SYDE 543 Course Notes

Cognitive Ergonomics

Paolo Torres

**University of Waterloo**

**Winter 2021**

Table of Contents

[1 Why Cognitive Ergonomics? 1](#_Toc63453571)

[1.1 What is Cognitive Ergonomics? 1](#_Toc63453572)

[1.2 The Descriptive Model of Human Information Processing 1](#_Toc63453573)

[1.3 Kind vs. Wicked Learning Environment 2](#_Toc63453574)

[2 Signal Detection Theory and UI/UX (Part 1) 2](#_Toc63453575)

[2.1 Signal-to-Noise Ratio 2](#_Toc63453576)

[2.1.1 Definitions 2](#_Toc63453577)

[2.1.2 Example 2](#_Toc63453578)

[2.1.3 Increasing Signal-to-Noise Ratio 3](#_Toc63453579)

[2.1.4 Visual Hierarchy 3](#_Toc63453580)

[2.1.5 Dynamic Noise 3](#_Toc63453581)

[2.1.6 Heuristics 3](#_Toc63453582)

[2.2 Signal Detection Theory (SDT) 3](#_Toc63453583)

[2.2.1 Neural Activity 3](#_Toc63453584)

[2.2.2 Hit, Miss, False Alarm, Correct Rejection 4](#_Toc63453585)

[2.2.3 Perceptual Sensitivity () 4](#_Toc63453586)

[2.2.4 Decision Criteria () 4](#_Toc63453587)

[2.3 Receiver Operating Characteristic (ROC) Curve 4](#_Toc63453588)

[2.3.1 ROC Curve 4](#_Toc63453589)

[2.3.2 Relationship Between ROC Curve and 5](#_Toc63453590)

[2.3.3 ROC Curve Axes 5](#_Toc63453591)

[3 Signal Detection Theory and Ui/UX (Part 2) 5](#_Toc63453592)

[3.1 Engineering Psychology and Human Performance 5](#_Toc63453593)

[3.1.1 The ROC Curve 5](#_Toc63453594)

[3.1.2 Fuzzy Signal Detection Theory 7](#_Toc63453595)

[3.2 Wicked (Open-Ended) Problem 7](#_Toc63453596)

[3.2.1 Vocal Biomarkers and COVID 7](#_Toc63453597)

[3.2.2 App to Detect COVID by Speech Analysis 7](#_Toc63453598)

[3.2.3 New Method of Detecting Illnesses 8](#_Toc63453599)

[4 Design for Decision Making with a Twist (Part 1) 8](#_Toc63453600)

[4.1 Are We in Control of Our Own Decisions? 8](#_Toc63453601)

[4.1.1 Intuition and Illusion 8](#_Toc63453602)

[4.1.2 Cognitive Illusion 8](#_Toc63453603)

[4.1.3 Can Experts Overcome This Issue? 8](#_Toc63453604)

[4.1.4 Gap Between Decisions and Actions 9](#_Toc63453605)

[4.2 Heuristics and Biases 9](#_Toc63453606)

[4.2.1 Origins of the Heuristics and Biases Approach 9](#_Toc63453607)

# Why Cognitive Ergonomics?

## What is Cognitive Ergonomics?

* Cognitive ergonomics is the field of study that focuses on how well the use of a product matches the cognitive capabilities of users
* Mainly focuses on work activities which have an emphasized cognitive component, are in safety-critical environments, and are in a complex, changeable environment
* Domain: Environment where the system operates, presents constraints and opportunities
* Operates with two underlying theories: a theory about domain and about human cognition

## The Descriptive Model of Human Information Processing

* Short Term Sensory Store (STSS): Events first processed by sight, sound, touch, etc.
* Perception: Determining meaning of events, long term memory of events
* Response Selection: A decision made based on either perception or working memory

Diagram

Description automatically generated

## Kind vs. Wicked Learning Environment

* Kind learning environments have next steps and goals that are clear, have rules that are clear and never change, get feedback that is quick and accurate (golf, chess, etc.)
* Wicked learning environments have next steps and goals that may not be clear, have rules that may change, may or may not get feedback
* The work world is a wicked environment, where hyper specialization can backfire
* In a wicked world, we need people who generalize first then specialize later on
* We need both frogs and birds, frogs to see the details up close, and birds to integrate the knowledge together, to succeed in a wicked world

