The Human Brain

Ahmed Sabbir Arif
University of California, Merced
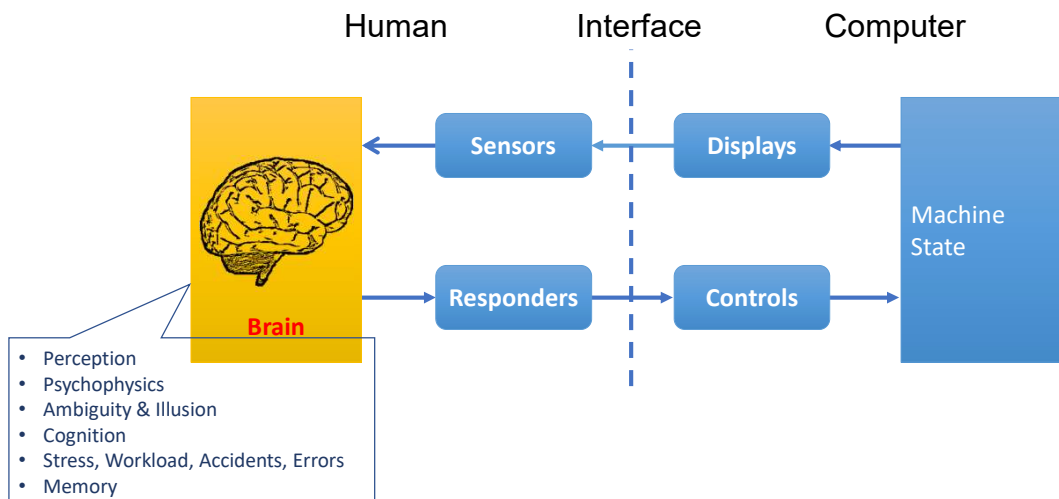https://www.theiilab.com/

Lecture notes in this series are based on
- Ahmed Sabbir Arif. 2021. Statistical Grounding. *Intelligent Computing for Interactive System Design: Statistics, Digital Signal Processing, and Machine Learning in Practice*, ACM
- Ann Blandford, Dominic Furniss, Stephann Makri. 2016. Qualitative HCI Research: Going Behind the Scenes. Morgan & Claypool
- Jonathan Lazar, Jinjuan Feng, Harry Hochheiser. 2017. Research Methods in Human-Computer Interaction. Morgan Kaufmann
- I. Scott MacKenzie. 2013. Human-Computer Interaction: An Empirical Research Perspective, Morgan Kaufmann
- Interaction Design Foundation. 2022. Design Thinking
- Lecture notes of Amy Bruckman, Mark Dunlop, Niels Henze, I. Scott MacKenzie, Laura Moody, Albrecht Schmidt, Kami Vaniea

1

Human Factors Model

Human   Interface   Computer

Brain

- Perception
- Psychophysics
- Ambiguity & Illusion
- Cognition
- Stress, Workload, Accidents, Errors
- Memory

Sensors — Displays — Machine State

Responders — Controls

2

The Brain

- Most complex biological structure known
- Billions of neurons
- Enables human capacity for
  - Pondering, remembering, recalling, reasoning, deciding, communicating, etc.
- Sensors (human inputs) and responders (human outputs) are nicely mirrored, but it is the brain that connects them
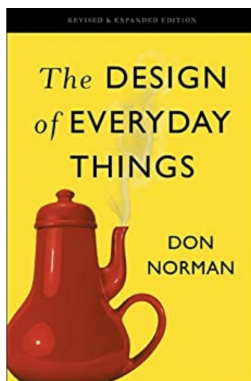
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3

3

Human Uniqueness

- With associations and meaning attached to sensory input, humans are vastly superior to the machines they interact with

"People excel at perception, at creativity, at the ability to go beyond the information given, making sense of otherwise chaotic events. We often have to interpret events far beyond the information available, and our ability to do this efficiently and effortlessly, usually without even being aware that we are doing so, greatly adds to our ability to function." – Don Norman

