Interview Prep 3

Terms and Concepts Review

Module 3: Research Methods, Experimental Design & Statistical Testing

Research Design Methods

Foundational & Common Designs

Experimental Design: The researcher manipulates one variable to observe its effect on another, with random assignment of subjects. Gold standard for establishing cause-and-effect.

Quasi-Experimental Design: Similar to an experiment but lacks random assignment of subjects to groups.

Correlational Design: Measures the relationship between two or more variables without controlling or manipulating them.

Descriptive Research: Accurately and systematically describes a population, situation, or phenomenon. Answers 'what, where, when, and how' questions.

Survey Research: Gathers data from a sample through questions, either written or oral.

Observational Design: Involves watching and recording actions of participants in their natural setting.

In-Depth & Qualitative Designs

Case Study: In-depth, detailed examination of a single subject, group, or event.

Ethnographic Research: Systematic study of people and cultures through immersive, long-term observation in natural environment.

Phenomenological Research: Seeks to understand the 'lived experiences' of individuals regarding a specific phenomenon.

Grounded Theory: Methodology for developing theory that is 'grounded' in data systematically gathered and analyzed.

Narrative Inquiry: Gathers and interprets stories and personal accounts to understand individual experiences.

Historical Research: Involves studying, understanding, and interpreting past events.

Time-Based Designs

Cross-Sectional Design: Collects data from a population at a single, specific point in time.

Longitudinal Design: Involves repeated observations of the same variables over short or long periods.

Cohort Study: Type of longitudinal study following a specific group sharing a common characteristic over time.

Panel Study: Specific longitudinal study where data is collected from the same sample at different points in time.

Mixed & Combined Methodologies

Mixed-Methods Design: Integrates both qualitative and quantitative data collection and analysis in a single study.

Convergent Parallel Design: Mixed-methods where quantitative and qualitative data are collected and analyzed separately, then merged for interpretation.

Explanatory Sequential Design: Begins with quantitative data collection, followed by qualitative data to explain the quantitative results.

Exploratory Sequential Design: Starts with qualitative data to explore a topic, then uses findings to build a quantitative phase.

Review & Analytical Designs

Meta-Analysis: Statistical technique for combining findings from multiple independent studies to reach a robust conclusion.

Systematic Review: Rigorous and comprehensive review of existing literature using transparent procedures to find, evaluate, and synthesize all relevant research.

Purpose-Driven & Applied Designs

Action Research: Cyclical and reflective process where researchers work to solve a practical, immediate problem within a specific setting.

Evaluation Research: Systematically assesses the effectiveness, merit, or worth of a program, policy, or intervention.

Explanatory Research: Aims to explain the 'why' behind an observed relationship or phenomenon.

Exploratory Research: Conducted for a problem that is not clearly defined; helps gain understanding and generate hypotheses.

Diagnostic Research: Focuses on determining the root cause of a specific problem or issue.

Causal-Comparative Design (Ex Post Facto): Attempts to identify cause-and-effect relationship where the cause has already occurred and cannot be manipulated.

Specialized Experimental & Field Designs

Factorial Design: Experimental setup involving two or more independent variables, allowing study of main effects and interaction effects.

Field Experiment: Experiment conducted in a real-world, natural setting rather than in a controlled laboratory.

IMRaD: Research Paper Structure

Title Page: Contains running head, full title, author(s), institutional affiliation, and contact information.

Abstract: Standalone summary (150-250 words) covering objective, method, key results, and primary conclusion.

Introduction: Follows funnel structure: broad opening, problem statement, research questions & hypotheses. Usually 10-15% of total paper.

Method: Provides roadmap for replication: research design, participants, materials, procedure, data analysis, ethics & data management.

Results: Objective presentation of findings with descriptive and inferential statistics, tables, and figures. No interpretation.

Discussion: Interprets data, restates findings, explains why results occurred, discusses limitations, and suggests future research.

References: Complete list of all cited sources in proper format.

Appendices: Supplementary materials like raw data, detailed procedures, or additional analyses.

Hypothesis Testing & AB Testing Concepts

Historical Foundations

Galileo Galilei (1564-1642): Father of experiments; tested ideas through observation and measurement using deductive reasoning.

Francis Bacon (1561-1626): Emphasized importance of experiments and replication for reliability of scientific findings.

Isaac Newton (1643-1727): Proposed scientific laws should be based on data and considered accurate until new evidence challenges them.

John Arbuthnot (1667-1735): Pioneering work in hypothesis testing by examining baptismal records; early example of significance testing.

Carl Friedrich Gauss (1777-1855): Connected measurement error to the normal distribution (Gaussian distribution).

Benjamin Pierce: Used normal distribution to identify outliers in measurements.

William Gosset (Student): Extended statistical methods to analyze variability in experiments; developed Student's t-test.

Ronald Fisher: Developed modern statistical methods for hypothesis testing; controversial role in smoking-cancer debate.