# Signal Detection Theory and UI/UX (Part 1)

## Signal-to-Noise Ratio

### Definitions

* Signal: Information that is relevant and useful to us
* Noise: Information that is irrelevant to our current need
* Signal-to-Noise Ratio: Ratio of relevant to irrelevant information in an interface

### Example

Graphical user interface

Description automatically generated

* If booking a flight, “Book Travel” is a signal, but everything else is noise
* UI elements may serve functions other than simple communication or task efficiency
* Aim for a reasonable signal-to-noise ratio rather than excluding all “irrelevant” parts

### Increasing Signal-to-Noise Ratio

* Pay attention to your content and have a strong visual hierarchy
* Start with a clear content strategy to help prioritize the information to convey
* Examples: Ensure every piece of text has some importance, avoid redundancy, separate paragraphs, bold keywords, use bullet points, etc.

### Visual Hierarchy

* Reflects the relative importance of different elements on the interface (highly relevant, high visual weight)
* Examples: Making font large and bold, changing colour on action, adding an icon, etc.

### Dynamic Noise

* What counts as noise can change from moment to moment, as the user’s task changes
* Example: Navigation on a website, where the navigation UI is noise while the user is focused on the page content, but becomes the signal once the user is done

### Heuristics

* Aesthetic and minimalist design (remove unnecessary elements from the user interface)

## Signal Detection Theory (SDT)

### Neural Activity

Diagram

Description automatically generated

### Hit, Miss, False Alarm, Correct Rejection

* Hit: Positive response when there is a signal
* Miss: Negative response when there is a signal
* False Alarm: Positive response when there is no signal
* Correct Rejection: Negative response when there is no signal

|  |  |  |
| --- | --- | --- |
|  | Signal + noise | Noise |
| Thinks phone ringing | Hit | False alarm |
| Thinks phone not ringing | Miss | Correct rejection |

### Perceptual Sensitivity ()

* How different the signal is from the noise
* Larger : Signal more distinguishable from noise, more hits and correct rejections
* Smaller : Signal less distinguishable from noise, more misses and false alarms

### Decision Criteria ()

* The degree at which the perceiver is biased to detect or not detect
* Conservative (large) : Minimal detection, more misses and correct rejections
* Liberal (small) : Maximal detection, more hits and false alarms

## Receiver Operating Characteristic (ROC) Curve

### ROC Curve

Chart

Description automatically generated

### Relationship Between ROC Curve and

* The steeper the curve, the higher the

### ROC Curve Axes

* : probability of a hit

# Signal Detection Theory and Ui/UX (Part 2)

## Engineering Psychology and Human Performance

### The ROC Curve

* Of the four values in SDT, only two are critical, and , since and can be specified as and , respectively
* The ROC curve plots against for different response criterions
* Each signal detection condition (each matrix) generates one point on the ROC
* Points falling on the curve have the *same* sensitivity
* Points in the lower left represent conservative responding, upper right risky responding

Diagram

Description automatically generated

* More efficient method, **confidence levels**:
* For example, if levels and are “no” and level “yes” classify as a conservative beta setting, but if level is “no” and levels and are “yes”, classify as a risky beta setting

Table

Description automatically generated

* The value of at any given point along the ROC curve is equal to the slope of a tangent drawn to the curve at any point
* Slope is equal to at points that fall along the **negative diagonal**
* Points on the **positive diagonal** represent chance performance: no matter how the criterion is set, equals , so the signal can’t be distinguished from the noise
* Alternative way of plotting is to use -scores, the bowed lines now become straight lines parallel to the chance diagonal

A picture containing text, antenna

Description automatically generated

* : A measure of the area under the ROC curve that provides an alternative sensitivity
* Represents the triangular area formed by connecting the lower left and upper right corners of the ROC space to the measured data point

### Fuzzy Signal Detection Theory

* Such “crisp” definitions of signal and noise are possible in everyday or work environments, yet more often than not, whether it is a signal or not is fuzzy
* Example: In air traffic control, a signal is when the flight paths of two aircraft come within horizontally and vertically of each other
* However, the controller will consider a signal requiring action when these distances are exceeding these minimum values, depends on other factors like complexity and time