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4

4

Perception

- 1st stage of processing for sensory input
- Associations formed…
  - Auditory stimulus → harmonious, discordant
  - Visual stimulus → familiar, strange
  - Tactile stimulus → warm, hot
  - Smell stimulus → pleasurable, abhorrent
  - Taste stimulus → sweet, sour

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5

5

Psychophysics

- Branch of experimental psychology
- Since 19th century
- Relationship between human perception & physical phenomena
- Experimental method
  - Present subject with two stimuli, one after the other (A/B testing)
  - Stimuli differ in a physical property (e.g., frequency)
  - Randomly vary the difference
  - Determine threshold below which the subject deems the two stimuli "the same"
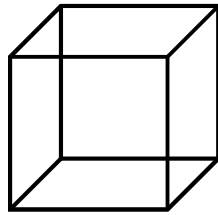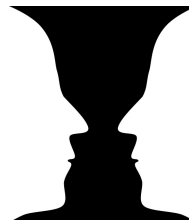 - This threshold is the *just noticeable different* (JND)

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6

6

Optical Ambiguity

Necker cube

Rubin vase
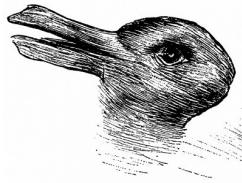
Which surface is at the front?
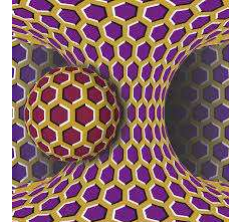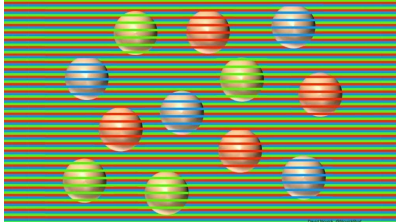
Wine goblet or two faces?

7

7

Optical Illusion

Ponzo lines

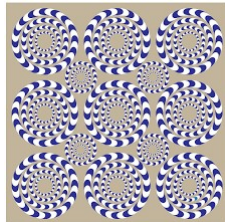Műller-Lyer arrows

Which black line is longer?
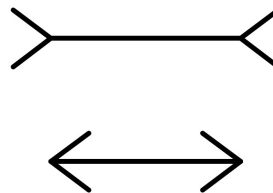
Which horizontal line is longer?

147 Visual Phenomena & Optical Illusions by Michael Bach: https://michaelbach.de/ot/index.html
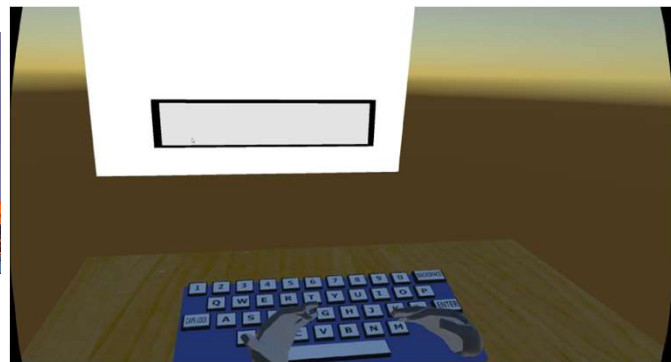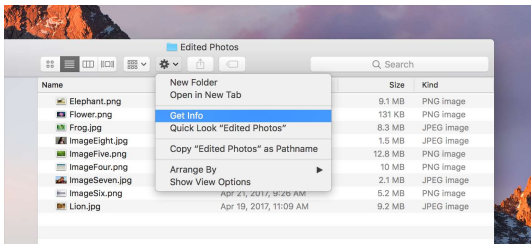
8

8

Ambiguity & Illusion in Digital Media

Toy Story: Woody & Buzz Flying

Dragon Ball Z: Goku vs. Cell
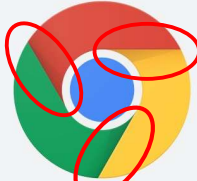
- Western animation: 24 fps
- Japanese animation: 6, 8, or 12 fps
  - Main objects animated at 8 to 12 fps
  - Background objects at 6 to 8 fps

