Experimental methods in Cognitive Science

weekly_readings #week-2/reading-2 #my-notes-755

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> **Section - 7.1**

Introduction

Of the fields contributing to Cognitive Science, Cognitive Psychology makes primary use of Experimental Methods

The goal of Sciences is to build theories that enable **explanation**, **prediction** and **control** of events in the domain of inquiry

Theories:

- Theories are mental models of the emperical domain
- systems of abstract concepts whose properties and rules of operation correspond to some emperical system.
- Evaluating a theory (to have confidence in the correspondence) depends on checking whether its implications are true or not.

Introspection:

- Many facts of human mind are apparent from introspection.
- But introspection as a whole had a dismal record of failure. Since,
    1. Much of the introspection are heavily influenced by the observer's theoretical preconceptions
    2. Moreover, many cognitive processes go beyond awareness, or occur too rapidly to be available for a consious report

Emperical Techniques

1. Naturalistic Observation
2. Correlational Studies

Naturalistic Observation

systematic observation and recording of behaviour in a somewhat "natural setting"

Examples:

1. *by Development Scientist* - to describe the average maturation sequence of physical abilities (at what age can infants talk, walk, ...)
2. *by Computer simulation scientist* - try to recreate (in their program) introspections of their own problem solving activities
3. *by a Linguist* - who tries to provide counter examples to some proposed linguist generalization

- Naturalistic observation can provide **descriptive generalization** about a class of phenomena.
- But they are weak in supplying evidence for **cause-effect** relationship

Correlational Studies

- More formal than naturalistic observation
- Try to measure the degree of association of two or more events / attributes
- The weakness is that - **correlation does not imply causation**. Since,
    1. There **might be a third variable** which is causing both the variables
    2. Even if we assume that the correlated variables are related. The correlation goes both ways and **does not specify the direction of causation**

Controlled Experiments

- The deficiencies of correlational studies for arriving at conclusions about cause-effect relationships are rectified by the use of experiments.

Basic idea of an Experiment

- We compare observations under two conditions:
    1. Experimental Condition - which has the crucial factor / treatment introduced
    2. Control Condition - which has the crucial factor / treatment omitted
- The comparison enables us to infer whether the experimental treatment causes a difference in behaviour

Hypothesis

- Hypothesis is a *generalization* or universal statement about the:
    1. **causal relation** between variables, and
    2. **the conditions** under which these relations are expected to hold
- Experiments are conducted to test specific hypothesis
- The factor that the experimenter manipulates is called the ***independent variable***
- The behaviour that is measured to detect the effects of manipulation is called ***dependent variable***

Measuring Experimental Effects

- *Experiments are conducted to measure changes in people's behaviour caused by manipulaing a certain independent variable.*
- But to measure the performance, we should be able to measure the behaviour **quantitatively**. Example- milliseconds for response time
- Although qualitative observations (eg- introspective protocols) can be useful at the start, but they should be repalced whenever possible by quantitative measures
- Quantitative measured can be **statistically summarized**

Isolating Causal Effects

- Even with constant conditions, human behavior can be variable.
- Hence, it is not reliable to compare single observations

Use of Groups

- Investigators therefore examine group (10-20) of subjects.
- *Extraneous* (unaccounted) sources of variabilitlity (indiv diff in abilities, etc) are NULLified
- There are 2 types of experimental design:
    1. *between-subjects* - different subjects are tested on different conditions, leading to a group for each condition. The average scores obtained from different groups are compared
    2. *within-subjects* - each subject is run in all conditions, and difference in subject's performance accross conditions is examined.
- Depending on practical factors, any of the above two methods can be better than the other

Use of Statistical Procedures

- The difference in average performances of groups accross conditions might have arisen simply "*by chance*"
- Statistical Procedures:
    - measure observable differences "*wrt baseline variability*" of that behaviourial measure
    - allow precise estimate of how likely a given observation is to occur by chance alone

Other methods to exclude/minimize extraneous factors

1. Randomly assigning subjects to conditions
2. Not informing subjects fully about the hypothesis
3. Using equivalent tests in each condition

Some other difficulty - "not knowing all the factors influencing a certain behaviour"

- The complexity of experiments must be arranged to account for the new variable grow

Coordinating Theory with Observables

Why to include "Theoretical Constructs"?

- Many lawful generalizations simply relate categories of **observable events**. Such emperical regularities are useful for controlling and predicting certain phenomena
- But sometimes its better, if we can know as to **why a given emperical law holds**.
- It is usually done by postulating **theoretical constructs** that *do not correspnd to categories of observable events*
- **Most variables of interest to cognitive scientist are unobservable. Examples:**
  - mentalistic contructs - goals, intentions, beliefs, ...
  - memory stores - STM, LTM, ...
  - mental processes - encoding, retrieval, ...

