

Experimentation allows for the development of new knowledge by introducing and then manipulating an independent variable to produce an effect on a dependent variable. Where we are confident that any effect on a dependent variable is caused by the independent variable, we have a cause and effect relationship. A sports drink causes endurance performance to improve, for example. It seems simple that we can establish causality and demonstrate that a cause and effect relationship exists, but that can only be true when we are sure that it really exists because we have controlled or eliminated all the other possible causes and influences. Some of these other possible causes or influences are known as extraneous variables.

In a simple example you may want to examine the effect of training programmes, the independent variable, on fitness levels, the dependent variable. This simple idea becomes more complex when we start to consider how often they should train, at what intensity, etc. These considerations and the decisions you make can be informed by reading the research of others. Consider also how their work or other activity may influence the results. This is the effect of extraneous variables. You need to develop a keen eye for the levels of control within your work.

In this example when we review our research it is important that we are confident that the training we have designed really is the reason there was an improvement in fitness levels. There is always a possibility that results seen are by chance or that another influence, an extraneous variable, has affected the outcome. Experimentation should be performed with a careful and systematic approach to minimise as much as possible those threats to validity. Minimising threats to validity increases confidence that any effect seen is because of the manipulation of the independent variable. Only when it can be logically determined that one factor produces a predictable influence on another is a cause and effect relationship said to exist.

If a cause and effect relationship is seen, robust repeated experimentation by others will confirm that this relationship is correct. This is also why it is acceptable to often repeat the studies of others; science is about reproducibility. However, it is not only about determining the present, what is seen here and now, but also about being able to generalise the relationship to conditions and situations outside the experiment with confidence, thereby allowing prediction of future events.

The experimental method

You may be keen to jump right in and start to design an experiment that appears to do what you want. Taking this approach gets on with the job but you find that many mistakes will be made that cannot be rectified later, so hold on, be patient. So, before we can design and carry out our experiment, we need to understand what we mean by the experimental method.

The experimental method of research is where a variable is manipulated and the effect of that manipulation is observed. Consider something like a strength training programme to help understand this. We would manipulate the weight lifted, by increasing it or by increasing the number of repetitions or sets over time and observe the increase in strength. The manipulation of the weight training programme by weight, repetitions, sets or any combination of these is the independent variable and the growth in strength, or not, is the observed effect of that manipulation, the dependent variable.

When we decide to observe the effects of manipulation of variables we have the choice to observe that either under known, tightly defined and controlled conditions, like in a laboratory, or as they would be under natural occurrence, like that which occurs in actual sport performance. This choice that we have is the start of the *basic* versus *applied* debate in sports research. Do we observe a performer in very unnatural conditions, like in a laboratory on a treadmill or other equipment, or should we observe them in the natural field of performance? This is another of the many choices that you have to make in your research project. There is no right or wrong as to where in the spectrum you choose, just different advantages and disadvantages.

Experimental research and sport

Let's look at some typical examples of experiments in sport. We will use these examples throughout the chapter. Try to always put your own research project in the context of these examples and perhaps make some notes to aid you as you do.

Example 1

If we give a group of people a training programme to follow over a period of weeks and observe the fitness levels of the group, both prior to and at the end of the programme, we may expect to see a difference in fitness levels at the end of the programme. By allowing people to follow a training programme without too many controls and restrictions on their daily lives the result is more representative of what normally happens. This is observing changes as they would be under more natural conditions. This is research that is further towards the *applied* end of the spectrum.

The training programme is the variable we can manipulate and the change in fitness levels the observed effect. One way to do this as an experiment is to take a group and measure fitness levels before they start, allow them to do the training programme, and then measure fitness levels at the end. The problem here is if they are allowed to be in *natural* conditions, how sure can we be that any changes in fitness levels are due to the training programme and not another influence, an extraneous variable?

We could take the group as a whole and divide it into two. Then, by asking some participants to follow the programme and others not to and observe the changes of fitness levels of both groups, we can compare differences between groups and be more confident that changes that occur are due to the training programme. This is an example of how we can design our experimental method. We may decide to manipulate the training programme in other ways with more groups, the amount of training they do, at what times and for how long, but if we start to do this we make things more complicated.

