RATIONALE
Psychology is the scientific study of mental processes and behaviour in humans. Biological, behavioural, cognitive and socio-cultural perspectives inform the way psychologists approach their research into the human condition.

The science of psychology has produced rapid expansion in knowledge, particularly in the fields of neuroscience and cognition. This growth has been fuelled by the emergence of new interdisciplinary approaches, advances in imaging technologies and a broader public interest in applications of psychology. As a result, new ethical frameworks have emerged for neuroscientific and psychological research, clinical practice and commercial applications.

In the VCE study of Psychology, students explore complex human behaviours and thought processes. They develop empathetic understandings and an understanding of mental health issues in society. Students are given the opportunity to apply psychological principles to everyday situations such as workplace and social relations. Psychology provides students with a sophisticated framework for understanding the complex interactions between biological, behavioural, cognitive and socio-cultural factors that influence thought, emotions and behaviour. The study assists students to further develop effective language skills for communication, and numeracy skills for research, data analysis and other applications. In addition, students develop a range of broader skills including those of problem solving, critical evaluation and the application of processes of scientific inquiry.

The study of Psychology leads to opportunities in a range of careers that involve working with children, adults, families and communities in a variety of settings. These include academic and research institutions, management and human resources, and government, corporate and private enterprises. Fields of applied psychology include educational, environmental, forensic, health, sport and organisational psychology. Specialist fields of psychology include counselling and clinical contexts, as well as neuropsychology, social psychology and developmental psychology.

ASSESSMENT Units 3 & 4
- Unit 3 School Assessed Coursework: 20%
- Unit 4 School Assessed Coursework: 20%
- End of Year Examination: 60%

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Assessment information

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  - 2.2 Placebos and procedures
  - 2.4 Experimental research designs
  - 4.1 Inferential statistics
  - 4.3 Conclusions and generalizations

The Human Nervous System

The Brain

Holiday Homework checklist

Focus on Research

Brain Anatomy
Required Materials

- Grivas Textbook
- "Nelson" Student Activity Manual
- Folder
- Loose leaf paper
- Plastic pockets
- Dividers
- Pens, pencils, etc.
- Completed holiday homework
- A positive and hard working attitude

Assessment Information

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<td>SAC 2</td>
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Research Methods

The following activities need to be completed either for homework or during transition.

- 2.2 Placebos and procedures
- 2.4 Experimental research designs
- 4.1 Inferential statistics
- 4.3 Conclusions and generalizations
2.2 Placebos and procedures

We have discussed the problem of demand characteristics, where participants' behaviour may affect the results of a study. However, we may also see a change in participants' behaviour due to their expectations.

Participant expectations can play a significant role in the way that participants behave in an experiment. Due to ethical considerations, participants will almost always be aware that they are being studied, but it is best that participants know as little about the study as possible.

Placebos and the placebo effect
In many experimental procedures, both the control and experimental groups may receive some sort of treatment (e.g. medication); however, one group – the experimental group – will receive the actual treatment (such as a new drug) and the other group – the control group – will receive a placebo (such as a sugar pill). A placebo is a fake drug or treatment, and is used so that participants in each group do not know whether they are being exposed to the experimental condition.

The use of a placebo minimises the impact of the placebo effect on the results. The placebo effect occurs when there is a change in a participant's behaviour due to the participant's expectation about the treatment to be received. For example, consider an experiment trialling a new headache drug. If the experimenter gives the experimental group a pill and does not give the control group a pill, participants in the experimental group may believe that their headache has improved, and therefore report that it has improved, simply because they received some sort of treatment. If this case the experimenter would not be able to tell whether the reported improvement in the headache is due to the effect of the drug or the placebo effect – the effect of the participant having been given some sort of treatment. If, however, both the experimental and control groups receive a pill, every participant will believe that they are receiving treatment, which minimises the placebo effect.

