EECS 4441 / CSE 5351
Human-Computer Interaction

Topic #2
The Human

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Topics

- Models of the Human
- Sensors (inputs)
- Responders (outputs)
- The Brain (memory and cognition)
- Human Performance
Topics

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The Model Human Processor

Includes:
• Long-term memory
• Working memory
  • Visual image store
  • Auditory image store
• Cognitive processor
• Perceptual processor
• Motor processor

Newell’s Time Scale of Human Action

<table>
<thead>
<tr>
<th>Scale (sec)</th>
<th>Time Units</th>
<th>System</th>
<th>World (theory)</th>
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</thead>
<tbody>
<tr>
<td>$10^3$</td>
<td>Months</td>
<td>Task</td>
<td>SOCIAL BAND</td>
</tr>
<tr>
<td>$10^2$</td>
<td>Weeks</td>
<td>Task</td>
<td>RATIONAL BAND</td>
</tr>
<tr>
<td>$10^1$</td>
<td>Days</td>
<td>Task</td>
<td>COGNITIVE BAND</td>
</tr>
<tr>
<td>$10^0$</td>
<td>Hours</td>
<td>Task</td>
<td>COGNITIVE BAND</td>
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<tr>
<td>$10^{-1}$</td>
<td>10 min</td>
<td>Unit task</td>
<td>COGNITIVE BAND</td>
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<tr>
<td>$10^{-2}$</td>
<td>Minutes</td>
<td>Operations</td>
<td>BIOLICAL BAND</td>
</tr>
<tr>
<td>$10^{-3}$</td>
<td>10 sec</td>
<td>Deliberate act</td>
<td>BIOLICAL BAND</td>
</tr>
<tr>
<td>$10^{-4}$</td>
<td>10 ms</td>
<td>Neural circuit</td>
<td>BIOLICAL BAND</td>
</tr>
<tr>
<td>$10^{-5}$</td>
<td>1 ms</td>
<td>Neuron</td>
<td>BIOLICAL BAND</td>
</tr>
<tr>
<td>$10^{-6}$</td>
<td>100 µs</td>
<td>Organelle</td>
<td>BIOLICAL BAND</td>
</tr>
</tbody>
</table>


Descriptive Models

- Newell’s Time Scale of Human Action is an example of a *descriptive model*.
- Descriptive models are common in HCI and other fields; they…
  - Delineate or partition a problem space
  - Are “tools for thinking”
- The next slide shows another descriptive model: the Frame Model of Visual Attention

Frame Model of Visual Attention

Point Frame – requires the greatest demand in visual attention. Interactions in the point frame demand a high degree of accuracy and, consequently, require sharp central vision (aka foveal vision). Examples are tasks such as selecting a thin line or very small target, such as a pixel.

Target Frame – below the point frame. Interactions involve selecting targets such as icons, toolbar buttons, or keys on a soft keyboard. Visual attention involving foveal vision is still needed, but with less demand than in the point frame. The targets are larger and, hence, require less precision and attention.

Surface Frame – applies to flicks, pinches, and most gestures on touchscreen devices. The user only needs to have a general spatial sense of the surface on which gestures are made. The visual demand is minimal; peripheral vision is sufficient.

Environment Frame – requires the least demand in visual attention. The frame of reference encompasses the user, the device, and the surroundings. Visual demand is low, and requires only peripheral vision. Some accelerometer or camera interactions apply to the environment frame.

Human Factors Model (1)


Human Factors Model (2)

Topics

• Model of human in interactive systems
  • Sensors (inputs)
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  • Human Performance

The Five Senses

• Sight (vision)
• Hearing (audition)
• Touch (tactition)
• Taste (gustation)
• Smell (olfaction)
Sight (Vision)

The Eye – Physical Reception

- Mechanism for receiving light and transforming it into electrical energy
- Images are focused upside-down on the retina
- Retina contains rods for low light vision and cones for colour vision
- Fovea – area in retina for sharp central vision
Visible Light (the electromagnetic band)

Interpreting the Signal (1)