## Wicked (Open-Ended) Problem

### Vocal Biomarkers and COVID

* A group of researchers have discovered that they can determine if a person is infected with the coronavirus by analyzing signals hidden in their speech
* **Problem 1: Silent Spread:** One can infect others even if asymptomatic, an estimated are asymptomatic, the virus has a highly variable incubation period
* **Problem 2:** **Delayed Results:** May take upwards of a week to get results, making results virtually meaningless for contact tracing
* **The Solution:** Have something that people can take in their own homes, with results being available within moments
* **Speech Signals:** Neurological diseases affect the brain’s ability to process speech, and these changes can serve as vocal biomarkers
* **Inflammation and COVID:** Coupling between lung inflammation and speech could serve as a biomarker, would not prove COVID but could indicate presence of it

### App to Detect COVID by Speech Analysis

* Strong evidence that COVID symptoms could be detected from human speech
* Speech contains inherent info about the physical, physiological, etc. status of a speaker
* This app would detect COVID symptoms at a much earlier stage
* **Speech Variations:** COVID will cause subtle variations to speech characteristics
* **Data Collection:** Recordings, along with body params, are measured and trained
* **Signal Processing and AI:** Techniques like filtering, voice activity detection, etc.
* **Challenges:** Minimizing false alarms (alert, no COVID) and misses (no alert, COVID)

### New Method of Detecting Illnesses

* Examining individual molecules (biomarkers) to detect presence of disease in blood
* In theory could speed up coronavirus testing (minutes) and provide accurate results
* Involves using DNA origami, used to capture biomarkers, which are the indicators
* By modifying DNA origami to capture COVID molecules, can detect the proteins that the coronavirus uses to invade human cells

# Design for Decision Making with a Twist (Part 1)

## Are We in Control of Our Own Decisions?

### Intuition and Illusion

* Visual illusion as a metaphor for rationality
* Our intuition fools us in repeatable, predictable, consistent ways, and there is almost nothing we can do about it, aside from taking a ruler and starting to measure it
* Examples: horizontal vs. vertical table but same length, shadow on Rubik’s cube but same colour

### Cognitive Illusion

* In cognitive illusion, it is much harder to demonstrate the mistakes to people
* Example: organ donation, opt-in vs. opt-out, countries with opt-in by default have way more organ donation vs. countries with opt-out by default
* Example: Subscription options
  + web, print, web and print
  + Results:
  + Since the print only option was , safe to remove right? No
  + When removed, results were:
  + Idea: Even though it was , it had an indirect effect on the choice of the web and print option, perhaps due to it being strictly inferior to the print only option

### Can Experts Overcome This Issue?

* Example: Medication and hip replacement
  + Send patient to hip replacement, but forgot to try one medication, most would call them back to try it
  + Send patient to hip replacement, but forgot to try two medications, most would let them go to hip replacement
* With more decisions comes more complexity, hence experts could still face problems

### Gap Between Decisions and Actions

* Many decisions are not residing within is, but rather in the person who is designing what is being used/interacted with
* We have such a feeling that we’re in the driver’s seat, such a feeling that we’re in control and we are making the decision, that it’s very hard to even accept the idea that we actually have an illusion of making a decision, rather than an actual decision

## Heuristics and Biases

### Origins of the Heuristics and Biases Approach

* Favours a skeptical attitude toward expertise and expert judgement
* Statistical predictions were more accurate than human predictions in almost every case
* Inferiority of clinical judgement was due in part to systematic errors
* Clinicians’ uncritical reliance on their intuition and their failure to apply elementary statistical reasoning
* Inconsistency is a major weakness of informal judgement: when presented with the same case information on separate occasions, human judges often reach different conclusions
* Human judgements are noisy to an extent that substantially impairs their validity
* **Illusion of Validity:** Unjustified sense of confidence that often comes with clinical judgement
* Sophisticated scientists reached incorrect conclusions and made inferior choices when they followed their intuitions, failing to apply rules with which they were familiar