Single-blind procedures
A single-blind procedure is when the participants do not know whether they have been assigned to the control or experimental group. Placebos are used in this case, and participants are unaware of whether they are receiving the placebo (control group) or the actual drug (experimental group). This reduces the impact of participant expectations on the results.

Double-blind procedures
A single-blind procedure may help to balance the impact of participants' expectations on results; however, the experimenters themselves still know which group is which in a single-blind procedure. The experimenter's behaviour towards these groups (such as body language, verbal cues and preferential treatment) may also influence the results of a study. This is known as the experimenter effect. The experimenter effect occurs when there is an unintentional change in participants' behaviour, and hence results, due to the experimenter's influence. For example, an experimenter may be more encouraging with the experimental group than with the control group, or may unwittingly drop hints about desired responses to help support their hypothesis.

To reduce the impact of the experimenter effect on the results, researchers may implement a double-blind procedure. This is where the participants and experimenter do not know which participants have been allocated to the control and experimental groups. This of course involves a third party being privy to which group is receiving the experimental treatment; however, this person is not directly involved with the participants in any way, and so cannot have any influence over them.
Check your understanding

1 Match each term with its definition.

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Double-blind procedure</td>
<td>An unintentional change in participants' behaviour, and hence results, due to the experimenter's influence</td>
</tr>
<tr>
<td>Experimenter effect</td>
<td>A fake/false drug or treatment</td>
</tr>
<tr>
<td>Single-blind procedure</td>
<td>The participants and experimenter are unaware of who is in the control and experimental groups</td>
</tr>
<tr>
<td>Placebo effect</td>
<td>The participants are unaware of who is in the control and experimental groups</td>
</tr>
<tr>
<td>Placebo</td>
<td>A change in a participant's behaviour due to their expectations of being involved in an experiment</td>
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</table>

2 Explain the similarities and differences between the terms in the table.

<table>
<thead>
<tr>
<th></th>
<th>Similarities</th>
<th>Differences</th>
</tr>
</thead>
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<tr>
<td>Placebo and placebo effect</td>
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</tr>
<tr>
<td>Single-blind procedure and double-blind procedure</td>
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</table>
2.4 Experimental research designs

As we learned earlier, the third step in psychological research is to decide on the experimental design that will be used; that is, how the participants will be allocated to groups within the experiment. There are several different experimental designs that can be implemented, and careful consideration of the experimental design is another way to minimise extraneous variables.

Independent-groups design

The independent-groups design involves randomly allocating the members of the sample to either the control or experimental group. Once you have your sample, you may draw participants' names randomly out of a container and assign the first name to the control group, the next name to the experimental group and so on until all participants are assigned to groups. The independent-groups design is a very quick and easy design to administer, and is therefore a popular technique in experimentation. It allows us to research large numbers of participants fairly easily.

The two groups in an independent-groups design should be free from bias but, due to the random nature of group assignment, there may be participant differences between the two groups; for example, members of one group may be naturally smarter than members of the other group. This design does not, therefore, effectively minimise differences in participant characteristics between the two groups.

Matched-participants design

The matched-participants design seeks to eradicate participant differences. The matched-participants design involves pairing each participant based on a certain characteristic that they share; for example, you may pair the two smartest students or the two most experienced netballers. Once you have matched these participants, you randomly allocate one to the control group and one to the experimental group. This helps to achieve an even spread of participant characteristics between the two groups, and hence minimises extraneous variables due to participant differences. For this reason, identical twins are often ideal candidates for a matched-participants design.

One limitation of this design is that it involves a pretest to match participants on particular characteristics (for example, you may administer an IQ test to match participants on intelligence) and is therefore more time-consuming than other designs. Also, during experimentation one participant may drop out, and in a matched-participants design this means that the other member of the pair (in the other group) must also be removed from the study.

Repeated-measures design

Although a matched-participants design seeks to ensure that both groups are equal in participant characteristics, it does still use different participants and hence there may be natural differences in their abilities. A repeated-measures design is implemented by using only one group of participants and exposing that group to both the control and experimental conditions. As the same participants are used in the control and experimental conditions, they are obviously completely identical in characteristics and abilities.

