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Hypotheses

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Hypotheses

The processes of creating and testing hypotheses are the backbone of scientific research. Scientific research commences from a deductive standpoint. We have many, many theories about why bodies work the way they do, why our minds function in particular manners, and about the observable patterns in social structures and cultures across the planet.

Whenever we set out in a research process to test a theory, or component of a theory, to see if it actually predicts and explains the world in the way it states, we will need to construct hypotheses. A working understanding of where hypotheses come from and their centrality in science is crucial for connecting the various stages in the scientific process.

What Is This Concept?

I very rarely encourage students to memorise a definition of anything, but the definition of hypotheses is one exception. An hypothesis is *a testable statement of relationship between two or more variables*. Let's take a closer look at the three essential features of an hypothesis: testability, relationship and variables. For the sake of ease, I discuss them in reverse order from how they appear in the definition of an hypothesis. But before we do that, let's consider an actual example of research from sport and exercise science.

Professor of physiology Tim Noakes is sort of a hero of mine. Not only is he a gifted runner, he is also a brilliant academic. I have read his book, *Lore of Running*, countless times. Noakes (2001) is a strong supporter of a theory called the central governor theory. What is the theory all about? It's basically a theory about why endurance athletes fatigue when they do in a race. Scientists and athletes have always thought that your muscles tire because they reach some kind of physical limit. Either they run out of fuel, or they drown in toxic by-products. Nasty stuff, really. In the past few years, Noakes (along with his colleague Alan Gibson) has begun to question the standard theory. They are convinced that athlete fatigue simply is not the same as a car running out of petrol. Fatigue, they argue, is an *emotional response* that begins in your brain. The essence of the 'central governor' theory is that your brain paces your muscles to keep them back from the brink of exhaustion. When the brain decides it's time to quit, it creates the distressing sensations you interpret as muscle fatigue and imminent system shutdown (based on an old physiological theory called 'catastrophe theory'). So, your mind quits before your body, and convinces the body to give up lest it dies! What athletes need to do then, is train their bodies and brains to perceive exertion as less threatening to the system. This will then push them through their current threshold/exhaustion barriers. One method of doing this, based on the theoretical logic of Noakes's (2001) research is interval training. Interval training is a technique where repeated bouts of high-intensity exercise are separated by short to medium length recovery periods. In physiological and cognitive theory regular bouts of interval training teach your system to push through, and be comfortable with, the pain.

Running legend Bart Yasso would agree with Noakes. Yasso developed a training system of interval work for marathon runners. Yasso argued that if marathon runners regularly incorporated sessions of 10 × 800m all-intensity interval sessions into their training regimens, not only would they improve their marathon performance, they would also be able to almost exactly predict their marathon times from work in these sessions! He argued that if you averaged, say 3:18 per 800m in your interval sessions, you could run a 3:18:00 marathon. All of Yasso's method is based on, for all intents and purposes, the theory of the central governor and its relationship to athlete performance. The sessions are intended to push the body through the central governor threshold. This is such an interesting idea to me as a marathon runner. I've used the method on several occasions. Each time, I posted a personal best for the marathon. A coincidence? Perhaps, but we could test it!

Let's illustrate how to write hypotheses using the example above. I wager there is a relationship between interval training and marathon performance. Note right away that I'm not saying a thing about the central governor at all. We will come back to that in a while. I intend to conduct an experiment with novice marathon runners. One group I will train with tempo, long and hill sessions (pretty standard in marathon training), and the other with tempo, long, hill and Yasso 800 interval sessions. My bet, based on Noakes's theory, is that the interval-trained athletes will fare better than the other group. Now, how do I summarise all of this as a testable hypothesis?

Hypotheses can be stated in a number of ways. For example:

- **As a negative relationship between two variables.** *Negative* means the values for the variables included move in opposite directions – as one variable increases the other decreases. In terms of the research on interval training, a negative relationship exists between the amount of interval work during training and finishing time in a marathon: that is, the higher the amount of interval training during one's marathon preparation time, the lower the marathon time. The words *inverse* or *indirect* are also used to describe a negative relationship.
- **In the form of a positive relationship between variables.** *Positive* means the variables move in the same direction – as one increases so does the other (or by contrast, as one goes down, the other goes down as well). The word *direct* is also used to describe a positive relationship. A positive or direct hypothesis can be expressed in several ways, such as: 'As one's Yasso 800m average time per session decreases, one's rate of perceived exertion at mile 20 in a marathon decreases.' Or you could simply write (but this is not preferred), 'There is a positive (or direct) relationship between Yasso 800m average times in training and rate of perceived exertion in the marathon.'
- **Some group (A) is different from another group (B).** This form of hypothesis occurs when the purpose of research is to find out if two groups are different with respect to some variable. Generally, however, we can go beyond just saying we expect to find some difference. Usually, a hypothesis specifies the direction of the difference by saying that the variable for one group is larger or smaller than for another group. To illustrate, we could hypothesise that marathon runners who train using Yasso 800 interval sessions have lower marathon times than individuals who do not interval train with the method.

