SYDE 543 COURSE NOTES
COGNITIVE ERGONOMICS

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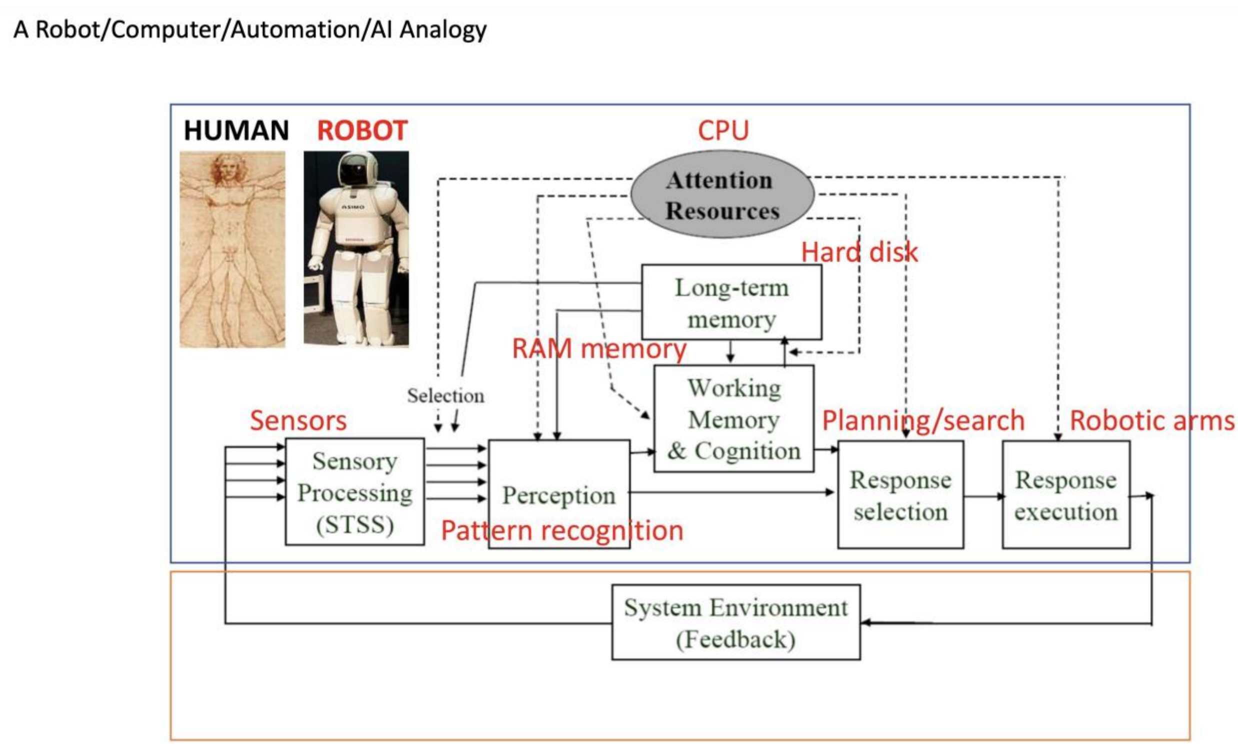
1 WHY COGNITIVE ERGONOMICS?

1.1 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

1.2 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



1.3 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

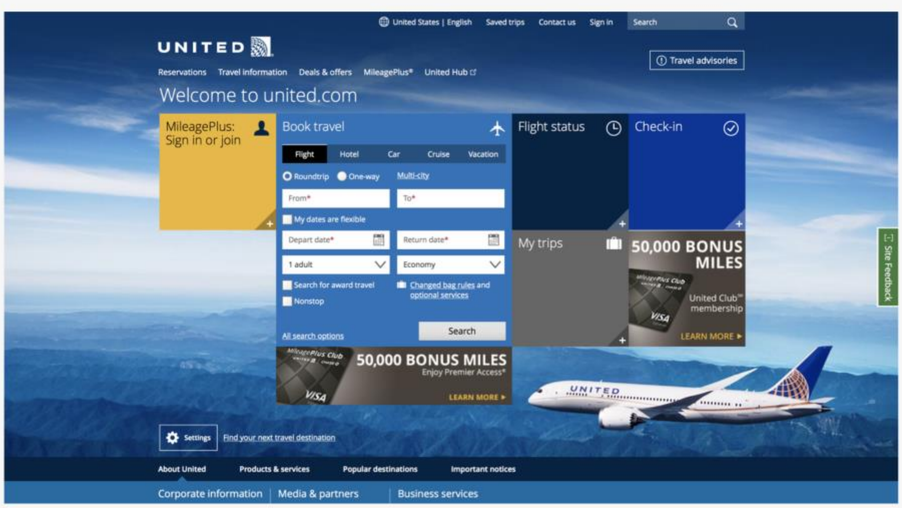
2 SIGNAL DETECTION THEORY AND UI/UX (PART 1)

2.1 Signal-to-Noise Ratio

2.1.1 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

2.1.2 Example



United Airlines' homepage has several elements that might be signal in some situations, but noise in others.

- 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

2.1.3 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.

2.1.4 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.