This experimental design eliminates the impact of participant differences as an EV but it does create a different problem known as order effects. Order effects occur when there is a change in results due to the sequence in which two tasks are completed; that is, due to the order in which participants complete the control and experimental conditions. The change in results may be an increase in performance due to knowledge or experience in a task, or may be a decrease in performance due to boredom or fatigue with carrying out a task more than once. An individual’s experience may therefore have an impact on the results of the study and this would be an extraneous variable.

For example, you may be involved in a repeated-measures study that investigates how different bathing suits affect swimming speed. You undertake the control condition first, in which you wear your normal bathing suit, and the experimental condition second, in which you wear a special bathing suit. The IV is supposed to be the type of bathing suit worn, but your performance in the experimental condition may be altered because you have already completed the control condition: it may be enhanced because you have had a warm-up swim, or it may be hindered because the first swim exhausted you. In this case, swimming performance may be due to factors other than the IV, and this is an example of order effects.

One way to minimise the impact of order effects is to use counterbalancing. Counterbalancing involves dividing the group of participants in half and arranging the order of the conditions so that each condition occurs equally as often in each position. That is, it involves exposing half of the participants to the control condition first and the experimental condition second, and exposing the other half to the experimental condition first and the control condition second. This counterbalances the potential impact of order effects on the results. In the swimming example, half of the participants would swim in their own bathing suit first and the new bathing suit second, while the other half would swim in the new bathing suit first and their own bathing suit second.
Check your understanding

1. Complete the table by comparing the different experimental designs.

<table>
<thead>
<tr>
<th></th>
<th>Explanation</th>
<th>Advantage(s)</th>
<th>Disadvantage(s)</th>
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<td>Independent-groups design</td>
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<td>Matched-participants design</td>
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<tr>
<td>Repeated-measures design</td>
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</tbody>
</table>

2. You would like to investigate whether drinking an energy drink helps individuals to remember a list of 50 three-letter words. You decide to expose all your participants to a control condition, where participants will learn List A and then recall as many words as possible; and an experimental condition, where they will learn List B while drinking an energy drink and then recall as many words as possible.

   a. Which experimental design has been used in this experiment? Explain your answer.

   b. Provide two examples of order effects that may impact on the results of this study.

   c. Explain how you could use counterbalancing in this experiment to eliminate the impact of order effects on the results.
4 Drawing conclusions

4.1 Inferential statistics

Typically, psychologists seek to discover general patterns of behaviour that apply widely to humans. For example, a researcher studying the effects of a new therapy on a small group of people suffering from depression would like to know if the therapy holds promise for all people with depression. Inferential statistics allow us to make inferences about the results of an experiment; to form conclusions and generalise findings; that is, to apply findings about the behaviour of small groups (samples) to the larger groups they represent (populations).

Experiments use inferential statistics to determine whether or not the results of an experiment support the hypothesis. The researcher must also determine whether differences between results yielded by the experimental and control groups are due to manipulation of the IV, or in chance. For example, if students in Ms Perfect’s class outperformed students in Ms Lenati’s class, could we simply conclude that Ms Perfect is the better teacher? Inferential statistics allow us to determine whether other factors are involved.

Statistical significance refers to the significance of the difference between two scores; that is, whether we can attribute the results to the IV or to chance alone. Therefore, inferential statistics allow us to infer a cause-and-effect relationship between two variables; something that descriptive statistics do not allow.

p-value

Before conducting an experiment, researchers set what is known as a p-value. A p-value is the level of probability that the results are due to chance alone, and determines statistical significance. In Psychology, it is typical to set a p-value at $p < 0.05$, which means that, for the results of a study to be statistically significant, the probability that the results are due to chance must be less than 5%.

