A Stronger Twin Paradox

By David Johnson

I know, I know, scientists don't want to hear it. They don't take the Twin Paradox seriously, but I believe it is a much bigger problem for the Theory of Relativity than they want to acknowledge.

The Twin Paradox is usually presented in the following way: Suppose that one of a pair of identical twins leaves earth on a spaceship and makes a long journey at near the speed of light and then returns; according to the Theory of Relativity he or she will have aged less than the twin who remained behind on earth because time itself slows down for a reference frame that is traveling at near the speed of light. But here is the paradoxical part: According to the Principle of Relativity the twin on the spaceship could just as easily regard himself/herself as being at rest and the earth as moving at near the speed of light. So which twin will have aged less?

The standard response is to say that the twin that travels in the spaceship accelerates more than the twin on earth, so this is the twin that experiences time dilation (the Relativistic slowing of time) while the other does not.

There are at least four problems with this response. The most obvious one is that it is not at all clear that the twin on the spaceship actually does accelerate more than his brother on earth. The earth is not an inertial or stationary reference frame, it is a uniformly accelerating frame. If we take into account the earth's orbit around the sun, the earth's spin, and even the fact that the twin on earth will likely travel around in cars, planes, and even walking, it is quite possible that this twin experiences more acceleration. Any change in speed or direction counts as an acceleration. The spaceship would accelerate a lot at the beginning of the trip and at the end, but once it was up to speed it may continue at a steady velocity for a long time, which means that for much of the trip it is moving inertially.

Secondly, if time dilation is related to acceleration then why would it keep happening once the reference frame was moving inertially? Is it traveling at a velocity that is close to the speed of light that causes time dilation, or is it acceleration? If the former, then what does acceleration have to do with anything?

Third, Einstein himself considered acceleration to be relative. This is from chapter 18 of *Relativity The Special and General Theory:*

> If the motion of the carriage is now changed into a non-uniform motion, as for instance by a powerful application of the brakes, then the occupant of the carriage experiences a correspondingly powerful jerk forwards. The retarded motion is manifested in the mechanical behaviour of bodies relative to the person in the railway carriage . . . *we feel compelled at the present juncture to grant a kind of absolute physical reality to non-uniform motion, in opposition to the general principle of relativity. But in what follows we shall soon see that this conclusion cannot be maintained*. (Italics added for emphasis.)

Einstein later returns to this example and elaborates at the end of chapter 20. Earlier in chapter 20 he argued for the equivalence of acceleration and gravity.

> We can now appreciate why that argument is not convincing, which we brought forward against the general principle of relativity at the end of section 18. It is certainly true that the observer in the railway carriage

> experiences a jerk forwards as a result of the application of the brake, and that he recognises in this the non-uniformity of motion (retardation) of the carriage. But he is compelled by nobody to refer this jerk to a "real" acceleration (retardation) of the carriage. He might also interpret his experience thus: "My body of reference (the carriage) remains permanently at rest. With reference to it, however, there exists (during the period of application of the brakes) a gravitational field which is directed forwards and which is variable with respect to time. Under the influence of this field, the embankment together with the earth moves non-uniformly in such a manner that their original velocity in the backwards direction is continuously reduced."

It is obvious from this passage that Einstein believed that acceleration (in this case deceleration, which is a form of acceleration) is relative. It is true that the observer would be able to feel the change in speed, but he argues that the observer could just as easily interpret this as his or her own frame being permanently at rest while other frames around it are accelerating. So is Einstein just wrong about this? If you think that the Twin Paradox can be resolved by saying that one twin accelerates more than the other you must think so, as that presumes that acceleration is absolute for all reference frames; if it was relative there would be no way to tell which twin accelerated more because observers in each reference frame would interpret the acceleration differently.

This brings us to my fourth point, which is actually the most significant: If there is no such thing as an absolute state of rest, as Einstein insisted, then there would be nothing left but relative motion. The frame has to be accelerating relative to *something*; if there is no absolute state of rest all that would be left is other reference frames and none of them would be preferred over any other. Acceleration would have to be relative, because, according to the theory, relative motion is the only kind of motion that there is.