9

Illusion in Interactive Systems

Tafadzwa Joseph Dube, Ahmed Sabbir Arif. 2020. Impact of Key Shape and Dimension on Text Entry in Virtual Reality. In Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems (CHI EA 2020). ACM, NY, 1–10.
https://youtu.be/V1veIq1bgig

10

Google Chrome Icon Update on Feb 4, 2022

2008   2011   2014   2022

- Shadows removed
- Revised proportions
- Brighter the colors

11

11

Google Chrome Icon Update on Feb 4, 2022

- Google found placing certain shades of green and red next to each other creates an unpleasant color vibration
  - Introduced a very subtle gradient to the main icon to mitigate that
  - Makes the icon more accessible

From https://michaelbach.de/ot/col-chromostereopsis/index.html
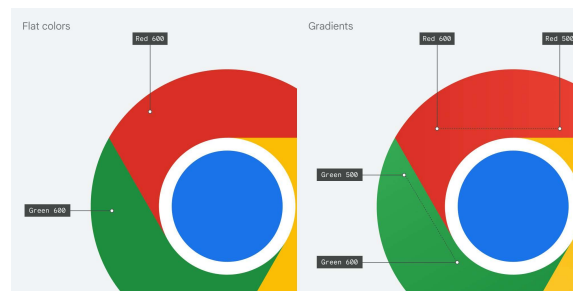
12