Key Statistical Concepts

Normal Distribution (Gaussian): Continuous probability distribution that is symmetrical and bell-shaped; defined by mean (μ) and standard deviation (σ).

Null Hypothesis (H_0): Statement of no effect or no difference; the default assumption to be tested.

Alternative Hypothesis (H_a): Statement of an effect or difference; what researchers typically want to demonstrate.

Independent Variable (IV): The factor that the researcher manipulates or controls (the 'cause').

Dependent Variable (DV): The factor that is measured for change (the 'effect' or outcome).

Control: Procedures used to minimize influence of extraneous variables (confounds).

Randomization: Randomly assigning participants to different experimental groups/treatments.

Replication: Repetition of experiment's procedures to ensure reliability.

Standard Error: Standard deviation of the sampling distribution; calculated as $\sigma/\sqrt{n}$.

Central Limit Theorem (CLT): States that for large enough sample size, the sampling distribution of the mean will be approximately normal.

Sample Size (n): Number of observations in a sample; larger n leads to narrower sampling distribution and greater precision.

Monte Carlo Methods

Monte Carlo Methods: Computational algorithms relying on repeated random sampling to obtain numerical results. Useful for integration, optimization, and generating samples from complex probability distributions.

Core Idea: Use randomness to estimate a deterministic value.

General Steps: 1) Define a domain, 2) Generate random inputs, 3) Perform computation, 4) Aggregate results.

Probability Distributions

Distribution Types

Bernoulli Distribution: Models a single trial with two outcomes (success/failure). Single parameter p (probability of success).

Binomial Distribution: Counts number of successes (k) in n independent Bernoulli trials. Generalization of Bernoulli distribution.

Normal Distribution: Continuous distribution; bell-shaped and symmetrical. Limit of binomial distribution as n increases.

Standard Normal Distribution: Normal distribution with mean $\mu=0$ and standard deviation $\sigma=1$.

Z-Score: Number of standard deviations a value is from the mean; used in standardization.

Distribution Functions

Probability Mass Function (PMF): For discrete distributions; gives probability of a single, exact value.

Probability Density Function (PDF): For continuous distributions; measures relative likelihood at a point (not a probability).

Cumulative Distribution Function (CDF): Calculates cumulative probability of variable falling below a certain value $P(X \leq x)$.

Percent-Point Function (PPF): Inverse of CDF; given a probability (percentile), returns corresponding value of random variable.

Hypothesis Testing Procedures

One-Sample Z-Test: Tests whether a sample mean differs from a known population mean when population standard deviation is known.

Significance Level (α): Threshold probability (commonly 0.05) for rejecting the null hypothesis.

P-Value: Probability of obtaining results at least as extreme as observed, assuming null hypothesis is true.

Type I Error (False Positive): Rejecting null hypothesis when it is actually true.

Type II Error (False Negative): Failing to reject null hypothesis when it is actually false.

Statistical Power: Probability of correctly rejecting a false null hypothesis (1 - β).

Effect Size: Magnitude of the difference or relationship; indicates practical significance beyond statistical significance.

Confidence Interval: Range of values likely to contain the true population parameter with specified confidence level.

Experimental Design Components

Sample Data Distribution: Distribution of data from a single sample; resembles population distribution as sample size increases.

Sampling Distribution: Theoretical distribution of all possible sample statistics (e.g., means) from a population.

Representative Sample: Sample that accurately reflects characteristics of the population.

Random Sampling: Each member of population has equal chance of being selected.

Confounding Variables: Extraneous variables that might influence the dependent variable.

Internal Validity: Extent to which causal conclusions can be drawn from the study.

External Validity: Extent to which results can be generalized to other settings or populations.

Blinding: Preventing participants or researchers from knowing group assignments to reduce bias.

Placebo Effect: Improvement in condition due to belief in treatment rather than treatment itself.

Important Statistical Relationships

Standard Error Formula: $SE = \sigma/\sqrt{n}$, where σ is population standard deviation and n is sample size.

Z-Score Formula: $z = (x - \mu)/\sigma$, standardizes values to compare across different distributions.

68-95-99.7 Rule: In normal distribution: 68% within 1σ, 95% within 2σ, 99.7% within 3σ of mean.

Sex Ratio at Birth: Approximately 21 boys born for every 20 girls (slightly skewed toward males).

Additional Key Terms

Outlier: Measurement that falls far outside the expected range; may indicate error.

Measurement Error: Difference between measured value and true value.

Error Distribution: Original name for normal distribution; reflects how errors distribute around true value.

Spurious Association: Apparent relationship between variables that is not causal.

Randomized Controlled Trial (RCT): Experimental design with random assignment; gold standard for causal inference.

Statistical Inference: Process of drawing conclusions about population based on sample data.

Deterministic vs. Probabilistic: Deterministic: exact outcomes; Probabilistic: outcomes based on probability.

Empirical Evidence: Information acquired through observation and experimentation.