# Theory

1. A Good Theory

**Explanatory scope**: able to explain a wide range of phenomena.

**Parsimony**: as simple as possible, avoiding unnecessary complexity.

**Falsifiability**: falsifiable, can be tested through experiment or observations.

1. Theory Test

**Within-subjects design**: each subject is tested in all conditions

**Between-subjects design**: different subjects are tested in each condition

We typically always prefer a within-subjects design over a between-subjects design, as it allows us to ignore factors that potentially have an influence

1. Replication Crisis

**Statistical power**: the chance that an effect is established, given that the hypothesis is true, p-value

1,600 measurements per condition (e.g., 25 subjects, 64 trials per condition)

1. Computational models

We can test the extent to which a computer model can accurately simulate behavior. The more accurately it simulates behavior, the more support we have for each of the model’s assumptions.

# Perception & Attention

1. **Sensation**

A physical, factual thing, not susceptible to interpretation etc.

1. Vision

**Fovea (1°)**: many cones, sharp vision (high acuity), color vision, lower sensitivity **Parafovea (6-8°)**: mix of cones and rods

**Perifovea (>8°)**: mostly rods, low acuity, no color vision, more sensitivity

1. **Perception**

the process of interpreting sensations

1. **The inverse projection problem**

The fact that from a retinal image alone there is no certainty about the visual environment.

From sensory processing alone we cannot say anything conclusive about the world.

1. **Bottom-up processing**

Sensory organs provide activation of ‘low’ cortical regions, cascades to ‘higher’ regions

1. **Top-down processing**

‘Higher’ regions influence activation of ‘lower’ regions

Semantics/memories <> words <> letters <> features < visual input

1. **Gestalt principles**

A set of assumptions about things that happen in an automatic, bottom-up fashion

a mere product of the system’s architecture:

similarity, proximity, symmetry, continuity, closure

and one that relies on motion: common fate.

Are all these ‘effects’ really the result of bottom-up processes?

Probably not. Our life experiences bolster the expectation that:

* Similar-looking things belong together
* Objects are most often symmetrical

1. **The word-superiority effect**

a letter is recognized faster if it is in a word than if it is in a non-sensical string

1. Perception in the brain

|  |  |  |
| --- | --- | --- |
| Frontal lobe | Front | Decision making, problem solving, control of purposeful behaviors, consciousness, emotions |
| Parietal lobe | Middle | Sensory information such as touch, temperature, spatial orientation |
| Occipital lobe | Back | Vision |
| Temporal lobe | Near the temples | Hearing, memory, emotion, some aspects of language and speech |

1. Dorsal and Ventral pathways

**Ventral pathway**: what, object recognition

**Dorsal pathway**: where, spatial processing, attention

1. Plasticity

Where do ‘detectors’ come from?

Our experiences shape dedicated clusters of neurons

1. **Attention**

Mind’s capacity to enhance and suppress sensory input and internal representations

Also applies to things that we keep in memory.

1. Overt & Covert attention

Overt: obvious to others, the eyes and head move

Covert: concealed to others, the eyes and head do not move

How might we track covert attention?

Posner's Cueing Task

Functional Magnetic Resonance Imaging (fMRI)

Event-Related Potentials (ERPs)

high-resolution eye-tracking

1. Spatial vs Feature-based attention

Attentional orienting in vision is often spatial… but you can choose to be more sensitive to apples.

We focus in terms of both where and what.

1. Endogenous vs Exogenous

Internally driven vs externally driven

Neurons have threshold for when to fire.

The more a neuron is excited (the more input it receives vis its dendrites), the more frequently it will fire action potentials.

Some connections are inhibitory rather than excitatory.

Neurons coding for upper visual field may have suppressed neurons coding for lower visual field when the thing happened.

Signals sent by the upper-visual-field neurons will have entered conscious awareness faster.

Exogenous attention: strong sensory input tips the balance

Endogenous attention: higher-order neurons suppress or excite neurons at the level of perception

1. Attentional disorders

(Hemi-spatial) neglect: one side (hemifield) is ignored, even though the patient can see things in that hemifield when attention is forcefully directed to it.

# Response Time, accuracy, SDT

1. Response time

Certainty that an effect exists depends not just on the means, but on the spread, the extent to which distributions overlap.

Distributions could reveal more information

A difference between two response conditions may be more strongly expressed in the faster portion of RTs than in the slower portion.

**Late temporal locus**

early RTs are very similar between conditions; late RTs differ a lot.

**Early temporal locus**

late RTs are very similar between conditions; early RTs differ a lot.

1. Accuracy

Speed-accuracy trade-off

1. **Inverse efficiency scores**

IES = RT / P(correct)

1. **Signal detection theory**

**Sensitivity:** the distance between signal and noise distributions.

1. **Staircase procedures**

Controlling the subjective distance between the relevant and the irrelevant

Adjust stimulus intensity, duration, etc., on the basis of incoming responses, so that all subjects perform equally.

Procedures:

After X correct trials, decrease stimulus duration by β

After Y incorrect trials, increase stimulus duration by β

After each oscillation, decrease β a bit (until it hits 0)

# Memory

1. **Memory**

Any way in which a past experience affects future thoughts or behaviors

1. **Sensory Memory**

Sensation ≈ sensory memory

Activity in early regions decays over time

1. **Short Term Memory**

Our senses register a lot of information (e.g., the whole visual field), but only part of it is consciously processed.

Interaction between top-down & bottom-up works for memory too.

Instead of framing the limit in terms of number of objects, frame it in terms of amount of information.

1. **Working Memory**

Limited Capacity: On average, people can hold about 7 items (±2) in working memory.

Transient Storage: information dissipates quickly if not actively rehearsed or processed.