The training programme experiment is an example of an experiment where we expect to see a difference. That is the participants who follow the training programme should show higher fitness levels at the end than the group who did not.

Example 2

We can take a participant, or even better a group of participants, in the laboratory and carefully increase running speed on a treadmill and measure blood lactate levels at set regular points until the participant reaches exhaustion. This manipulating of the variable of treadmill speed under known, tightly defined

and controlled conditions then observing the changes in blood lactate levels is an example of more *basic* research.

The treadmill speed is the variable we manipulate as we increase its speed and the blood lactate level is what we observe. How we decide to manipulate the treadmill speed, by how much it increases, and how often and for how long we ask the participant to run at that speed is an example of how we design our experimental method. We could build on this design by measuring other participants and observing their responses to increases in treadmill speed and collecting all that data together as a whole group.

In this experiment we may expect to see a relationship between what we manipulate and what we observe in the participants. As we increase running speed on a treadmill and measure blood lactate levels at regular points until exhaustion we expect to see a relationship between running speed and blood lactate levels.

Consider both examples. One looked for a difference; the other looked for a relationship. The question, *Am I looking for a difference or a relationship?* is important to answer as soon as possible, and it is important that we understand some of the complexities contained in it. If we have two separate groups, such as a training and a non-training group, we may look for a difference between those groups. In this example we may be able to clearly identify a cause and effect type of relationship. If we have two separate variables, such as lactate and running speed, we may look for a relationship. We cannot be sure that the relationship we see is caused by one or the other variable; in some cases it will be, in others it will not.

It seems straightforward so far. Now we consider using one group which we may test in two conditions. An example of this would be a sports drink experiment. We take a group of athletes, test them on time taken to complete 10,000 metres running *without* the sports drink, then a week later test them again on time taken to complete 10,000 metres running *with* the sports drink. We may expect to see a difference in the times, but also because the same athlete does both tests we may expect to see a relationship between improvements in time and amount of drink consumed. These are just examples of considerations that we have to think through before we can go forward with the design of our experiment.

The experimental method and protocols

How we actually put our participants through the experiment is called the protocol. To design a protocol and follow an experimental method we need to understand the variables, the things that can change or stay constant, to ensure our protocol and experiment gathers data on what we are examining.

Already in the examples we have seen we have identified variables, such as training programmes and running speeds, and effects we may observe, such as changes in fitness levels and blood lactate. Using our knowledge of the subject area we can intuitively make a prediction of what we may expect to observe following manipulation of a variable. We may expect to see a difference in fitness levels between those who do the training programme and those who do not, or we may expect to see a relationship between blood lactate levels as running speed increases. These intuitive predictions are the beginning of the development of hypotheses.

What we need to ensure before we continue is that we can clearly identify in our hypothesis the variables we manipulate and the effects we are going to observe. In a hypothesis, the variable we manipulate is the *independent variable* and the effect we observe is the *dependent variable*. Hypotheses will have one or more independent variables that you will manipulate and you will have an objective measurement, a dependent

variable that is the effect of this manipulation. All this talk of variables and hypotheses can seem confusing, but let us consider two examples.

A hypothesised difference

We can hypothesise that there will be significant difference in fitness levels between groups who do a training programme compared to those who do not train. The independent variable, the one we can manipulate, is whether a group trains or not. The dependent variable, the objective measurement you can make, is the degree of fitness of the group. It is important to notice here that we are looking for a *difference between* two groups.

A hypothesised relationship

We can hypothesise that there is a significant relationship between running speed and blood lactate levels. The independent variable is the speed of the treadmill. The dependent variable is their level of blood lactate.

	Hypothesis	Independent variable	Dependent variable
Experiment that looks for a difference between measurements	There will be significant difference in fitness levels between a group that do a training programme compared to a group who do not train.	Whether a group trains or not – in this case this variable has two levels.	Degree of fitness.
Experiment that looks for a relationship in measurements	There will be a significant relationship between running speed and blood lactate levels.	Running speed.	Blood lactate levels.