Now maybe one would argue that acceleration could be considered invariant without an absolute state of rest or a preferred reference frame because observers in all frames would see that frame accelerate by the same amount no matter how fast their own frame is moving; for example, if a reference frame speeds up from 100 kph (62.1 mph) to 103 kph an observer that is at rest and another that is moving at 90 kph (55.9 mph) will both measure the acceleration of that frame to be 3 kph. The problem, though, is that this would only be the case for frames that are at rest or moving inertially. (But at rest or moving inertially relative to what? How could we even say that without an absolute state of rest to compare it with?) It would not be the case for frames that are themselves accelerating.

When you speed up to pass another car on the freeway it sometimes looks like the other car is slowing down. If you considered yourself to be moving inertially then relative to you it would be. The speedometer in that other car will show that it stayed at the same velocity and an observer standing next to the road will agree with that assessment and say that the other car stayed at the same speed while your car accelerated, but the Relativistic argument would be that from the perspective of your reference frame one could just as easily say that you are moving inertially and the other car is slowing down. If one were to object that more observers (such as the observer standing on the side of the road) would agree with the other driver than with you, Einstein would find that to be irrelevant. If you considered yourself to be in a permanent state of rest, which in Relativity one is always entitled to do because there is no absolute state of rest, then you could say that the other car is backing up, moving in your direction at the speed of the acceleration, similar to if that car was in reverse. Hence, observers could disagree over which frame accelerated.

It is also possible for observers to disagree over how much a reference frame has accelerated. Suppose I accelerated by 5 kph (3.1 mph) while the car ahead of me accelerated by 10 kph (6.2 mph) according to the observer next to the road. Einstein would say that I could agree with this, but I am also entitled to consider myself to be at rest, the observer standing by the road to have accelerated by 5 kph, and the car ahead of me to have accelerated by 5 kph (in opposite directions). So did the car ahead of me accelerate by 5 kph or 10 kph? Einstein would say that the answer is relative to the frame of reference and how observers choose to interpret the motion.

What if two cars were accelerating in opposite directions? Suppose that a car passes me going the opposite way on a two lane road. An observer standing on the side of the road would judge both my car and the other car to be accelerating by an equal amount. But if I considered myself to be at rest then I would judge the other car to be accelerating by twice as much as what the observer standing next to the road would calculate.

Finally, let's suppose, for the sake of argument, that acceleration was absolute in Relativity Theory. Well, in that case, observers obviously would not be able to consider themselves to be at rest while they are accelerating. So, we are saying that while a car is accelerating up to 100 kph (62.1 mph) the driver must know that the car is moving, and therefore would trust what the speedometer tells them about how fast they are moving, but then once the cruise has been set and the car is moving inertially they instantaneously stop trusting the speedometer and could then just as easily consider themselves to be at rest? Is the observer stupid? How could they not know that they are still moving? A body in motion stays in motion unless some outside force acts upon it (law of inertia); knowing that, and knowing that they accelerated up to a certain speed, and not detecting any outside force that has caused deceleration (we already acknowledged that they are able to detect it), they ought to be able to deduce as an objective fact, if their acceleration was an objective fact, that they are still moving. Thus, in opposition to the Principle of Relativity, they would not be entitled to regard themselves as being at rest, even once the motion became inertial.

To me it seems obvious that Einstein thought that acceleration is relative, just like inertial motion, and that is the only view that is consistent with the Principle of Relativity and the claim that there is no preferred reference frame or absolute state of rest. But rather than continue to quibble over acceleration, we could just modify the original thought experiment so that the twins experience an exactly equal amount of acceleration during the experiment.

Imagine that we have a circular track with a radius of 120 million kilometers. There are three starships unimaginatively labeled A, B, and C. Ships A and B are out at the circumference of the circle while C is at the center and will be at rest relative to the other ships. On each of these ships we have one of a set of triplets: Andrew is on ship A, Benjamin is on ship B, and Clyde is aboard ship C. We will also assume that the track is far away from planets and stars so that the gravitational force is negligible.

