PSY.RES10 Probability, Significance and Type I and Type II Errors

Total Marks

AQA 7182 · Calculators not allowed · about 50 minutes

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 In the context of psychological research, define the term 'probability' as it is used when reporting statistical results. Give the numerical range and explain its meaning with reference to the null hypothesis.

Define 'probability' in psychological research reporting, including the numerical range and interpretation with reference to the null hypothesis.

(Total for Question 1 is 2 marks)

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2 Explain in plain terms what a p-value of 0.04 means for a psychological experiment testing whether a new study technique improves memory scores. Make explicit reference to chance and the null hypothesis.

Explain the meaning of p = 0.04 in a memory study context, referring to chance and the null hypothesis.

(Total for Question 2 is 3 marks)

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3 Distinguish between a one-tailed and a two-tailed significance test in hypothesis testing. Name which corresponds to a directional hypothesis and which to a non-directional hypothesis, and apply both to this example: testing whether music tempo affects task speed.

Distinguish one-tailed and two-tailed tests, name the link to directional/non-directional hypotheses, and apply to a music tempo study.

(Total for Question 3 is 3 marks)

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4 State one empirical situation in psychology where a researcher would appropriately use a directional (one-tailed) hypothesis rather than a non-directional hypothesis, and briefly justify the choice with reference to prior evidence or theory.

Give one empirical situation where a directional hypothesis is appropriate and justify briefly with reference to prior evidence or theory.

(Total for Question 4 is 2 marks)

5 Give concise definitions for a Type I error and a Type II error in the context of a psychology experiment testing a new anxiety therapy. Each definition must refer to the null hypothesis and whether a real effect exists.

Define Type I and Type II errors for an anxiety therapy trial, referring to the null hypothesis and the presence or absence of a real effect.

(Total for Question 5 is 4 marks)

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6 Explain how choosing a smaller significance level (for example changing from 0.05 to 0.01) affects the risks of Type I and Type II errors. Refer to the concepts of critical region and statistical power in your answer.

Explain the effect of lowering α from 0.05 to 0.01 on Type I and Type II error risks, mentioning critical region and power.

(Total for Question 6 is 3 marks)

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7 A researcher runs a clinical trial comparing a drug to placebo and sets α at 0.01 because the drug has potential side effects. Identify two reasons why this choice is sensible, and one disadvantage of using such a strict significance level in this context.

Consider a drug trial where $\alpha = 0.01$ is chosen because of side-effect risk. Give two reasons why this is sensible and one disadvantage.

(Total for Question 7 is 3 marks)

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8 A small-scale pilot study ($n = 12$ per group) tests whether a cognitive training app reduces reaction time. The researcher uses $\alpha = 0.05$ and finds $p = 0.06$. Explain two plausible reasons, other than 'there is no real effect', why the study might have failed to reach statistical significance.

Explain two plausible non-null reasons why a pilot study with $p = 0.06$ might not reach significance.

(Total for Question 8 is 4 marks)

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9 Explain the difference between 'statistical significance' and 'practical significance' in psychological research, and give one brief example where a statistically significant finding might not be practically important.

Distinguish statistical significance from practical significance and give an example where significance lacks practical importance.

(Total for Question 9 is 4 marks)

10 A researcher must choose between a one-tailed test at $\alpha = 0.05$ and a two-tailed test at $\alpha = 0.05$ for an experiment where prior evidence suggests an increase but the consequences of a mistaken conclusion in the opposite direction would be serious. Recommend which test to use and justify your choice referring to risk management for Type I and Type II errors.

Recommend one-tailed or two-tailed test at $\alpha = 0.05$ given prior evidence of increase but serious consequences if effect were in the opposite direction. Justify regarding Type I/II risks.

(Total for Question 10 is 4 marks)

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11 A psychology journal requires that authors report the chosen significance level and justify it. Identify three pieces of information an author should give in that justification when reporting a study on a new educational intervention, and briefly explain why each piece matters.

Identify three pieces of information to justify the chosen significance level in a report on an educational intervention, and explain why each matters.

(Total for Question 11 is 6 marks)

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12 Discuss the consequences of setting significance levels either too strict (e.g. $\alpha = 0.01$) or too lenient (e.g. $\alpha = 0.10$) for psychological research and for real-world decision making. In your answer evaluate the trade-offs between Type I and Type II errors, the impact on scientific progress and replication, and give applied examples.

Discuss the consequences of choosing significance levels that are too strict or too lenient, evaluating trade-offs between Type I and Type II errors, impact on science and real-world decisions; include applied examples.

