we are to get the atom away from its molecule. This requires us to put energy into the process, just as you would have to expend energy if you were to prise two items apart that had become stuck together.

Then, once all 10^{28} atoms had been coaxed to exist alone, they would have to be "stored" somehow before we can construct some sort of matter beam for transmission (the *STTNG Technical Manual* tells us that they are held in a "pattern buffer" at this point). However, how would one conceive holding these atoms without their reacting with one another?

And, once again just as if that wasn't enough, even if we can get through this hurdle without falling, how do we then transmit those atoms (together with the "information") to our receiving point at *B*? To get an atom to be projected forward at close to the speed of light would require expending an energy roughly equivalent to the atom's rest mass energy (the energy the atom possesses when it isn't moving) which we must then multiply by, at least, 10^{28} to get the rest of the atoms moving.

Finally, we've so far confined ourselves to a consideration of the physics involved in teleportation, but there are other disciplines that have something to say.

The "Awareness" Debate

We've spoken about somehow moving, or reconstructing, a person's constituent atoms, but what about other aspects, such as the many electrical impulses taking place in the brain. For example, I've often wondered the following: If the teleportee was thinking of something during the initiation of the teleportation process, would he / she still be thinking of that thing when they are reconstructed at *B*?

Penrose looks beyond the physics in his discussion of teleportation to ask some fundamental philosophical questions. When the reconstruction of our teleportee is complete, does he / she have all the exact same memories, feelings, impressions, hopes and intentions of the "original"? If this is so, it has important consequences for the debate on whether a computer can ever have a mind, and therefore *awareness*. There are people (the so-called "Strong AI" fraternity) who claim that it is perfectly probable that a computer can have awareness purely by algorithm (i.e. software). In other words, the hardware, either the electronics of the computer or the organic matter of the human brain, is irrelevant. Penrose likens this situation to the teleportation of a human by converting him / her into a data stream (as discussed). They would then claim that even the data stream, during actual storage / transmission, contains the very awareness of the teleportee. Penrose refutes this (as do I). What happens if the copy teleportee is standing at *B* complete with the full awareness of the original, but the original has not yet been killed? Is the teleportee's awareness really in two places at once? Penrose believes that human awareness is likely related to some as-yet undiscovered quantum issues within the brain. But then he is able to contradict his "feeling" but pointing out that the findings of Quantum Teleportation suggest that the awareness of the original would be destroyed by the teleportation process. Perhaps the original would die naturally as a result, and in any case would not be aware of it!

Notice that I haven't mentioned the human "soul" (and deliberately so). "Soul" is one of these vague words that tend to be used in arguments when people don't know what they're talking about any more. For example, when someone says "Well, that's the 'soul', isn't it", they actually mean "Look, I don't know how to continue this discussion, so can we talk about something else please?" When we talk about teleportation, we essentially assume that all there is to a human being is atoms and information, but this may not necessarily be the case. Krauss states that "the transporter would be a wonderful experiment in spirituality". This is because, if we could build a working transporter and successfully teleport a person somewhere and show that they are exactly the same person, physically and "spiritually" then this would pretty much prove that the soul didn't exist and that would *really* get pub arguments rolling. But imagine if when we make the first human teleportation with our working transporter only to find that the spiritualists are right. There's a thought to close on.

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[8] I say "firmly", but this is not to say that the electrons are nailed in place, as it were, around the nucleus. As you might already gather, quantum theory tells us otherwise. However, for the purposes of what I'm talking about, "firmly" will do nicely.

So What Do I Think?

In our debate, we've not only delved into modern-day physics, but also into philosophy, computer science and even cosmology. And in many of these areas there are massive issues to deal with before teleportation can be considered seriously as an option. But remember, much of our thinking is polarised by what we've seen on television, in films, and when playing computer games. The reason we concentrated our discussion on converting our poor teleportee into a data stream (with or without their constituent atoms in tow) is because this is how it is considered to be done in Star Trek, and has been duly recorded and "described" by "Trekkie Techies" since the 1960's[9]. Furthermore, it is likely that Gene Roddenberry, the creator of Star Trek, created the transporter machine so as not to land his beautifully designed starship on planet surfaces, thus avoiding televisual trickery.

If a teleportation technique is discovered in the future I personally feel it will probably have nothing to do with these discussions. It may well have more to do with a better understanding about how to move around in spacetime than with quantum theory.

The experiments which have demonstrated the principle of teleporting photons will more likely have applications in communications and computing, and for that we should perhaps be grateful. With all that we've had to say on this subject we have to ask ourselves — is this really a way to travel? Indeed, Penrose himself asks, more fundamentally, is it indeed really travelling?

I think, on reflection, I'll stick with the Channel Tunnel.

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[9] In fact, the *STTNG Technical Manual* (see footnote 4) states explicitly that the Star Trek transporter works by first scanning the teleportee, then dematerialising them, holding them in the "pattern buffer" before transmitting the "matter stream" to the required destination. The matter stream is, it seems, composed of both the scanned atomic information *and* the actual atoms that are described in this information.