Ship A is 300 meters directly above ship B in the vertical or y coordinate plane so that the ships can pass each other without having to change direction. There are sensors on the bottom of ship A and others located at the top of ship B that will detect when the ships pass each other.

We will now assume that ship A accelerates to .75c and maintains that as a constant velocity while ship B accelerates to .25c and also maintains that as a constant velocity, both in the counterclockwise direction. According to the Theory of Relativity, observers on each ship could regard themselves as being at rest and the other ship as moving around the track at .5c. No frame of reference is ‘special’ or ‘privileged’, so each observation would be equally legitimate. From the perspective of A, B would be judged to be moving backwards (in terms of how the ship is oriented) and moving in the clockwise direction, but each would see themselves as being at rest and the other as moving at .5c.

To alleviate any concerns that maybe Andrew and the other crew members of ship A experience more acceleration while getting up to speed we will say that they only start the experiment once both ships are at full speed. The reason that the triplets supposedly age at different rates is because time itself slows down, so all clocks in that reference frame would slow by the same amount, including a person’s metabolism. As an example, if the ship was moving at .95c the prediction of the theory is that a crew member’s metabolism would slow to only 4.5% of its normal rate. At extremes such as this, and given enough time, this would of course become quite noticeable after awhile, but to ensure that they get accurate data we will say that the crew of each ship will also use a timer to keep track of exactly how much time passes for them during the experiment. Radio signals could cut across the circle so there should not be much of a delay as each ship communicates with the others, but just to make sure, none of the ships start to time themselves until they have all confirmed with each other that both A and B are up to speed and ready to begin; then, as previously agreed, all three begin to time themselves on the next pass of A and B. For both A and B the ship’s computer starts the timer as soon as the sensors detect the sensors on the other ship. Ship C would be tracking the acceleration, speed, and position of the other two ships, which would also be in accordance with a previously agreed upon plan, so their ship’s computer could calculate fairly accurately when ship A will pass ship B; ship C’s computer starts its timer when it estimates that this has taken place.

Since this is merely a thought experiment rather than one that we have to actually perform, let’s say that they keep going for 30 years according to ship C’s time. Then ship C sends out a signal to the others, and once both have confirmed that they received it they all stop timing when the two ships pass each other the next time. They will not keep track of the time while both ships are slowing down.

Once the ships have slowed down sufficiently, they both go to rendezvous with ship C where all three crews meet up on ship C to compare results and have a party. We will assume that both ships travel at the same speed as they go to ship C. What do you suppose their results will be?

Obviously the results that they are supposed to get is that Clyde and his crew will have aged the most, Benjamin, who was traveling at .25c will be the next oldest, and Andrew will have aged the least. One would expect the timers to confirm this. The least amount of time will have passed for Andrew and his crew, and the most will have passed for Clyde's crew.

The explanation that would be given for why Andrew aged the least according to all three crews would be that ship A experienced the most acceleration. But we cannot really say that because according to the Principle of Relativity observers on each ship (A and B) could regard themselves as being at rest and the other ship as moving at .5c; they would consider their own time to be 'normal' and would think that time had slowed down for observers on the other ship because to them that was the only ship that was moving.

One could not say that either ship was ever moving inertially, even though they maintained a constant speed during the experiment, because the ship's computer would have to continually change the direction of the ship to keep it moving in a circle, but they both would have experienced the exact same amount of acceleration during the experiment relative to the other. In fact, the results would be exactly the same as what you would get if either ship remained at rest and the other moved around the track at .5c (assuming that they do not start timing until the ship has reached full speed). In that case as well both ships could regard the other as moving and themselves as being at rest. The ship that was moving would be going around the track in a counterclockwise direction at .5c according to the ship at rest; but according to Relativity, observers on board that ship could just as easily consider themselves to be at rest and the other ship to be flying around the circle in a clockwise direction with a backwards orientation. So which one accelerated? It depends on which one was moving and which was at rest. Both crews consider their ship to have been stationary throughout the experiment and the other ship to have moved, and both are equally authoritative. In the original Twin Paradox a ship leaves earth, accelerates up to speed and then at some point slows down (presumably), turns around and comes home, once again speeding up and slowing down; all of the proposed solutions utilize in some way the asymmetry of this twin's motion in comparison to the motion of the twin on earth as part of their answer, but in this case how observers on each ship view the motion of the other would be completely equivalent, it would just be inverted. Neither ship changed speed at all, and neither one changed direction any more than the other.