Table 5.1: The relationship between independent and dependent variables

Learning Activity 5.1

This activity is designed to help you identify your independent and dependent variables. The first part of this task is to state definitively what your experiment is aiming to find, a difference or a relationship. Then create a table of three rows and two columns, and in the first column list the following:

- my hypothesis is ...;
- my independent variable is ...;
- my dependent variable is

In the column next to these headings identify the statements you need to make. It would be worthwhile checking these with friends or perhaps your tutor or supervisor to ensure you are correct.

Now you have clearly identified your independent and dependent variables you could start to think about what methods you could use to measure them. Create a list of action points from this work.

Error and how to control it

Let's explore a little more about what we can do to ensure an experiment is likely to produce data that we can use before we begin to look at how to design one.

The more complex the science, the more essential is it, in fact, to establish a good experimental standard, so as to secure comparable facts, free from sources of error.

(Bernard, 1949)

From this quote we can deduce that even the simplest science, the simplest experiment, to produce worthwhile results needs a good experimental standard – but what exactly do we mean by *good experimental standard*? A good experimental standard is one where we should aim to carry out an experiment free from sources of error.

An experiment has something which we manipulate (our independent variable) and something we observe that shows the effect of that manipulation (our dependent variable). What we should aim for is that the measurement of our dependent variable should be a *true* score, which is one that is free from error.

If we take a dependent variable and look at what could influence it in an experiment, what we see is that we actually have a measurement that has:

- a *true* score;
- *systematic error*, that is, some error added to the true score that is systematic, in that it affects all the scores in a similar way. An example of systematic error can be using weighing scales that are a few kilograms out. As long they are not adjusted they will always remain the same number of kilograms wrong. The error is systematic and is always produced, as long as things do not change.
- *random error*, that is, some error that adds to the true score that occurs randomly. Random error can result from the experimenter reading a score incorrectly, for example.

An experiment would want measurements as close to the *true* score as possible. If there is too much error, whether systematic or random, then our measurements are not likely to be valid. If it has a lot of random error then it will not be reliable. See the section on *threats to internal validity from equipment* later in this chapter for some examples of random and systematic error.

The question you have now is, *how do I ensure I measure my dependent variable as close to the true score as possible*? For this text to be specific to your study is very difficult as every research project will differ and require a slightly different approach. It is something that should be discussed with your tutor or supervisor. Generally, I can recommend that you maximise your measurements' validity. This will certainly help in avoiding error.

Maximising your measurements' validity

This section will help you understand the concepts of reliability and validity better because you will place them into the working context of your own experiment.

As a researcher any experiment we carry out has to have internal validity and external validity. Internal validity is the degree to which we can be sure that the measurements we have and can show are due to manipulation of the variables and not something else. External validity is the degree to which we can generalise what we find in our experiment to the general population.

Let us use the earlier examples of training programmes affecting fitness levels and running speed affecting blood lactate levels to help us understand the threats that can occur to internal and external validity.

Threats to internal validity from your sample group

Your sample is the selected participants drawn from the population under investigation. If the sample undertaking the fitness programme is very different to the sample chosen to do no training then there is a danger we may be measuring differences that are there to start with, not any differences that come about because of the training programme. This can be controlled by randomly assigning people into groups; random assigning evens out differences. Sometimes you may have a study that requires groups to be different. You may be looking at age differences or differences between genders. In this type of research project, threats to internal validity from the sample group are unavoidable but should be discussed to show you understand the principle.

Another threat to consider under this heading is the consideration of participant drop out. This is also rather scarily known as differential mortality. It is inevitable that you are likely to lose some participants from your sample. It may be that some of the participants you lose were all those upon whom your treatment, manipulation of the independent variable, had an effect. This will affect the results and make them invalid. To help with this you should aim to over-recruit participants for your study.

Reflection Point

Paula, a student who has recently finished a research project that examined the effect of music on training performance, commented:

I realised very early that a lot of the people I expected would be participants for me were also going to be busy with their own research projects. I was lucky in that I had a squad of netball players I could call upon to be my participants. A lot of my friends struggled to get enough participants though.

The point Paula makes is that you need to think about participant recruitment early in your study.