Goal of "Theoretical Contructs":

- To provide coherent explanation for diverse range of emperical phenomena
- **Example:**
  - A broad range of cognitive processes are influenced by "attention" of the subjects.
  - Attention is *not observable*
  - However, the contruct of attention simplifies a large number of unrelated observable events. Like observable factors which influences attention (eg- time of day, stimulant drugs, ...)
- Positing a link between a **theoretical construct** (*attention*) and a **set of outcomes** is more generalized than,
- Enumerating separate links between **many observable independent variables** (*time of day, stimulant drugs*...) and **many dependent variables**

Need for "Coordination" between theory and observables

- Then how to check the correspondence of the theories experimentally?
- **Terms in the theory** must be **coordinated** to **observable stimuli, responses, events** in the experimental setting
- Therefore, we can now
  1. Manipulate a theoretical variable by altering observable factors (presumed to affect it)
  2. Indirectly measure a theoretical variable through the observable behaviors it affects.
- **EXAMPLE:**
  1. Induce "thirst" (*theoretical variable) by having the subjects "eat salty crackers" (*observable stimuli*).

2. "Amount of water subject drinks" (*observable response*) is a measure of his "thirst"

Study by Gluck and Bower (1988)

Experiments on Human Cognitive Process

- Experiments on cognition generally involve studying a subject's behaviour while they perform a certain task.
- Subjects are presented with a **stimulus** in a particular **task context** and must **respond** to that stimulus in some way.

Information Processing Approach

- Performance in cognitive tasks commonly described by the analogy of a computer program, that takes **input** ("stimulus"), executes a "mental" **program**, and produces an **output** ("response")
- Several questions can be asked about it:
  1. **What function the program computes?**
     - EXAMPLE: Subjects presented with tones of different intensities, and asked to give magnitude of loudness. Here function is the relation between intensity and loudness
  2. **Which algorithm/strategy is used to compute this function?**
     - EXAMPLE: Researchers investigating development of problem-solving-skills are interested in the particular procedures that the subjects use to solve the problem.
  3. **Physical Implementation of the cognitive process?**
     - By tradition outside the province of cognitive science.

Task as a windows to fundamental cognitive properties

- Cognitive Psychologists believe that, by observing subjects' performance in various laboratory tasks, they can investigate basic properties of human cognition in situations sufficiently simple and transparent that those properties can be revealved.
- However, performances in some lab tasks often reflect the underlying strategy used to solve that task rather than the more fundamental cognitive process.
- Inverstigators usually try to focus on those aspects of that are controlled by basic, or non-strategic factors.

Characterizing Psychological Process

- One of the goals of Cognitive Science is to **"decompose an emperical system" into a set of hypothetical related components**, and then **"validating this decomposition" through experiments**
- The "Mind" is treated as a system that can be decomposed into a collection of *somewhat separable subsystems*.
  - EXAMPLE: memory, language, attention, visual perception, reasoning, etc.
- The distinctions need to be justified. How?
  - By observing whether the two components proposed to be distinct, are actually guided by different sets of independent variables (*in which case the distinction is justified*), OR
  - Are they affected by the same set of independent variables in some way.

Analyzing Representation Types

A standard issue in Cognitive Science is to:

1. Specify the form in which a particular info is represented in the mind
   - Experiment by - **Posner and Mitchell 1967**
2. How the form of this representation changes over time
   - Experiment by - **Posner and Keele 1967**

Several methods used in measuring the analysing the nature of the memory code:

1. **Judgement time**
2. **Similarity** of two or mote stimulus
3. **Interference** in processing the target info
4. **Clustering** of items in *free-recall*

Posner and Mitchell 1967

Given: Subjects presented with 2 stimuli (which are 2 letters)

Task: To identify whether they have

1. "same-form" - AA, BB, but not Aa, Ab
2. "same-name" - Aa, Bb, but not AB ab, BC

Observations:

1. In the "same-name" task, subjects were faster (by 70-100 ms) in recognizing *same-name pairs* with *similar physical form*
2. In the "same-form" task, pairs having *different names* didn't have any disadvantage in flagging the *same-form pairs* to be same

Interpretation:

- The "name-code" becomes available some time after the "physical-code"

Posner and Keele 1967

Given: Subjects presented with 2 stimuli (which are 2 letters) but now with a delay of 0-2 seconds.

Task: To identify whether they have

1. "same-form" - AA, BB, but not Aa, Ab
2. "same-name" - Aa, Bb, but not AB ab, BC

Observations:

1. The advantage in the "same-name" for the "physically identical pairs (same form)" reduced from 90ms to 10ms

Interpretations:

- The "physical-code" (visual) is converted *as quickly as possible* into a "name-code" (phonetic)
- The "physical-code" decays rapidly (and is thus not actively maintained for long)

Judgement Time

- Based on the assumption that, retrieval and matching is quicker when the internal rep of 1st stimuli matches more closely to that of the 2nd stimuli

Similarity of two or more stimuli

- Internal representations (based on some coding-schemes) are selective, and may ignore (squash out) some features. Eg- You don't remember each and every detail of a geo-map
- Two stimuli patterns that differ in features - which are ignored by the coding scheme - will have internal representations more mutually similar than their original counterparts

Interference in processing the target info

- Material that is encoded similarly to the target material will create greater intereference in the processing of the target material.
- Example- people tendency to shadow one message and ignore a second simulateneous message is increased if the 2 messages are somewhat similar (in terms of pitch, context, voicing, ear of arrival, etc.)