(By the way, I am not entirely sure how ship C would fit into this picture; could the other two ships really consider it to be moving and themselves to be at rest? I don't see how, because it is located at the center of the circle while they are out at the circumference. They most definitely would not think that ship C was moving in a circle around them at .25c, .5c, or .75c, even if they did think that they were at rest. Would this violate the Principle of Relativity? I wonder if maybe what Einstein would say is that observers on ships A and B would see ship C's orientation change as they went around the circle, but maybe he thinks that they would attribute that to ship C slowly spinning in place rather than thinking that it meant that they were moving around it. But would it really be true that they could not tell the difference between going around a stationary ship and seeing it spin in place while they are stationary? I have doubts about that. For one thing, their own ship would be oriented a little bit differently and it would feel different to them as it turned to go around the circle than it would if it was completely at rest and ship C was slowly spinning. I guess Einstein would say that they could still attribute that difference in feel to some other factor, such as an increase or decrease in the gravitational field around their ship, but that seems like a stretch. They could also check how fast time is moving on ship C in comparison to their own ship. It should run at nearly the same speed if they are stationary and it is spinning in place, but much slower on ship C if they were moving at either .75c or .25c.)

Relativity says that time slows down when a reference frame moves at a high speed relative to light, but observers on each ship would disagree over which ship was moving and which was at rest, so it is unclear whether Andrew or Benjamin would have aged less, or whether they would both think that the other had aged less than himself. The crew of ship A would think that they experienced no acceleration at all during the experiment, as they believe that they were at rest the entire time, and would thus think that ship B experienced all of the acceleration and time dilation; the crew of ship B would think the exact opposite.

The only answer that is consistent with the Principle of Relativity is to say that both Andrew and Benjamin, along with their respective crews, would see the other as having aged less than themselves. Everyone agrees that both would see length contraction that way. (According to the Theory of Relativity, as an object approaches the speed of light its length contracts in the direction of motion.) It is never the case that an observer would perceive the length of their own reference frame, or anything in it, to be contracted. Observers always perceive their frame, and everything in it, including themselves, to be 'normal' and the Relativity effect to occur in the other frame.

Think about it this way: If Andrew really did see Benjamin as having aged more than himself then it would have to be the case that he and the other members of his crew saw time speed up for ship B during the experiment, not slow down. The closer that they themselves got to the speed of light the more that they would judge the clocks in other reference frames to have sped up, just as those reference frames would observe their clocks to be running slower. This would be a way of being able to detect the absolute motion of your reference frame. Whenever you observe time to move slower for another reference frame than it does in yours you would know that this frame must be moving faster than yours, and if time moves faster for that frame than it does in yours then you would know that frame must be moving slower than your frame. Based upon how much of a difference there is you could even estimate how much faster or slower that frame is moving than your frame. In short, this would mean that time dilation is absolute or invariant across all reference frames, and one could then use that to determine the absolute motion of each frame. (According to the General Theory of Relativity one would have to account for the gravitational force as well, but that could be done.)

If you say that one can perceive time dilation to have occurred in her own reference frame then you are tacitly acknowledging that this observer knows with certainty that her frame must have been moving.

Once again, the only answer that is consistent with the Principle of Relativity is to say that both brothers, and their respective crews, see the other as having aged less than themselves. (Or at least that they both could; we'll come back to that at the end.) This means that ship A and ship B would also disagree over which ship had the most time pass: Andrew and his crew would think that more time had passed for them, while Benjamin and his crew would perceive more time to have elapsed on their own timer than on ship A's timer.