12

Google Chrome Icon Update on Feb 4, 2022

- Looks 3D on MacOS

13
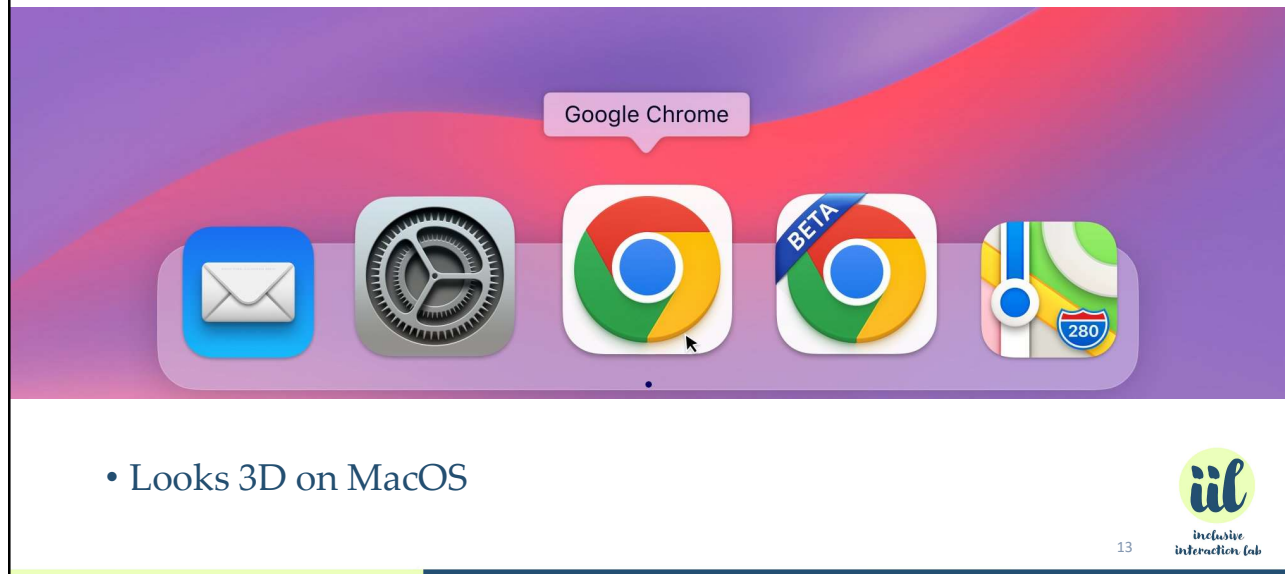
13

Perceptual Mismatch

- Vision dominates when senses conflict (tactition vs. vision)
- For example, a person moving her hand along a straight surface while wearing distorting glasses perceives the straight surface as curved
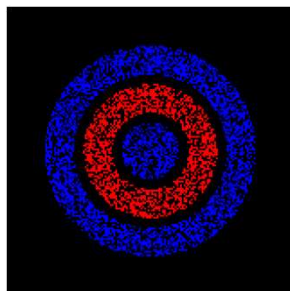 - Used for haptic redirection in virtual reality by creating perceptual mismatch or illusion

Mahdi Azmandian, Mark Hancock, Hrvoje Benko, Eyal Ofek, and Andrew D. Wilson. 2016. Haptic Retargeting: Dynamic Repurposing of Passive Haptics for Enhanced Virtual Reality Experiences. In Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16). ACM, NY, 1968–1979. https://youtu.be/v-5u0z4zA_8

14

14

2/3/2023

Illusion in Other Senses

- If illusion is possible for the visual sense, the same should be true for the other senses
- Tactile/haptic illusion
  - Phantom limb
- Auditory illusion

Artist: Alexander

  - Shepard tone

Cognition

- Cognition is the human process of conscious intellectual activity
  - Thinking, reasoning, deciding, etc.
- Spans many fields
  - Neurology, linguistics, anthropology, etc.
- Sensory phenomena → easy to study because they exist in the physical world
- Cognitive phenomena → hard to study because they exist within the human brain

Making a Decision

- Not possible to directly measure the time for a human to "make a decision"
  - When does the measurement begin and end?
  - Where is it measured?
  - On what input is the human deciding?
  - Through what output is the decision conveyed?
- There is a sensory stimulus and motor response that bracket the decision

17

17

Making a Decision in Parts
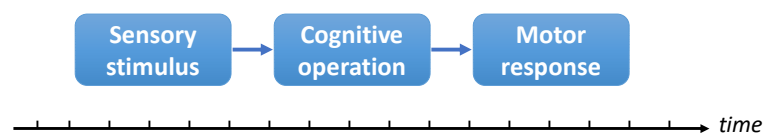
Operation	Typical time (ms)
Sensory reception	1 – 38
Neural transmission to brain	2 – 100
Cognitive processing	70 – 300
Neural transmission to muscle	10 – 20
Muscle latency and activation	30 –70
Total:	113 - 528

Large variation!

18

18

Examples of Simple Decisions

- Driving a car → decision to depress the brake pedal in response to a changing signal light
- Using a mobile phone → decision to press REJECT-CALL in response to an incoming call
- Reading news online → decision to click the CLOSE button on a popup ad

- These are *reaction time* tasks

19

19

Stress & Workload

Environmental and Psychological Stressors

20

20

Stress

- Stress is an emotional state of heightened arousal that can impair performance
- Can disrupt behavior and have negative consequences for health if severe enough
- Not always negative, it may also serve as an energizing force that motivates people to perform well

21

21

Stressors

- Environmental: noise, vibration, heat, dim lighting, high acceleration
- Psychological: anxiety, fatigue, frustration, anger
- Time: limited time to perform a task
- Organizational: severe penalties for poor performance

- Can have <u>external</u> or <u>internal</u> influences on human performance:
  - External stressors influence the quality of information received by the receptors or the precision of the motor or vocal response
    - Their influences & effects are easily predictable
  - Internal stressors:
    - External source can be identified: noise, sleep loss
    - External source can't be identified: fear, incentives
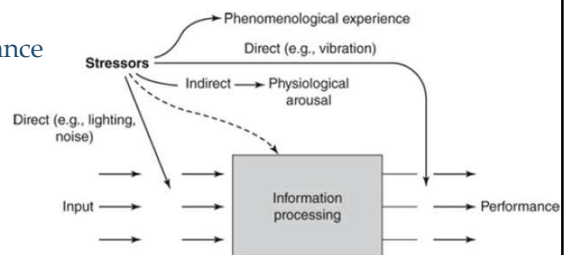
C. D. Wickens, W. S. Helton, J. G. Hollands, S. Banbury. 2021. Engineering Psychology and Human Performance. Routledge.