None of the above hypotheses is preferable to the others from a researcher's perspective. However, they are all hypotheses. How? First, hypotheses contain two well-identified variables. Remember that a variable is something that can be changed, such as a characteristic or value. Or, stated differently, it is a 'thing' that can take on different values for people. Every research hypothesis contains two variables, an independent variable and a dependent variable (see the entry on Variables as a reminder). As a quick reminder, the independent variable is assumed to be the one responsible for changes in the dependent variable. In our running example, interval training is the independent variable and marathon time is the dependent variable. Hypotheses express an expected relationship between an independent and dependent variable. As a matter of syntax, think of an hypothesis as a single sentence with three parts:

1. The subject, which generally is the independent variable;
2. A connecting verb, which defines the relationship between the independent and dependent variables;
3. The object, which is the dependent variable.

Try to express any hypothesis you write in the same way – as a single sentence with a subject, a connecting verb and an object. Also, since most hypotheses deal with the actions of groups of persons, plural forms are generally used. In addition, because you want to generalise to empirical conditions as they currently exist, hypotheses are generally expressed in the present tense.

The crux of an hypothesis is the proposed, directional statement (positive or inverse) of relationship between the two variables. Embedded in the statement of directionality is a causal and not just a correlational assertion. An hypothesis is a statement derived from a theory predicting how one variables changes another variable. Finally, an hypothesis must be testable: it cannot be dogma, ideology or faith alone. The variables must be measurable (we have to be able to score interval training and marathon performance in quantifiable, reliable and valid ways) through the use of empirical indicators.

Why Is This Relevant to Me?



The development of research hypotheses needs to be sorted out well before any piece of empirical evidence is gathered, as the form and content of the hypotheses dictate everything about the data collection and interpretation process. Hypotheses rather narrowly prescribe the focus of the data collection process.

In order to state a hypothesis we have to have a sound set of theoretical reasons for saying why we think the hypothesis will be supported by some body of data. I often tell students that hypothesis testing is really theory testing. A study with a shaky theoretical basis does not explain very much to us in the end. A good theory teaches us how and why the two variables are related. It proposes a detailed explanation of a causal relationship by specifying the mechanism of change associated between the two variables. In the world of academic knowledge production, it is not enough to state: 'Interval training seems to improve marathon time, if my data are correct.' We need to be able to tell people, using a blend of physiological and psychological theory what changes in the body and mind result through interval training to produce better marathon times. The data allow us to empirically see (or not) theories in action. Researchers refer to this rationale as the theoretical framework underlying the hypothesis. Without theory, we are simply shooting arrows in the dark at targets we cannot see.

Show Me How It's Used!

As outlined above, a *research hypothesis* is a statement of prediction between two variables. It describes in concrete (rather than theoretical) terms what you expect will happen in your study. Not all studies have hypotheses.

Sometimes a study is designed to be exploratory. There is no formal hypothesis, and perhaps the purpose of the study is to explore some area more thoroughly in order to develop some specific hypothesis or prediction that can be tested in future research. Nevertheless, so far we have covered how to generate research hypotheses. Students and non-quantitative researchers almost always get tripped up when we introduce a different kind of hypothesis into the research mix: the statistical hypothesis.

A statistical hypothesis (test) is a method of making statistical decisions about the results of our research. In statistics, results from a study are said to be 'statistically significant' *if they are unlikely to have occurred by chance alone in our research process*. Say I find in my experiment with a sample of runners that, indeed, there is a huge difference in times between people who have interval trained and those who have not (the latter being far slower). How do I know whether the results were atypical – for instance, caused by a strange sample of people? In research we are interested in whether or not the relationships in my sample could be generalised to the level of the population (say, all marathon runners, everywhere). So, our sample statistics are hopefully very good representatives of the true 'population parameters' (i.e. the actual relationships we would see if we sampled all marathon runners, everywhere). This assumption may or may not be true. The best way to determine whether results are 'statistically true' would be to examine the entire population. Since that is often impractical or impossible, researchers typically examine a sample from the population. To test whether or not the results from the sample are likely to be observed at the level of the population, we engage in statistical hypothesis testing.