(Total for Question 12 is 8 marks)

Mark scheme · PSY.RES10 Probability, Significance and Type I and Type II Errors

Question 1

- **B1** probability is a numerical measure of how likely an event or outcome is to occur, ranging from 0 to 1 oe
- **B1** in hypothesis testing it indicates how likely the observed result would be if the null hypothesis were true oe
- **Answer: Probability is a numerical measure from 0 to 1 of how likely an outcome is; in hypothesis testing it indicates how likely the observed result would be if the null hypothesis were true.**

Question 2

- **M1** states that p = 0.04 means there is a 4% probability of obtaining the observed results, or more extreme results, if the null hypothesis is true oe
- **A1** applies this to the memory study, e.g. there is a 4% chance the apparent improvement happened by chance alone oe
- **A1** links to decision at $\alpha = 0.05$: result would be classed as statistically significant and the null hypothesis rejected oe
- **Answer: p = 0.04 means there is a 4% chance of observing this result, or something more extreme, if there really were no effect; in the memory study it suggests a 4% chance the apparent improvement was due to chance, and it would be significant at $\alpha = 0.05$ so the null hypothesis would be rejected.**

Question 3

- **M1** one-tailed test looks for an effect in one specified direction and is used with a directional hypothesis oe
- **A1** two-tailed test looks for an effect in either direction and is used with a non-directional hypothesis oe
- **A1** applies to example: directional hypothesis 'faster tempo increases speed' would use one-tailed; non-directional 'tempo affects speed' would use two-tailed oe
- **Answer: A one-tailed test assesses an effect in a specified direction and matches a directional hypothesis; a two-tailed test assesses effects in either direction and matches a non-directional hypothesis. In the music example, predicting faster tempo increases speed is directional and would justify a one-tailed test; predicting only that tempo affects speed is non-directional and requires a two-tailed test.**

Question 4

- **B1** identifies a plausible situation, e.g. testing whether a well supported cognitive training program increases working memory compared with control oe
- **B1** brief justification that prior theory or strong evidence predicts the direction of the effect oe
- **Answer: E.g. testing whether an established cognitive training program increases working memory compared with control; a directional hypothesis is appropriate because prior studies and theory predict an increase.**

Question 5

- **M1** Type I error: rejecting the null hypothesis when the null hypothesis is actually true, i.e. concluding the therapy works when it does not oe
- **A1** labels this a false positive and links to the anxiety therapy context, e.g. offering an ineffective treatment oe
- **M1** Type II error: failing to reject the null hypothesis when the null hypothesis is false, i.e. concluding the therapy does not work when it actually does oe
- **A1** labels this a false negative and links to the anxiety therapy context, e.g. missing a beneficial treatment oe
- **Answer: Type I error: rejecting the null hypothesis when it is true, a false positive, e.g. concluding the new anxiety therapy works when it does not. Type II error: failing to reject the null hypothesis when it is false, a false negative, e.g. concluding the therapy does not work when it actually does.**

Question 6

- **M1** states that lowering α reduces the size of the critical region, therefore decreasing the risk of a Type I error oe
- **M1** states that lowering α makes it harder to reach significance, which tends to increase the risk of a Type II error oe
- **A1** links increased Type II risk to reduced statistical power and gives consequence, e.g. smaller chance of detecting a real effect oe
- **Answer: Lowering α from 0.05 to 0.01 reduces the critical region and so decreases the risk of a Type I error, but it also makes it harder to reach significance, increasing the risk of a Type II error. This reduces statistical power and so lowers the chance of detecting a real effect.**

Question 7

- **B1** reason 1: reduces the risk of a Type I error, so fewer false positives and lower chance of approving a harmful or ineffective drug oe
- **B1** reason 2: protects patients by requiring stronger evidence before concluding the drug is effective, which is important when there are safety concerns oe
- **B1** disadvantage: increases risk of a Type II error, so a genuinely effective drug might be missed, delaying a beneficial treatment oe
- **Answer: Sensible because it reduces Type I error risk so fewer false positives and reduces chance of approving a harmful or ineffective drug, and it demands stronger evidence before exposing patients to side effects. Disadvantage is higher Type II error risk, so a real beneficial drug might be missed.**

Question 8

- **M1** reason 1: small sample size leading to low statistical power, so a real effect could fail to reach significance oe
- **A1** explains how low power makes type II error more likely, linking to the small n in the pilot study oe
- **M1** reason 2: high variability in reaction time measures (large standard deviation) which can mask an effect and increase p-value oe
- **A1** explains that measurement error or heterogeneous participants increase variability and reduce ability to detect an effect oe
- **Answer: Two plausible reasons: small sample size gives low power so a real effect might not reach significance, and high variability in reaction times (measurement error or participant differences) can mask an effect and increase the p-value.**