22

22

Stressors: Environmental

Stressors	Effect			
	Health	Input	Indirect	Performance
Light		X		
Noise	X	X	X	X
Vibration	X	X		
Motion Sickness			X	
Heat/Cold	X	X	X	X
Air Quality	X		X	X

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23

23

Stressors: Psychological

- Anxiety, fatigue, frustration, anger, fear, embarrassment, loss of esteem
  - Perceptual or attention narrowing or tunneling
    - Cognitive tunnel vision happens when we fail to recognize an unexpected stimulus in plain sight
  - Working memory loss
  - Strategic shifts, e.g., tendency to react too quickly
- Effect depends on individual factors
  - Personality traits
  - Level of experience
  - Life stress
  - Level of physiological arousal induced by the stressor
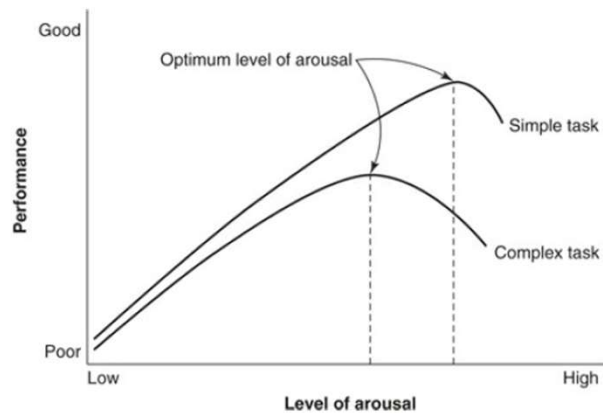   - Yerkes-Dodson law

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24

24

Yerkes-Dodson Law (1908)

- Empirical relationship between pressure and performance
  - Performance increases with physiological arousal, only up to a point
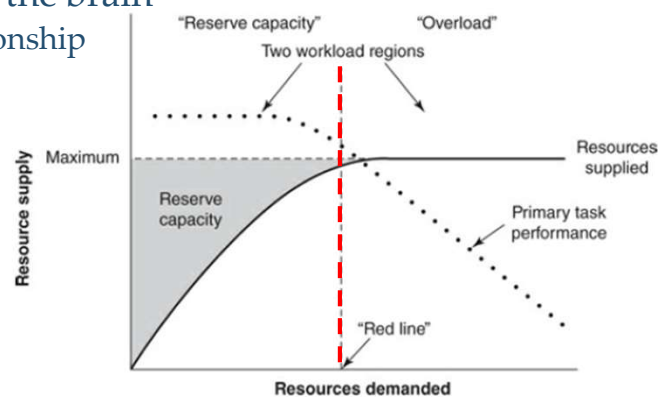

25

Mental Workload

- The demands of tasks imposed on the limited information processing capacity of the brain
  - Supply-demand relationship
  - Information overload

C. D. Wickens, W. S. Helton, J. G. Hollands, S. Banbury. 2021.
Engineering Psychology and Human Performance. Routledge.

26

Workload Measures

- Time required / Time available (TR/TA) ratio
  - Based on task analysis
  - Percentage computed per time unit on task timeline
  - Useful predictor, but difficult to construct

FUNCTIONAL

- Primary task measures
  - Measure the *influence* of mental workload
- Secondary task methods
  - Measure the *reserve capacity*
- Physiological measures
  - Allow non-intrusive measures
- Subjective measures
  - SWAT, **NASA-TLX**
    - NASA Task Load Index: https://humansystems.arc.nasa.gov/groups/tlx/downloads/TLXScale.pdf

MENTAL

27

27

Interface Design Tips

- Reduce stressors in your interface
  - Optimal vibration duration, automatic brightness adjustment, etc.