When results are obtained, they must be tested for their statistical significance. Tests of significance include t-tests and chi-square tests. We will not investigate the tests here, but both allow researchers to determine the p-value for a particular set of results, and hence whether the results are statistically significant. If the p-value for the experiment is set at $p < 0.05$, the results of that experiment, when tested for significance, must be $p < 0.05$ in order for them to be deemed statistically significant.

If the results are found to be statistically significant, it is likely that the IV caused the change in the DV. This would support the experiment’s hypothesis, and conclusions and generalisations could be made from the study. If the p-value is greater than ($>) 0.05$, the results are not statistically significant, and the results are likely to be due to chance and not to the IV. Hence, the hypothesis is rejected and no conclusions can be drawn.

A p-value may be set lower (for example, at $p < 0.01$) for very important studies, such as when trailing medical drugs.

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**Figure 4.1** Determining statistical significance

- Researcher sets level of statistical significance, a p-value (typically $p < 0.05$)
- Researcher runs a test of statistical significance on the results obtained from the study (t-test or chi-square test)
- p-value of results is determined
  - $p < 0.05$
    - Results are statistically significant
    - Results are likely to be due to the IV
    - Hypothesis accepted; conclusions may be drawn
  - $p > 0.05$
    - Results are not statistically significant
    - Results are likely to be due to chance
    - Hypothesis rejected; conclusions cannot be drawn
Check your understanding

For each experiment below, the p-value set at the beginning of the experiment was \( p < 0.05 \).

1. Experimenters conducted research investigating a link between frequency of meditation and length of sleep. A test of significance on the results was found to be \( p \leq 0.05 \).
   a. This means that the probability that the results occurred due to chance is:

   b. This means that (tick the appropriate endings to the sentence):

<table>
<thead>
<tr>
<th>the results are statistically significant</th>
<th>the results are not statistically significant</th>
</tr>
</thead>
<tbody>
<tr>
<td>the independent variable has caused a change in the dependent variable</td>
<td>the independent variable has not caused a change in the dependent variable; chance factors have caused the change</td>
</tr>
<tr>
<td>a conclusion may be drawn</td>
<td>no conclusion can be drawn</td>
</tr>
</tbody>
</table>

2. Experimenters conducted research investigating a link between birth order and intelligence. A test of significance on the results revealed that \( p > 0.05 \).
   a. This means that the probability that the results occurred due to chance is:

   b. This means that (tick the appropriate endings to the sentence):

<table>
<thead>
<tr>
<th>the results are statistically significant</th>
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</tr>
</thead>
<tbody>
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</tr>
<tr>
<td>a conclusion may be drawn</td>
<td>no conclusion can be drawn</td>
</tr>
</tbody>
</table>

3. Experimenters conducted research investigating the impact of driving lessons on driving test scores. A test of significance on the results showed that \( p < 0.01 \).
   a. This means that the probability that the results occurred due to chance is:

   b. This means that (tick the appropriate endings to the sentence):

<table>
<thead>
<tr>
<th>the results are statistically significant</th>
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</tr>
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<tr>
<td>a conclusion may be drawn</td>
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</table>
4.3 Conclusions and generalisations

As stated earlier, the main intention of research is to apply what has been learned to the population of interest. A conclusion is a decision or judgement about the research results. A conclusion addresses the hypothesis in research. If the results found are statistically significant, a researcher may conclude that the hypothesis is supported; if not, the hypothesis has been rejected. Before making a conclusion, you may also have to consider whether any extraneous variables may have impacted on the results. It is important that the researcher is confident that the change in the dependent variable is due to the independent variable.

If a conclusion has been made and the research meets certain other criteria (see below), the research findings can be applied to the broader population, or the wider group of research interest. When we apply research findings to the wider population, this is known as a generalisation.

A generalisation should only be made if all of the following criteria are met.

- The results are statistically significant.
- The sample is representative of the population.
- The method of sampling is appropriate.
- Wherever possible, extraneous and confounding variables have been controlled for.