A self-contradiction is the kiss of death for any theory. The Twin Paradox is often thought to reveal a self-contradiction for Relativity, but to be fair, I do not think that it is a true self-contradiction to say that both brothers perceive the other to be younger than himself. The results are contradictory, but not self-contradictory. Logically, it is not problematic to have two contradictory claims, it is only problematic if the same claim is self-contradictory.

In this way it is similar to Moral Relativism. Perhaps in society A stealing is considered to be morally wrong, while in society B it is not considered morally wrong. The two cultures contradict each other about whether stealing is wrong but this is not logically problematic for the theory of Cultural Relativism because according to that theory there is no absolute universal standard of right and wrong. So one could just say that stealing is wrong for the members of society A, and not wrong for members of society B. In other words, whether stealing is wrong can only be answered relative to a particular society. Therefore it is not self-contradictory to say that for society A it is, and for society B it is not. The only way that it would be self-contradictory is if one of the two societies said that stealing was both wrong and not wrong in their culture.

Einstein's Theory of Relativity has some significant differences with Moral Relativism, of course, but it is similar in the respect that both theories assert that there is no absolute universal standard of comparison. In Einstein's theory there is no absolute space and no absolute time. If that is correct then it would not be self-contradictory or internally inconsistent to say that the observations of each crew contradict the other's account. You would just say that the crew of ship A has observations that are true for them, and B has observations that are true for them. To argue that it is an absurdity for both to perceive the other as being younger than themselves (or in other words both of them perceive time dilation to have occurred for the other one) presumes that both are younger than the other in terms of absolute time, which would be self-contradictory if that was the claim, but absolute time is something that Einstein specifically rejects. It is a weird counterintuitive result, but it is not self-contradictory.

Nevertheless, it is important to recognize just how weird it is. Imagine that the triplets were 60 years old when they started the experiment and a couple of years after it is finished Clyde dies of natural causes incident to old age, at 92 years old according to ship C's time. Some years after that Benjamin dies as well, also of natural causes. Or at least he does according to the crew members of ship B; but what would Andrew and the crew of ship A perceive? If less time passed for ship B, and Benjamin was significantly younger than Andrew according to ship A's reckoning of time, how could they perceive him to die of old age before Andrew does? Maybe they don't.

Let's imagine the funeral. The crew of ship B mourning for their fallen comrade, while the crew of ship A sees Benjamin there at his own funeral because for them he has not died yet. (They must see younger versions of all the crew members of ship B that attend, who would not be mourning because Benjamin has not died yet for them.) Perhaps Benjamin even delivers the eulogy. Nobody from the crew of ship B can see or hear him (according to ship B's account of time), but Andrew and the crew of ship A assure them that it was very special. Perhaps they could record it as long as they used a recording device from ship A, but unfortunately the crew of ship B (the old version of them) won't be able to see or hear it. That is too bad, because Benjamin gives an emotional heartfelt tribute to himself. He says: 'We're all gonna miss you big guy. Especially me.' Then he breaks down in tears while both old Andrew (the one that crew A sees) and young Andrew (the one that crew B sees) try to comfort him. Or at least young Andrew would do that, if he was able to perceive young Benjamin, or old Andrew.

So is Benjamin lying in the casket or standing at the podium giving the eulogy? Apparently, according to Relativity, it just depends on who you ask. (If it is a closed casket perhaps Schrödinger's cat is in there as well, but I guess we just have to say that it both is and isn't until somebody opens the casket to take a look.)

What is strange is that we have three different versions of time, yet somehow they can interact with each other. Well, sort of, anyway: Do they really if crew A looks at ship B's clocks and calendars and their timer and perceives something different than what crew B sees when they look at them? I don't know. It is unclear how these fractured overlapping timeframes are supposed to fit together, and why simply moving at a really high speed would cause this permanent fracturing of time.