- Compensate for environmental stressors
  - Such as, alternative approach to enter text when riding a subway

- Find and exploit optimal level of arousal (OLA)
  - Facilitate faster transition from novice to expert

28

28

Example: Exploiting Stressors for Learning
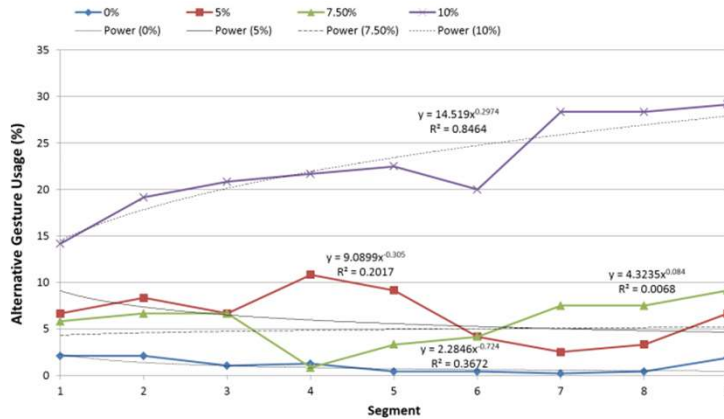
Ahmed Sabbir Arif, Wolfgang Sturzlinger. 2014. User Adaptation to a Faulty Unistroke-Based Text Entry Technique by Switching to an Alternative Gesture Set. In *Proceedings of Graphics Interface 2014* (**GI 2014**). Canadian Information Processing Society, Toronto, Ontario, Canada, 183-192.

29

Human Errors & Accidents

30

15

Human Errors & Accidents

- Human error are instances where a planned activity fails to achieve its intended outcome
- Human errors can result in accidents

- Some differentiated errors & accidents in the context of human factors:
  - <u>Errors:</u> intentionally performed incorrect actions thinking that they were correct
  - <u>Accidents:</u> unintentionally performed incorrect actions, for example, accidentally pressing the ☑ button instead of ❌

On Jan 13, 2018, a ballistic missile alert was accidentally issued via the Emergency Alert System and Wireless Emergency Alert System over television, radio, and cellphones in the U.S. state of Hawaii.

An employee clicked the button to send out an actual notification on Hawaii's emergency alert interface during what was intended to be a test, then clicked through a second screen, which had been intended as a safeguard, to confirm.

31

31

Another Accident Example: <u>Climate Orbiter</u>

- <u>Dec 11, 1998:</u> NASA launched Mars Climate Orbiter to study the Martian climate, atmosphere, surface changes
- <u>Sep 23, 1999:</u> Communication with it was permanently lost when it went into orbital insertion (too close/farther away from the planet)
- <u>Sep 30, 1999:</u> Caused by a measurement mismatch between NASA (<u>Metric</u>) & U.S. spacecraft builder Lockheed Martin (<u>Imperial</u>)
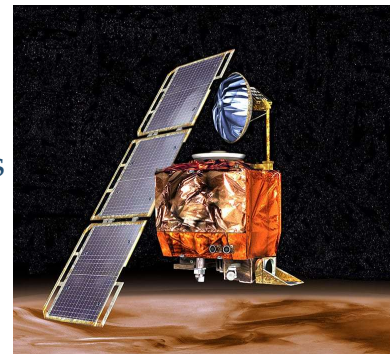
Artist's conception of the Mars Climate Orbiter 2 robotic space probe (338 kg). Built at a cost of **$125 million**. NASA/JPL/Corby Waste

32

32

Yet Another Accident Example: <u>Gimli Glider</u>

On July 23, 1983, Air Canada's Flight 143, with 69 people onboard, ran out of fuel at an altitude of 41,000 ft. The pilot managed to glide the plane down safely as he was very experienced glider pilot. 22,300 pounds of jet fuel had been put instead of 22,300 kg.