For example, a researcher may find a statistically significant link between listening to music and enhancement of memory, but if the sample only contained 16-year-olds, the link cannot be generalised to other age groups. As another example, a teacher may have conducted research investigating the effect that the number of hours of study had on scores obtained in a maths test; however, if her sample only comprised students in her class, this sample is biased and not representative of the population. A final example might involve investigating the influence of mnemonic devices on the capacity of short-term memory. If Group A, which uses mnemonic devices, comprises only males, and Group B which does not use mnemonic devices, comprises only females, then gender is a possible confounding variable and the findings cannot be generalised.

Generalising results to the population is one of the main goals of psychological research. Experimenters do not often endeavour to discover something for only a small group of people; instead, they seek to discover something that can be applied to a large group of people, or an entire population.

'I didn’t just jump to conclusions. I hopped and skipped first.'

Figure 4.2 Jumping to conclusions, without appropriate experimental procedures, can create misleading findings.
Check your understanding

1 Read the following articles. Discuss two reasons why it is difficult to generalise the results from these studies.

a The simple way to make people remember what you say

Chip Heath is a professor at the Stanford Graduate School of Business. His students are among the best and brightest in the country.

During one of his classes, Heath asked his students to give a one-minute speech on a topic such as crime patterns in the USA. After each speech, the students in the audience rated each speaker. Not surprisingly, the most polished speakers usually received the highest ratings. The surprise happened 10 minutes after the last speaker. Heath asked the students to pull out a sheet of paper and write down every idea they could remember from each speaker.

The class was shocked to discover how little they recalled. For some speeches, students couldn’t remember any ideas. In the average one-minute speech, speakers used 2.5 statistics. Only 1 in 10 told a story. But when it came time for recall, 63 per cent remembered the stories, compared to 5 per cent for statistics.


b Does ginkgo biloba affect memory?

The three-year study involved 115 people age 85 and older, with no memory problems. Half of the participants took ginkgo biloba extract three times a day and half took a placebo. During the study, 21 people developed mild memory problems, or questionable dementia: 14 of those took the placebo and seven took the ginkgo extract. Although there was a trend favouring ginkgo, the difference between those who took ginkgo versus the placebo was not statistically significant.

The researchers made an interesting observation when they examined the data at the end of the trial. Taking into account whether people followed directions in taking the study pills, they found that people who reliably took the supplement had a 68 per cent lower risk of developing mild memory problems than those who took the placebo. Without further study, it is unclear if this difference is real or just a chance occurrence.

The Nervous System

NERVOUS SYSTEM

Central nervous system

Peripheral nervous system

Brain

Spinal cord

Somatic nervous system

Autonomic nervous system

Forebrain

Midbrain

Hindbrain

Cerebrum

Thalamus

Hypothalamus

Limbic system

Reticular formation

Sensory nerves

Motor nerves

Sympathetic nervous system

Parasympathetic nervous system

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Diagram of the left-hand side of the human cerebral cortex. Note the central fissure.

A diagram of the left and right human cortices viewed from above. Note the longitudinal fissure which separates the brain into the right and left hemispheres.
FIG 7.15 The location of primary cortices and association areas of the left hemisphere. Note the location of the primary cortices and association areas.

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The Brain

ROLES OF THE LOBES IN COGNITIVE PROCESSES

FIG 7.17» The main functions of the lobes of a typical left cerebral cortex. Although most people have Broca's and Wernicke's areas in their left hemisphere, some people (about 3–5 per cent) have them in their right hemisphere.

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Four lobes of the cerebral cortex

- Each cortical area (lobe) is associated with different structures and functions
- Named after the bone in the skull they lie beneath
- Each lobe contains:
  - Sensory areas and/or
  - Motor areas
  - Association areas

FRONTAL LOBES

- Largest lobe, located in the upper forward section of EACH cerebral hemisphere
- Contains the primary motor cortex
  - Runs laterally (across) the top of the brain at the rear of the lobe
- Primary motor cortex is characterised by:
  1. Cerebral lateral organisation - left motor cortex controls voluntary movements on the right side of the body and vice versa
  2. Topographically (how they are mapped out) - the size of the motor cortex devoted to body parts reflects the dexterity of the part.
  3. Inverse representation of body - feet at top and face at bottom

Primary motor cortex...