2.1.5 Dynamic Noise

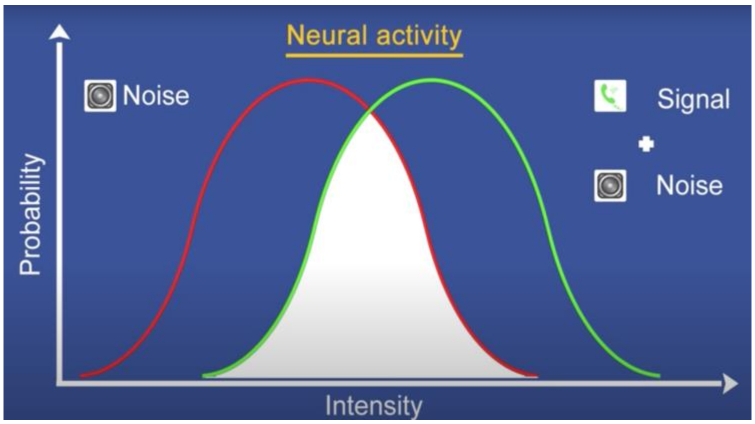
- What counts as noise can change from moment to moment, as the user’s task changes
- Example: Navigation on a website, where the navigation UI is noise while the user is focused on the page content, but becomes the signal once the user is done

2.1.6 Heuristics

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

2.2 Signal Detection Theory (SDT)

2.2.1 Neural Activity



2.2.2 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

2.2.3 Perceptual Sensitivity (d')

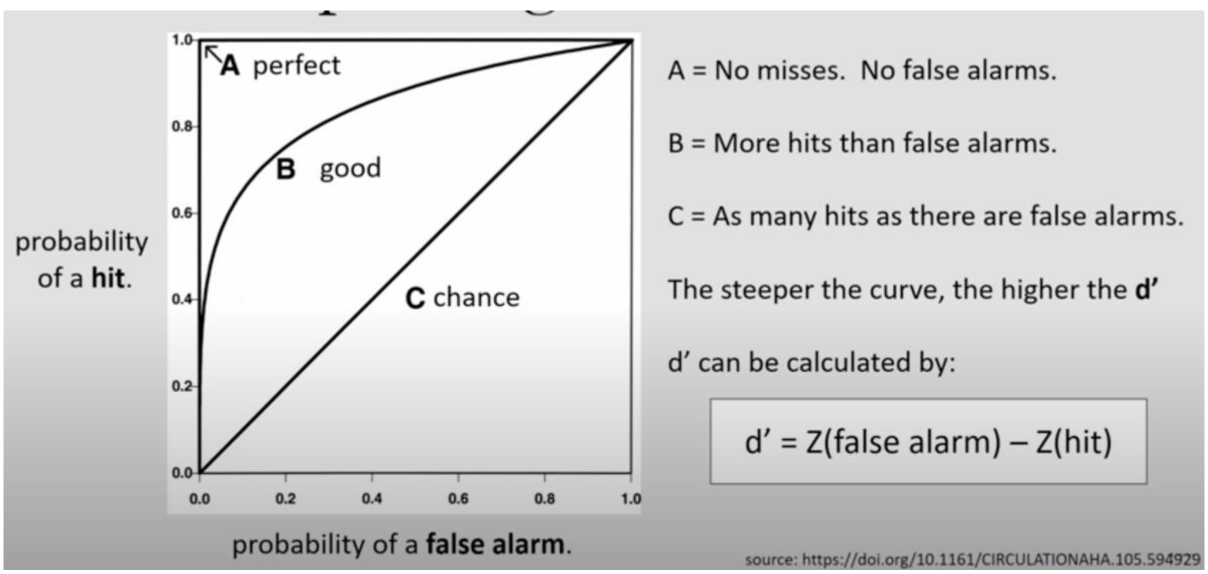
- How different the signal is from the noise
- Larger d': Signal more distinguishable from noise, more hits and correct rejections
- Smaller d': Signal less distinguishable from noise, more misses and false alarms