Clustering of items in free-recall

- **Free recall:** Unconstrained recall of a set of items in any order as they come in mind.
- During free-recall subjects tend to cluster items into various categories and sub-categories as per their topical knowledge.

Additive Factors Method

What is Additive Factors Method?

- A cognitive task can be dissected into various component processes.
- These processes can be executed either concurrently or serially
- The "additive-factors method" is a general experimental logic or method for dissecting the different processes involved.
- It provides a way to decide whether two independent variables that influence the overall RT (reaction time) do so by affecting the same or different component processes.

How is it done?

- We divide the task into multiple stages (supposedly independent)
- However, the truth maybe:
    1. The stages are actually independent, OR
    2. They are not independent (there exist some set of independent variables which affect more than one stages)
- We attempt to manipulate independently the duration of different stages by using several independent variables, (each of which afffects only a single stage)
- This (change in duration of stages by changing vars) should be possible if the stages are really independent (Truth-1)
- *Since, **variables that affect different independent stages** may have an **additive effect** on the **total RT***

Saul Sternburg, 1966-67

- *Task similar to that of Posner and Keele*
- **Task:** A small *set of items* `S = {'H', 'G', 'A'}` shown to the subjects. These items to be held in the memory before a *probe item* `p` is presented. Subjects task is to tell whether that probe item matched to any in the set.
- **Observation:** A linear increase in the RT as `|S|` increased from 1 to 6
- *The figure below shows the different stages (component-processes) involved in the task*

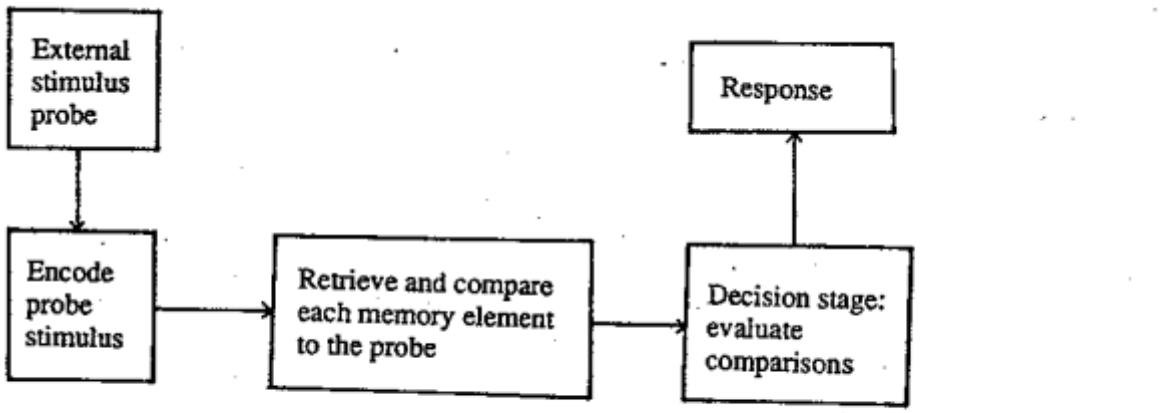

Figure 7.3 A proposed series of mental events that occur during each trial of Sternberg's memory-scanning experiment.

- `Total RT = T(encoding) + T(retrieve and compare) + T(decision)`
- He used the "additive-factors, method" to demonstrate the several stages.
- EXAMPLE:
  - "Blurring the probe item" (an independent *var*, supposedly affecting the "encoding-stage") increased the RT.
  - But this effect in "encoding stage" was independent of another *var* say `|S|` which affected the "retrieve and compare stage".
  - Hence, the two stages are "actually independent" (Truth-1) since the independent variables affecting each of them had an additive effect on the Total RT

Dual Task

- One of the fundamental propositions of ognitive science: "The *processing* resources of the mind is limited".
- It is assumed that we allocate more or less to the several tasks the processing resources
- **Dual-Task Experiments** are used to investigate how much processing capacity is required for particular task.

Example Experiment:

Task-1:
Subjects hear a tone, and they have to press a button as quickly as possible. The reaction time for this task will be noted.
Task-2:
Subjects read a comprehension text which will be tested later.

Subjects are divided into 2 groups:

Group-1:
They have to do only task-1. Let their average reaction time be T.
Group-2:
They have to do task-1 while being actively engaged in task-2 as well. Let their reaction time be T'

Observation:

- T' > T. which means (in case of Group-2) some amt of processing resources is being used by task-2 which degrades the performance of task-1.
- The difference in time, k = T' - T is the time needed to read/comprehend the text, (task-2)
- This k gives a ratio of the processing resources used by task-2.

Signal Detection Theory

- Signal Detection Theory can be applicable to experiments using discrete trials.
- In this, Subjects are presented a weak signal(s), and then asked to:
    1. detect a weak signal
    2. discriminate/differentiate it from other signals

> *Read from the pdf...*