Homonculus of the motor cortex

Frontal lobe continued...

- Association areas:
  - Higher mental functioning such as reasoning, planning, judging and using initiative
- Also involved in personality and emotional behaviour
- EG Phineas Gage – change of personality
Example - Phineas Gage

- Railway construction supervisor, 1848.
- After an accidental explosion, an iron rod (3.5cm diameter, 1m long & 6kg) was shot through his skull, damaging his frontal lobes.
- His personality, social behaviour and temperament changed after the incident.
- Phineas lived for another 12 years.

Broca’s Area

- Located in left frontal lobe
  - Near face, tongue, jaw and throat of motor cortex
- Involved in production of clear fluent & articulate speech

- Broca’s aphasia (expressive aphasia) – damage to area - a language disorder characterised by an impaired ability to produce speech
- Can understand others, can read, but likely to have difficulty with speaking (motor) and poor grammar and pronunciation. Know what they want to say but can’t get the words out.
- So: - Poor grammar, slow and laboured speech
  - Mainly verbs and nouns, no conjunctions
  - (May have difficulty interpreting the meaning of words if the usual order of words is changed)
- E.g. “here...head...operation...here...speech...none...talking...what...illness...”

Parietal Lobes

- Located at the top and centre of the brain between the frontal and occipital lobes of EACH cerebral hemisphere
- Involved in functions such as:
  - Sense of touch
  - Detection of movement
  - Location of objects in the surrounding environment

- Primary somatosensory cortex
  
  Contains the primary somatosensory cortex
  
  Runs laterally (across) the top of the brain at the front of the lobe
  
  Primary somatosensory cortex is characterised by:
  1. Contra-lateral organisation – left somatosensory cortex receives sensory information from the right side of the body and vice versa
  2. Topographically (how they are mapped out) - The size of the somatosensory cortex devoted to body parts reflects the sensitivity of the part.
  3. Inverse representation of body – feet at top and face at bottom
Homunculus of the sensory cortex

Parietal lobes cont...
- Association areas:
  - Sense our body in space (using information from visual and auditory cortex)
  - Determining where objects are in the environment (using visual and spatial reasoning)
- Damage to the parietal lobe association areas:
  - May result in 'Neglect Syndrome' i.e. ignoring the left side of the 'world'
  - May result in spatial disorientation e.g. unable to find the way home

OCCIPITAL LOBES
- Located at the back of the brain
- Contains the primary visual cortex
  - Receives visual information from photoreceptors (rods and cones) in the back of the eye
- Association Area:
  - Allows us to form visual perceptions, think visually and remember visual things

What might occur if there is damage to the occipital lobe?
TEMPORAL LOBES

- Located in the lower, central area of the brain
- Used in auditory perception, memory, visual perception & recognizing faces
- Contains the primary auditory cortex
  - Receives and processes auditory information
- Has different locations for different aspects of sound (pitch, frequency etc)
- Association Areas:
  - Involved in memory & linking emotions
  - Involved in facial recognition

Wernicke’s Area

- Located in left temporal lobe
- Near primary auditory cortex
- Involved in comprehension of speech, interpreting sounds, and locating appropriate words to express meaning

Wernicke’s aphasia (receptive aphasia) – no trouble with a word’s pronunciation or grammar but the words chosen may be inappropriate and the meaning may be expressed in a round about way. Also, difficulty with understanding the meaning of the spoken word.