Flight 143 between Montreal and Edmonton was glided to a former Royal Canadian Air Force base in Gimli, Manitoba
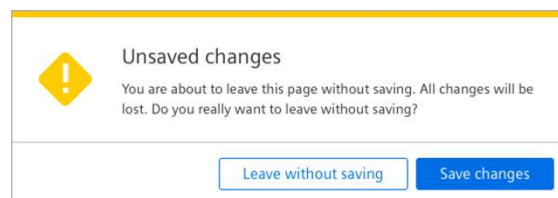
33

33

Interface Design Tips: <u>Reducing/Handling Errors</u>

• Limit human interactions, when possible (more on this later)
• Display a confirmation prompt for potential erroneous actions

Unsaved changes
You are about to leave this page without saving. All changes will be lost. Do you really want to leave without saving?

Leave without saving   Save changes
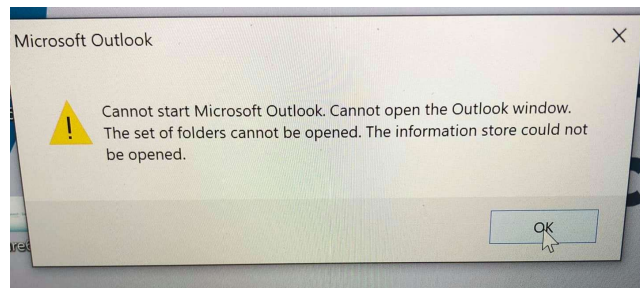
Confirmation Prompt

34

34

Interface Design Tips: <u>Reducing/Handling Errors</u>

- Provide graphical, auditory, haptic feedback on potential errors
    - Correctness feedback informs users if an action is correct/incorrect
    - Directive and facilitative feedback directs users to correct actions
- Provide clear, meaningful messages in prompts and feedback
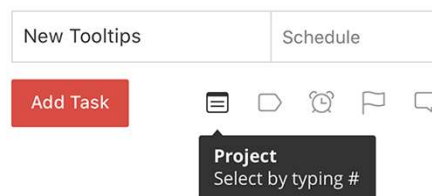

What really went wrong? How to fix it?

Interface Design Tips: <u>Reducing/Handling Errors</u>

- Provide directive/facilitative feedback for novices
    - Include guide for novices: tooltips and labels
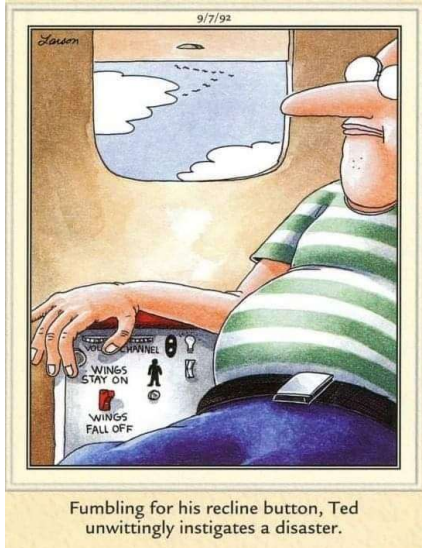- Transition to correctness feedback when novices become experts

Facilitative Feedback

Interface Design Tips: <u>Reducing/Handling Errors</u>
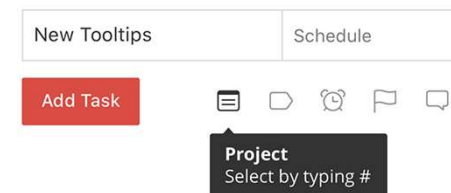

Fumbling for his recline button, Ted unwittingly instigates a disaster.