Threats to internal validity from time

Things naturally change over time, and so how your experiment is designed and the timing of when you take measurements is crucial. If we use the example of blood lactate, the time course of how blood lactate levels are reflected in blood taken at a sample site is important to understand so that when measurements are taken they are likely to be an accurate reflection of what is actually happening. Equally, with training programmes fitness levels change over time. Expecting to see changes after only one week is unlikely, but measuring fitness levels six weeks after they have finished is also likely to produce invalid results.

Threats to internal validity from history

When we talk of threats to internal validity that arise from history, we are referring to events that could occur in the lives of the participants that are unrelated to our manipulations of the independent variable, which could give rise to changes similar to those we are expecting. An example of this would be if one of the training participants' car was to break down and they had to walk to work for six weeks – they might get fitter as a result of this. We would not be able to fully determine the extent to which they got fitter because of our training programme or because of the fact they were walking more. This may be unavoidable but asking participants relevant questions can help indicate if it occurs. So in physiological studies you may ask participants when the last time they exercised was, or other questions relevant to the factors you are examining.

Threats to internal validity from equipment

The results that you measure can only be as good as the equipment you use to measure it and how familiar you are with that equipment. Doing a research project, perhaps for the first time, means it is likely that you will be using some equipment for the first time. As you become more familiar with the equipment, the more often you use it, you may begin to be less careful about its operation and so random error may start to creep in. This can result in data which become more and more invalid over time. Another possibility is that you fail to calibrate the equipment prior to using it or ensure it remains calibrated, so that any measurements you take are invalid. This can result in systematic error.

Threats to internal validity from reactivity and experimenter effects

Because sport research deals mainly with human participants, whenever you place a person in an experimental situation it is likely this will affect their behaviour. A common example of this is how a person's blood pressure often shows a higher reading caused by the stress of having their blood pressure measured. This type of reactivity to an experimenter threatens the validity of the results and so should be reduced. You may wish to carry out some familiarisation trials with the participants prior to actually carrying out the data collection. These familiarisation trials are where the participant is brought in, shown what is going to happen and in some cases allowed to have a go, a trial run if you like. It reduces their anxiety and is also good practice for you.

It is also likely as a young researcher that you will use people you know as participants in your study. Why not? These are people who are friends and often willing participants but potentially you could influence those people as an experimenter because the participant may try to please you by attempting to make the experiment work. One method to reduce this effect is the use of a double blind design. This

is where the experimenter and the participant are both unaware of which condition the participant is in. Unfortunately it is unlikely that the resources for this to happen in student research will be available, therefore you should employ at least a single blind design. This is where the participant is unaware of which condition they are in.

Other threats to internal validity

There are other threats to internal validity from other considerations but these are less likely to occur in research into sport and exercise. Considerations such as maturation, the changes that will occur as people naturally develop, are particularly important in studies of children over time. Another possible threat is regression to the mean. This is where participants or observations produce extreme, either high or low, measurements on a pre-test or occasion by chance. Consequently they are likely to produce scores closer to the mean on a subsequent test and this regression, moving back, to the mean, can be misinterpreted as an effect when it is not.

Take some time to now consider your project. What are the potential threats to validity to your research? Draw a mind map to help you consider them. They can be very useful because all the questions asked make you think of what needs to be considered and found out.

Threats to external validity

It is best to highlight here two threats to external validity that are likely to occur in research projects.

Remember external validity is the degree to which we can generalise what we find to the general population:

- the overuse of special participant groups;
- restricted numbers of participants.

In research projects you will tend to look for participants from your own peer group or local area. This is likely to mean that participants are reasonably fit, young, and possibly more intelligent than the normal population. Using these participants for research limits the ability to be able to generalise to the population because the population as a whole are not as fit, young, and possibly intelligent as you. The other common occurrence in student research is the limited number of participants a study will use. This will affect the reliability but also affects the ability to generalise to the population. Sample size is an important factor in finding statistical significance. Now that you have a clearer idea of threats to validity and reliability, what are you going to do next?

Experimental research

If we want an experiment that is free from error, one thing will help, that is, keep it simple. The simpler and more focused your experiment the more likely it is to produce worthwhile results. No one method is better than any other but some methods are more relevant to your project than others. You will want the answers you find to be the most plausible answers to the question you have posed. To ensure this, have a clear, well-defined research question, remain focused on that question, and above all keep the experiment you design to collect your data simple.