Why isn't time dilation like length contraction? Recall that length contraction reverts back to the so-called 'rest length' once the reference frame slows down. If you had a measuring rod of one meter that accompanied the crew of ship A, the Theory of Relativity says that it would have contracted while they were traveling at .75c but it would revert back to being a meter long once it was at rest on ship C and all three crews would measure it to be the same length. So why is time dilation supposed to be a permanent irreversible effect of moving at .75c but length contraction is not? Why wouldn't time be synchronized for all three groups once they were back together in the same frame of reference?

(Actually, I think I know the answer to that question: it is because time dilation is tied to gravity while length contraction is not. Stronger gravitational fields are thought to cause time dilation as well. But why couldn't time revert back to how it was once the observer was back in a weaker gravitational field? I suppose there is some justifiable hesitancy to say that gravity is relative to the observer, but if gravity is tied to motion, and motion is relative, then it would have to be.)

What we have described so far is not a self-contradiction. It is not equivalent to saying 'P and not-P' unless Benjamin is both dead and not dead within the same frame of reference, and that is not what is being asserted. Crews A, B, and C all have contradictory accounts of time but none of them are self-contradictory. But we are not done yet. The Principle of Relativity leads to other problems. Did Andrew travel at .75c and Benjamin at .25c, or did Andrew move at .5c while Benjamin was at rest, or was Andrew at rest while Benjamin moved at .5c? If the first or the second then Andrew would be younger than Benjamin according to the crew of ship B, and there would be no difference between them in terms of how the crew of ship B perceives Andrew and ship A, but there would be a significant difference in how they perceived other reference frames, such as ship C. If Benjamin perceives himself to have been moving at .25c during the experiment then he will have perceived time dilation to have occurred for his own reference frame, meaning that he will see himself as being younger than Clyde. On the other hand, if he considers himself to have been at rest relative to Andrew and ship A then he would think that time dilation did not occur in his reference frame, which means that he would be the same age as Clyde, as they both would have been at rest throughout the experiment. (He may think that ship C is spinning slowly in place, but it would be so slow that it would have practically no effect as far as time dilation.) Benjamin will always see ship A as moving at .5c faster than he is, but how he and the crew of ship B perceive ship C would depend upon whether he thinks that he was moving during the experiment. So which is it? Does Benjamin perceive Clyde to be the same age as himself and think that the same amount of time passed for both ship B and ship C because they were both at rest during the experiment, or does he think that he was moving at .25c and has therefore aged less than Clyde? Would Benjamin say that ship A was moving .5c faster than ship C, or .75c faster? That would, of course, make a very big difference in how much younger he would perceive Andrew to be than Clyde.

What if the crew of ship B agreed with ship A's account and considered Andrew to be at rest while they moved at .5c? In that case Benjamin and the crew of ship B would recognize time dilation as having occurred in their reference frame and would thus perceive Benjamin to be younger than Andrew, and younger than Clyde, because both of them would have been at rest while only ship B moved. Thus, according to the reckoning of the crew of ship B, it is possible for Andrew to be perceived as either younger than Benjamin or older, depending upon whether the crew says that their ship was moving or stationary.

This result is perhaps even more problematic than prior examples because it is within the same reference frame. However, even this is still not equivalent to 'P and not-P', it is 'P or Q', which is not self-contradictory. But I see no non-arbitrary way of deciding whether it is P or Q unless we say that all observers must always consider themselves to be at rest. But Einstein did not think that one is required to consider themselves to be at rest, only that they could (and if he had said that it was required that would clearly be false), which, I guess, means that Benjamin could see himself as having aged more than Andrew, but he could also just as easily see himself as having aged less.

I think we need to very seriously consider whether it is reasonable to say that how much a person has aged depends upon whether they consider themselves to have been moving or at rest, and whether it is really true that they could not tell the difference between moving and being at rest, as that would imply that it is impossible for them to know how much they have aged. Do we really believe that all of the crews would see different numbers on their respective timers if they consider themselves to have been moving during the experiment than the numbers they would see if they considered themselves to have been at rest? If they changed their minds during the experiment and went from saying that they were moving to instead regarding themselves as being at rest would the numbers that they see on their timer then change?