- Most importantly, invest time in interface design to avoid confusions and human errors
  - Iterative design process
  - User in the loop approach

37

37

Interface Design Tips

- Limit human interactions, when possible (more on this later)
- Display a confirmation prompt for potential erroneous actions
- Provide directive/facilitative feedback for novices
  - Include guide for novices: tooltips and labels
- Transition to correctness feedback when novices become experts

Correctness Feedback

Facilitative Feedback

38

38

Interface Design Tips

- Provide

Confirmation Prompt

39

39

Interface Design Tips

- Limit human interactions, when possible (more on this later)
- Display a confirmation prompt for potential erroneous actions
- Provide graphical, auditory, and/or haptic feedback on potential errors
  - Correctness feedback informs users if an action is correct or incorrect
  - Directive and facilitative feedback directs users to correct actions
- Provide directive/facilitative feedback for novices
  - Include guide for novices: tooltips and labels
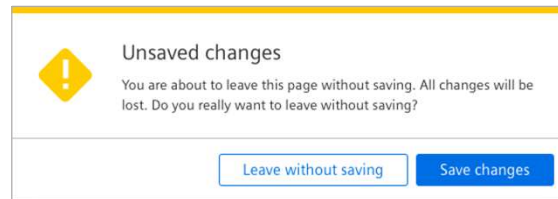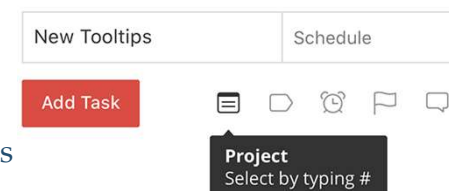- Transition to correctness feedback when novices become experts

Correctness Feedback

Facilitative Feedback

40

40

Memory

Short and Long-term Memory

41

41

Memory

- Vast repository
- Long-term memory
  - <u>Declarative/explicit area:</u> information about events in time and objects in the external world
  - <u>Implicit/procedural area:</u> information about how to use objects and how to do things
- Short-term memory
  - Aka *working memory*
  - Information is active and readily available for access
  - Amount of working memory is small, about 7 (±2) units or chunks

G. A. Miller. 1956. <u>The Magical Number Seven Plus or Minus Two: Some Limits on Our Capacity for Processing Information</u>. Psychological Review, 63, 81-97.
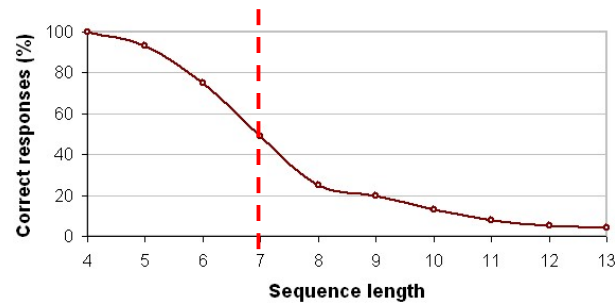
42

42

Short Term Memory Experiment

- Random sequences of digits recited to subjects
- Sequences vary from 4 to 13 digits
- After recitation, subjects copy sequence from memory to a sheet of paper
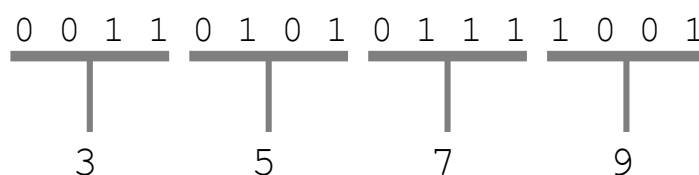- Transcriptions on sheets scored (correct/incorrect)
- Results ($n \approx 60$):

43

Chunking

- Units in short term memory may be recoded as a chunk
- Expands capacity of short term memory
    - A trait of expert/experienced users
- E.g., Commit to memory and recall…

0 0 1 1   0 1 0 1   0 1 1 1   1 0 0 1   ☹

3   5   7   9   😃

44

44

Interface Design Tips

- Don't provide more than 9 choices, 5 or less is preferred
- Allow chunking to help short-term memory
  - Also, groups, modes (more on this later)
- Use representative icons
- Use visual landmarks