Question 9

- **M1** statistical significance refers to whether a result is unlikely to have occurred by chance according to the chosen α level oe
- **M1** practical significance refers to whether the size of the effect is large or important enough to matter in real-world terms oe
- **A1** gives an example: a drug that reduces symptom score by 0.5 points on a 100 point scale might be statistically significant in a large sample but clinically trivial oe
- **A1** explains why the example shows limited practical importance despite statistical significance oe
- **Answer: Statistical significance means the result is unlikely under the null at the chosen α; practical significance asks whether the effect size matters in real life. Example: a treatment that lowers a 100 point symptom scale by 0.5 points may be statistically significant in a large sample but clinically meaningless.**

Question 10

- **M1** recommends a two-tailed test if consequences of a mistaken conclusion in the opposite direction are serious, even if prior evidence suggests an increase oe
- **A1** explains that a two-tailed test guards against unexpected effects in either direction, reducing the risk of a Type I error in the unpredicted direction oe
- **M1** acknowledges that a one-tailed test would give more power to detect the predicted increase and reduce Type II error risk oe
- **A1** justifies the final choice by weighing that avoiding a harmful false positive in the opposite direction is more important than the small gain in power from a one-tailed test oe
- **Answer: Recommend a two-tailed test at α = 0.05 because, despite prior evidence for an increase, the serious consequences of being wrong in the opposite direction mean the researcher should guard against effects both ways. A one-tailed test would increase power and reduce Type II risk for the predicted increase but risks missing or**

Question 11

- **M1** piece 1: state the actual significance level chosen (e.g. $\alpha = 0.05$ or 0.01) oe
- **A1** explains why this matters: makes the decision rule transparent and allows readers to judge the strictness of evidence required oe
- **M1** piece 2: justify choice with reference to potential consequences of false positives or false negatives in the educational context oe
- **A1** explains why this matters: different consequences (e.g. wasting resources on ineffective intervention versus missing an effective programme) change how strict the α should be oe
- **M1** piece 3: provide information about sample size/power calculations or expected effect size used to choose α oe
- **A1** explains why this matters: shows whether the study is sufficiently powered to detect meaningful effects and helps interpret non-significant results oe
- **Answer: Authors should state the exact α chosen, justify it in terms of the likely consequences of false positives versus false negatives in the educational setting, and report sample size or power calculations and expected effect size. These show the decision rule, how risks were balanced given practical consequences, and whether the study had adequate power to detect meaningful effects.**

Question 12

- **Level 4** (7-8): Knowledge and understanding of significance levels and error trade-offs is accurate and detailed. The discussion evaluates consequences for research practice, replication and applied decisions, using well chosen examples. Counterarguments and nuances, such as power and effect size considerations, are used to support evaluation. The answer is well organised and uses appropriate terminology.
- **Level 3** (5-6): Knowledge is clear and mostly accurate. The discussion considers consequences for research and real-world decisions and includes some evaluation and examples, although some points may be less developed. Some reference to power or effect size is present.
- **Level 2** (3-4): Knowledge is present but basic. The answer lists consequences of strict and lenient alpha levels with limited evaluation or minor inaccuracies. Examples may be general and links to power or replication are superficial.
- **Level 1** (1-2): Very limited knowledge. Response is largely descriptive or confused, with little or no evaluation and no useful examples.
- **Level 0** (0): No creditable content.
- **Indicative content:**
  - Define what is meant by a significance level (alpha) and remind that it sets the probability threshold for rejecting the null hypothesis, linking to Type I error rate.
  - Explain the effect of setting alpha very strict (e.g. 0.01): reduces Type I errors but increases Type II errors, lowers statistical power, and may cause real but small effects to be missed. Applied example: in drug safety, strict alpha reduces approving unsafe drugs but may prevent beneficial drugs reaching patients.
  - Explain the effect of setting alpha lenient (e.g. 0.10): reduces Type II errors and increases power for detecting effects but raises Type I error risk, increasing false positives. Applied example: in education, lenient alpha might promote many unproven programmes, wasting resources.
  - Evaluate impact on scientific progress and replication: strict alpha may slow discovery and discourage publication of marginal but real effects, contributing to file-drawer problems; lenient alpha may flood literature with false positives, reducing replicability and undermining trust.
  - Discuss interaction with sample size and effect size: appropriate alpha cannot be chosen in isolation, because larger samples can allow strict alpha while retaining power, and reporting effect sizes and confidence intervals mitigates over-reliance on p-values.
  - Consider ethical and practical trade-offs: the context matters, so policy decisions should weigh costs of false positives versus false negatives, and preregistration and replication can reduce the harms of both types of errors.
  - Conclude with balanced judgement: neither extreme is universally correct; justify choice by context, use power calculations, report full statistics, and emphasise replication and effect sizes to support robust conclusions.