**Models and Components:**

**Central executive:** control and coordinates the activities of other components.

**Phonological loop:** processes verbal and spatial information.

**Visuospatial sketchpad:** deals with visual and spatial information.

**Episodic Buffer:** integrates information across domains and links it with long-term memory.

Prefrontal Cortex coordinate activation in perceptual regions during retention.

1. **Long Term Memory**

The seemingly infinite archive into which we have stored every experience since our existence.

Though the archive is infinite, stored files may wither.

Throughout our lives, we are automatically building the archive - for strategic purposes

Learning, automatization, bolstering WM

1. Interaction between WM and LTM

Experiment: The serial position curve

When asked to recall as many words as possible, subjects report the first and last words best.

primacy effect (first word advantage): first words get full attention; STM not occupied by other things, and/or words were rehearsed for a longer amount of time.

recency effect (last word advantage): Last words are still in STM.

1. Various types of LTM

**Episodic**: specific events

**Procedural**: skills and habits

Implicit vs explicit: unconscious and conscious

**Semantic**: facts and concepts

1. LTM in the brain

1) Cortical neurons activate associate hippocampal cells.

2) Hippocampal cells later on re-activate the cortical cells, allowing the connection in the neocortex to strengthen.

3) The cortical association is consolidated (LTP), the hippocampal connection is allowed to deteriorate.

With repeated activation, there is a chemical change at the synapse. The synaptic transfer is strengthened. Ergo, faster processing.

# Decision Making

1. **Decision-making**

Decision-making is the bridge between perception and action.

1. **Expected utility theory**

Given knowledge about what the outcomes of various options will be, people choose whatever yields maximum value.

Having all relative information, people will make a decision that **yields the most utility/value/achievement**.

Not true.

1. **Confirmation biases & Overconfidence biases**

**Confirmation biases**

We give more weight to information that confirms our expectations

**Overconfidence biases**

We trust ourselves more than others

1. **Prospect theory**

People act on predicted emotions

People are often risk-averse; but it also depends on how the problem is framed.

**Framing effect:**

the phenomenon where people react differently to a particular choice or decision based on how it is presented to them.

1. **The drift diffusion model**

Two competing neuronal clusters, evidence accumulate until one cluster (representing one decision) reaches threshold.

Until then: doubt.

Evidence: in Rhesus monkeys, direction-selective neuronal clusters are activated until one cluster’s spike rate hits threshold.

1. Neural complexity

To understand decision-making is to understand the brain entirely.

We have neuronal clusters driving the onset of billions of actions.

Those clusters are excited in billions of ways.

We can predict decisions of single neurons and human populations; nothing in between.

# Eye-tracking & Pupillometry

1. Terminology

**Saccade**: a rapid, ballistic eye movement that shifts gaze from one point to another.

**Saccadic amplitude**: angular distance or degree of the eye movement during a saccade.

**Saccadic latency**: the time it takes for a saccade to begin after a stimulus is presented.

**Fixation**: a period when the eyes are relatively stationary and focused on a single location.

**Fixation duration**: the length of time the eyes remain stationary during a fixation.

**Microsaccade**: a very small, involuntary saccade that occurs during fixation.

1. Eye position

Two signals: **pupil location**; **corneal reflection of (infrared) light sent from camera**.

# LMMs

1. The logic of LMMs

**Fixed effects**: experimental variable(conditions), those things about which we have hypotheses; (a specific direction of effect)

**Random effects**: those things that we expect may be variable, but for which we do not expect a particular patter.

Both in terms of intercept and slope, i.e., overall performance and effect strength.

**Covariates**: for which we expect a particular pattern

1. Random intercept & Random slope

**Random intercept**: (subjects) may on average vary from one another

**Random slope**: the effect of conditions may vary across (subjects).

\* operator tests interaction plus main effects,

: operator tests only the interaction

(1|) random intercepts (1+FE|RE) random slope

1. **Likelihood-ratio test**

The likelihood-ratio test is statistical method used to compare the goodness of fit of two models.

R: anova function.

1. Data Analysis

**lmer results**:

Values of **t>|1.96|** are deemed significant

b-value: estimate of fixed effects.

SE: standard error.

positivity/negativity of b and t indicates direction of effect.

**anova results**:

lower AIC & BIC

p-value < 0.05

# Language & Reading

1. Language & Communication

**Communication**: any transmittance of any signal in any perceptual modality. Communication is the overarching thing;

Language is but a means to communicate.

**Language** is a hierarchical system

Comprises **building blocks** that can be combined into building blocks

Comprises **rules** about how to combine building blocks at each level of the hierarchy

The set of structures that can be built following the rules is infinite

1. Letter Transposition Effect

**Positional noise**: letters activate not only their slot but also surrounding slots.

**Bigram representations**: an intermediate layer between letters and words, where (location-invariant) letter combinations are activated.

**Positional Ordering of N-Grams**:

The brain is a sequence learner.

The brain estimates the laterality of N-grams through bi-hemispheric activation differences

We’re multiple words in parallel.

Our expectations constrain the mapping of words onto locations.

# Interfaces

1. Interfaces

All man-made environments are interfaces

Design determines how well its users can achieve their goals and tasks

Environments are interfaces because they provide information that guide user decisions

1. Good design

Perception

1. Reduce signal-to-noise ratio
2. Don’t refer to more than 5 things with a single sensory dimension
3. Take top-down processing into account
4. Redundancy gain: convey information in multiple ways
5. Make things discriminable

Expectation

1. Realism: display elements should correspond to the real world
2. Realism: moving edition

Attention

1. Minimize access cost (i.e., navigating from one important location to another shouldn’t take effort)
2. Proximity compatibility
3. Divide processing load among senses

Memory

1. Balance memory and perception: we do not have to memorize what we can see
2. Aid predictions (same as principle 11)
3. Safeguard consistency