- So:
  - Causes fluent, meaningless strings of words
  - Sounds like normal speech, but makes no sense
  - E.g. “I was over the other one, and then after they had been in the department, I was in this one”

Besides Wernicke’s aphasia, what other problems might arise as a result of damage to the temporal lobe?
Holiday Homework

☐ Research Methods
  o 2.2 Placebos and procedures
  o 2.4 Experimental research designs
  o 4.1 Inferential statistics
  o 4.3 Conclusions and generalizations

☐ Focus on Research
  o “The Stammering Brain”
  o Focus on Research “The Brain at Work”

☐ Brain Anatomy

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The stammering brain

For the first time, researchers have spotted differences in brain anatomy between stutterers and non-stutterers. The findings could help predict who is at risk for stuttering and perhaps lead to individually tailored treatments.

A research team, led by neurologist Anne Founds at Tulane University Health Science Centre in New Orleans, Louisiana, used magnetic resonance imaging (MRI) to measure the volume of speech-related brain regions in 13 men and three women who had stuttered since childhood. They also measured a control group of 16, matched for sex (male stutterers outnumber females four to one) and handedness (stutterers are twice as likely to be lefties), as well as age and education. The researchers then compared two brain areas associated with speech and language -- Broca's area in the frontal lobe, and parts of Wernicke's area in the temporal lobe.

The stutterers tended to have a much larger and more symmetric planum temporale, a region in Wernicke's area associated with language and music processing. Ordinarily, this feature puts out more on the left side in right-handers. Stutterers also had more folds, or gyri, on the brain surface in Broca's area, which Founds suggests could disrupt connections between auditory and motor areas of the brain. 'There was not one distinct feature across all stutterers,' Founds says. Rather, each had an average of four unusual features, while non-stutterers averaged only one. The study 'very conclusively' shows anatomic differences between stutterers and non-stutterers, says speech pathologist Roger Ingham of the University of California, Santa Barbara. He says it provides 'an important link' in a growing body of biological evidence on stuttering.

Source: Agrawal (2001).

Questions
1. What is the name of the type of research design employed by the researchers?
2. What differences were found in Broca's area and Wernicke's area between stutterers and non-stutterers?
3. How could a greater surface area on Broca's area disrupt speech function?
4. What was the researchers' conclusion?
5. What are the implications of this research for those who stutter?

The brain at work

According to folklore, a person with a large head and a high forehead is likely to be intelligent. But brain efficiency has as much to do with intelligence as brain size does (Gazzaniga, 1995).

Psychologist Richard J. Haier and his colleagues found that the brains of people who perform well on mental tests consume less energy than those of poor performers (Haier et al., 1988). Haier measured brain activity with a PET scan. You will recall that a PET scan records the amount of glucose (sugar) used by brain cells. The harder neurons work, the more glucose they use. By using radioactively labelled glucose, it is possible to record an image of how hard the brain is working (see Figure 2.20 on the opposite page).

What did PET scans reveal when subjects took a difficult reasoning test? Surprisingly, the brains of those who scored lowest on the test used the most glucose. Although we might assume that smart brains are hardworking brains, the reverse appears to be true. High performing participants actually used less energy than poor performers did. Haier believes this shows that intelligence is related to brain efficiency: less efficient brains work harder and still accomplish less. We've all had days like that!

Questions
1. This research examined the relationship between two variables. What were the variables?
2. Why was a PET scan used?
3. Why was the finding so surprising?
4. What did the researcher conclude?
5. What further research would you be interested in conducting in this field? Why?

Figure 2.20 PET scans are used to map brain activity rather than brain structure. PET scans provide colour-coded maps that show areas of high activity in the brain over time. The red and green areas indicate high activity in brain areas when a participant worked on a verbal short-term memory task.
1. Shade and label all the "lobes" of the brain
2. Colour and label all the "cortices" of the brain
3. Identify Broca’s and Wernicke’s areas
4. On a separate piece of paper write the main functions of all the above areas (including the association areas of the lobes) and the Cerebral Cortex, Corpus Callosum and Cerebellum.