Scientific Method

Everyone experiments. Everybody makes hypotheses. Every single person who can learn is, in short, a scientist. They simply don't speak the language of science yet. All the same, while they may not be as rigorous in its application as a fully trained doctor, they are using the scientific method.

At its heart, science is the art of asking questions. Not just any question, of course. The art comes into the picture in this: asking a *good* question. Let us be fair to ourselves, and to all humanity. There are plenty of stupid questions to be asked, answered, and dismissed. Among them: does this lemon actually taste like chocolate? If I hold my breath, can I suddenly speak Chinese? If I step on this crack, will my mother's back break? If I throw salt over my shoulder, will good things happen to me?

Among the better questions, we could ask: what is the relationship between mass and acceleration? How do distractions affect people's ability to think? Do certain kinds of plastic contribute to cancerous diseases?

Now, the real trick lies in not just asking a good question, but in making a specific prediction about the relationship between two things. This is important because it is specific, and because specific predictions are testable. For example, let us look at the last example of a bad question: If I throw salt over my shoulder, will good things happen to me? The problem isn't in the first half of the question, but in the last part. A fairly specific prediction can be drawn from the first part...throwing salt over your shoulder can have some effect. We can argue about which shoulder, or how much salt, and the direction and angle of the throw, but for the most part, there isn't much to talk about. The latter half, though, is highly problematic. What is a good thing? Who is judging? How do we evaluate an event as good or bad? Does getting a parking space close to the mall’s entrance count? What about finding a penny?

The major problem is, based on the question, our prediction seems true whether you get a free candy bar or win the lottery. It just isn't very specific, which means we can't prove it easily at all. Proof, of course, is the key part. It is what science is all about.

So, allow us to pick a simple question from my childhood: does holding my breath cause traffic lights to turn green when my mom is driving us somewhere? To you, the obvious answer is likely a "No, of course not." To me as a child of age six, it was not so obvious. I suspected it was not true, but at the same time, it seemed possible, and there was evidence in favor of the proposition. Whenever we pulled up at a red light, I would hold my breath, and strongly hope the light would turn green soon. More often than not, my breath holding was rewarded: the light would turn green before I had to give up and gulp in a breath of fresh air.

Retroactively, I will make a very specific hypothesis. (Hypothesis, by the way, is a word that comes from Greek philosophers. "Hypo" means below, or less than. A "thesis" is an idea, or explanation. A hypothesis was therefore a lower, more basic idea. It was, in some way, the foundation for other, more developed ideas. A proposed process was that a basic idea, or hypothesis, when combined with an opposing idea, an antithesis, would lead to a combined and improved idea, a synthesis.) My specific hypothesis is, "if I hold my breath, then the traffic light will turn green, because my internal stress from holding my breath can affect traffic lights."

Please note that my hypothetical prediction is fairly specific, and includes a rationale, or a reason why my hypothesis should be true. In general, I could pick any rationale and still have a valid hypothesis, but a good rationale should make sense. (Making the same prediction because the moon is made of cheese is, for example, a pretty poor rationale.) Even better, this hypothesis is only making a prediction about two variables. The first variable we can talk about in this case is the traffic light color. In this case, it is the dependent variable, because I'm guessing that the color depends on something else. The thing it is depending on is known as the independent variable. In our case, it is how long I've been holding my breath. So, if I hold my breath long enough (the independent variable,) then the light color will change (the dependent variable) because lights respond to stress.

So, let us suppose that I tested my hypothesis, (as I certainly did,) and that after a few times, I had accumulated confirming evidence: if I held my breath, then the light would turn green. I was correct! Right? Right! Right...

Of course, there were some major flaws in my method. Primarily, I was not measuring when I started holding my breath. Maybe I was waiting until right before the light was about to change. I also was doing this at any light we stopped at, but maybe some lights changed faster than others. Maybe I was only getting impatient and holding my breath at the long lights...

All these things needed to be controlled. Heck, maybe even the car we were in made a difference! In order to be sure that other factors weren't affecting when the light changed, I needed to keep things the same. I needed to be in the same car, at the same light, at the same time of day, and start holding my breath at the same time after the light turned red. Otherwise, there were a bunch of other explanations for why the light would turn green.

Keeping everything the same from try to try is known as controlling for variables. In fact, each try has its own special name: a trial. If each trial is controlled for its variables, then each trial should be pretty much identical. That way, if there are any changes in results, you know the changes aren't because of any differences you allowed as the experimenter.

So, let's pretend that I started holding my breath 10 seconds after the light turned red. (I controlled for the variable of the time after the light changed.) I only did this at the intersection of Main and 4th (I controlled for the variable of the location,) when traveling south (I controlled for the variable of the direction,) at 4 PM (I controlled for the time,) when we were driving the blue Mazda (I controlled for the car type.) Now, I could have kept trying to control for numerous other variables, like the current temperature, and the outfits we were wearing, and what we'd had for breakfast that day, but after a certain point, controlling for variables can become ridiculous and counterproductive.

But let's assume I did all that, and it turned out that the light consistently went from red to green after about 20 seconds.

Was my hypothesis correct?

At this point, I would hope that most of you readers would be nodding your heads and thinking, "Yes, holding his breath did cause the light to change. It is obvious!" This is of course not true, but it is an obvious statement to make. It is an obvious conclusion to come to. It is also not *necessarily* true. It could be true, but it isn't the only explanation. Right now, the best question is this: how do we know that the light wouldn't have changed after 20 seconds *no matter what I did*?

The answer is that we don't. We need a control trial. We need a comparison, where we don't do anything much at all, and then we look to see if the result from our experiment would show up even if we don't do anything to cause it.

In this case, we need the kid version of me to show up at the same intersection, in the same car at the same time of day coming from the same direction. And here's the important part: we need the kid version of me to do nothing but sit there with a stopwatch, and do nothing but measure exactly how long it takes for the light to turn green. And he needs to do it more than once. Now, if the light doesn't take the same amount of time as when he's holding his breath, then we know the kid me was onto something. Everything else is the same: any difference must be because of the breath holding.

If nothing changes, though, and the light turns green on the exact same schedule as when he was sitting there holding his breath, then we know that it wasn't his breath that was controlling the light: that would have changed no matter what, apparently.

And there we have the magic of science. The method of performing multiple versions of the exact same experiment (trials) and of keeping all the trials identical (controlling the variables) and of creating a series of trials without the presumed cause, just to make sure things wouldn't happen anyhow (using a control trial,) is the scientific method. And it is the best way we have of making sure a hypothesis is true or not.

As a species, it isn't just what makes us smart. It is what makes us *right*. And we have the experiments to prove it...

Questions

Find the following terms and concepts in the text above, and create a definition or explanation for each based on context.

1. Hypothesis
2. Variable
3. Independent Variable
4. Dependent Variable
5. Controlled Variable
6. Trial
7. Control Trial