2.2.4 Decision Criteria (β)

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

2.3 Receiver Operating Characteristic (ROC) Curve

2.3.1 ROC Curve



2.3.2 Relationship Between ROC Curve and d'

- The steeper the curve, the higher the d'
- $d' = Z(false\ alarm) - Z(hit)$

2.3.3 ROC Curve Axes

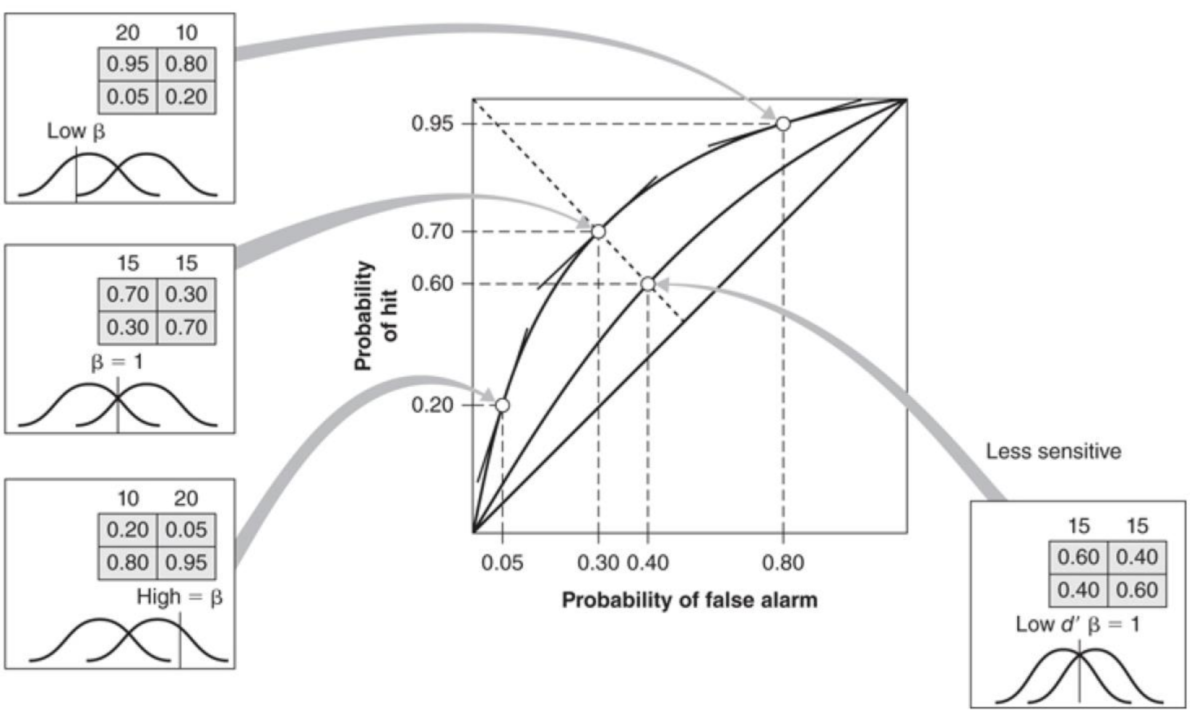
- $x - axis: probability\ of\ a\ false\ alarm$
- $y - axis$: probability of a hit

3 SIGNAL DETECTION THEORY AND UI/UX (PART 2)

3.1 Engineering Psychology and Human Performance

3.1.1 The ROC Curve

- Of the four values in SDT, only two are critical, $P(H)$ and $P(FA)$, since $P(M)$ and $P(CR)$ can be specified as $1 - P(H)$ and $1 - P(FA)$, respectively
- The ROC curve plots $P(H)$ against $P(FA)$ 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

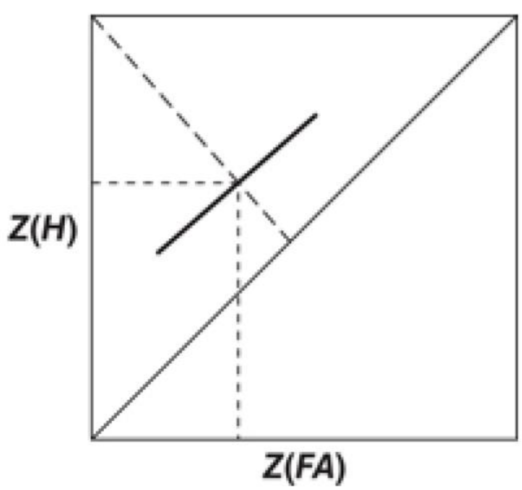


- More efficient method, **confidence levels**: $1 = confident\ no\ signal\ present, 2 = uncertain, 3 = confident\ signal\ present$
- For example, if levels 1 and 2 are "no" and level 3 "yes" classify as a conservative beta setting, but if level 1 is "no" and levels 2 and 3 are "yes", classify as a risky beta setting

TABLE 2.1 Analysis of confidence ratings in signal detection tasks

Subject's Response	**Stimulus Presented**		**How Responses Are Judged**	
	Noise	**Signal**		
"1" = "No Signal"	4	2	**No**	**No**
"2" = "Uncertain"	3	2	**No**	**Yes**
"3" = "Signal"	1	4	**Yes**	**Yes**
Total No. Of Trials	8	8	↓	↓
			Conservative Criterion	Risky Criterion
			P(FA) = 4/8	P(FA) = 4/8
			P(HIT) = 4/8	P(HIT)= 6/8

- The value of $beta$ 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 1 at points that fall along the **negative diagonal**
- $P(H) = 1 - P(FA)$
- Points on the **positive diagonal** represent chance performance: no matter how the criterion is set, $P(H)$ equals $P(FA)$, so the signal can't be distinguished from the noise
- Alternative way of plotting is to use z-scores, the bowed lines now become straight lines parallel to the chance diagonal



- A': 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

$$A' = 0.5 + \frac{\big(P(H) - P(FA)\big)\big(1 + P(H) - P(FA)\big)}{4P(H)\big(1 - P(FA)\big)}$$

3.1.2 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 $5\ nautical\ miles$ horizontally and $1{,}000\ feet$ 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

3.2 Wicked (Open-Ended) Problem

3.2.1 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 40% 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

3.2.2 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)

3.2.3 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