Research hypothesis: The statement of relationship between two variables driving your study and/or the statement of expected relationship tested within a sample of people.

Statistical hypotheses testing: A processes in which we test whether or not the observed relationships between variables in our sample are likely to be observed at the level of the population.

Actually, whenever we talk about a statistical hypothesis, we are really thinking simultaneously about *two* hypotheses. Let's say that you predict that there will be a relationship between two variables in your study, like interval training and performance. We conduct the study and observe a relationship. Now, can we trust this relationship from the sample at the level of the population? We need statistical hypotheses. The way we would formally set up the statistical hypothesis test is to formulate *two hypothesis statements*, one that describes your prediction and one that describes all the other possible outcomes with respect to the hypothesised relationship. Your prediction is that variable A and variable B will be related (in statistical hypothesis testing, you don't care whether it's a positive or negative relationship). Then the only other possible outcome would be that variable A and variable B are *not* related. Usually, we call the hypothesis that you support (your prediction) the *alternative* hypothesis, and we call the hypothesis that describes the remaining possible outcomes as the *null* hypothesis. Sometimes we use a notation like H_A to represent the alternative hypothesis or your prediction, and H_0 to represent the null.

If your prediction specifies a direction, we call this a *one-tailed hypothesis*. For instance, a one-tailed test in our running study would be written as follows:

The null hypothesis for this study is:

H_0 : There is no relationship between interval training and marathon times.

Which is tested against the alternative hypothesis:

H_A : Interval training produces a significant *decrease* in marathon times.

When your prediction does *not* specify a direction, we say you have a *two-tailed hypothesis*. In this case, you might state the two hypotheses like this:

The null hypothesis for this study is:

H_0 : There is no relationship between interval training and marathon times.

Which is tested against the alternative hypothesis:

H_A : There is a statistically significant relationship between interval training and marathon times.

Remember, hypothesis testing is the use of (inferential) statistics to determine the probability that a given null hypothesis is true at the level of the population and *not just* the sample (see the entries on Inferential Statistics, and Populations and Samples). The usual process of statistical hypothesis testing consists of four steps. All of these occur after we have collected the data in our study:

1. Formulate the null hypothesis and the alternative hypothesis;
2. Identify a test statistic (*t-test*, *F-test*, etc.) that can be used to assess the truth of the null hypothesis;
3. Compute the *P*-value (probability value) using a computer program like STATA, R or SPSS, which is the probability that a test statistic at least as significant as the one observed would be obtained assuming that the null hypothesis was true. The smaller the *P*-value, the stronger the evidence against the null hypothesis;
4. Compare the *P*-value to an acceptable significance value (sometimes called an alpha value). If the observed effect is statistically significant, the null hypothesis is ruled out and the alternative hypothesis is accepted.

At the beginning of the research process, it is important for students to understand the generic and specific differences between research and statistical hypothesis. Each is unique and has its own role in the research process: one is essentially oriented towards measurement and data collection, while the other is for statistical analysis.

Problems, Pitfalls and Controversies

Is a single study ever enough to test a theoretical idea? I could run my little experiment on Yasso 800 interval training, but is this study enough to test the central governor theory? What Noakes and others are proposing is an incredibly complex rendering of how body/mind systems work in a complementary fashion in situated environments to regulate behaviour. No single study could ever test all of its dimensions adequately. When we inspect the theory closely, we realise that even central concepts in the theory, like perceived exertion levels, are difficult to measure at all – the standard use of the Borg RPE scale aside. Therefore, we never fully test many of our theories, but instead test fractions or principles from them. If our research efforts are partial, then our explanations of the world are only ever partial, tentative and probable.

Students also love to speak and think in languages of proof and cause. Maybe this stems from the impact of crime shows like *Law & Order* and *CSI* or medical dramas like *House* where cause and effect are slickly and tidily packaged into 60-minute snippets of contrived life. While hypotheses are built on the pursuit of such lofty concepts as proof and cause, our research results never come close to either. Hypothesis-based research is excellent at revealing tentative relationships, probable associations and supported patterns. These results provide better understandings of if and how our theories operate. But do not be misled by the tone and content of hypotheses! Scientists tend to be a conservative lot, and only until survey or experimental data have been replicated many times does even quasi-confidence in demonstrated empirical relationships develop. I plead with students to remove the word 'proof' from their lexicons, and every year it is a tough task.

See also: [Causality](#); [Experiments](#); [Positivism](#); [Questionnaires](#); [Variables](#).



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