- Size and depth
  - Visual angle indicates how much of a view an object occupies (relates to size and distance from eye)
  - Visual acuity is ability to perceive detail (limited)
  - Familiar objects perceived as constant size, in spite of changes in visual angle when far away (e.g., at night, headlight spacing infers distance of car, based on “perceived size of a car”)
  - Cues like overlapping help perception of size and depth
Interpreting the Signal (2)

- Brightness
  - Subjects react to levels of light
  - Affected by luminance of object
  - Measured by just noticeable difference (jnd)
  - Visual acuity increases with luminance, as does flicker

- Colour
  - Made up of hue, intensity, and saturation
  - Cones sensitive to colour wavelengths
  - Blue acuity is lowest
  - ~8% males, ~1% females are colour blind

Test for Colour Blindness

- What do you see?

- From…
Interpreting the Signal (3)

• The visual system compensates for
  • Movement
  • Changes in luminance
• Context resolves ambiguity
  • E.g., reading road signs or reading text with parts missing

Visual Ambiguity

Necker Cube  Rubin Vase
Visual Illusion

• Sometimes occurs due to over compensation

![Ponzo Illusion](image1)

![Escher’s Staircase](image2)

![Müller-Lyer Arrows](image3)

Reading

• Several stages:
  • Visual pattern perceived
  • Decoded using internal presentation
  • Interpreted using knowledge of syntax, semantics, pragmatics
• Reading involves saccades and fixations of the eye
• Perception occurs during fixations
• Word shape is important to recognition
• Negative contrast (dark characters on a light display) improves reading from computer screen
Eye Dominance

- Are you left handed or right handed?
  - (more later)

- Are you left eyed or right eyed?
  1. Find a spot on a wall opposite to you (e.g., a light switch)
  2. Get a CD and hold it at arms length
  3. Move the CD in front of the spot and fixate on the spot through the hole
  4. Now close one eye then the other to determine which eye you were using for step 3. That’s your dominant eye!

References


Hearing (Audition)
Hearing (Audition)

- Hearing is the detection of sound
- Sound is transmitted in the environment as waves (cyclic fluctuations of pressure in a medium, such as air)
- Sound waves are created when physical objects are moved or vibrated, thus creating fluctuations in air pressure
- Examples
  - Plucking a string on a guitar, slamming a door, shuffling cards, a human speaking, clicking a button

Sound Characteristics

1. Pitch – sound frequency (in Hertz)
2. Loudness – amplitude or intensity (in dB or deciBells)
3. Timbre – type, quality, or harmonic structure
4. Attack (aka envelope) – the build-up over time of harmonics
Pitch

- Humans hear frequencies from ~20 Hz to ~15 kHz
Hearing + Perception

- Provides auditory information about environment
  - Distance, direction, type of object, quality, familiarity, etc.

Auditory Illusions (Perception)

- Sheppard scale

![Figure 1](./image1.png)  ![Figure 2](./image2.png)

Demo
Touch (Tactition)

- Tactile = “the sense of touch”
- Provides important feedback about environment
- Particularly important for the visually impaired
- Stimulus received via receptors in the skin:
  - Thermoreceptors (heat and cold)
  - Nociceptors (pain)
  - Mechanoreceptors (pressure)
- Some areas more sensitive than others; e.g., fingers
- Kinesthesia
  - Awareness of body position
  - Affects comfort and performance
Importance of Tactile Feedback

- Tend to assume (e.g., physical keys and keyboards)
- When missing, problems arise
- Alternative feedback; e.g.,

![Visual feedback](image1)

![Auditory & vibrotactile feedback](image2)

Click for demo

Designers Unleashed (beware)

- Touchpad – sleek, but no tactile feedback for edges
- Users revolt (duct tape to the rescue!)
Smell (Olfaction) and Taste (Gustation)

Smell and Taste

• Smell (olfaction) – the ability to perceive odors
• Taste (gustation) – the chemical reception of sweet, salty, bitter, and sour sensations
Smell in Motion Pictures (1)

- Smell-o-vision
- Used in *Scent of Mystery* (1960)

Smell in Motion Pictures (2)

- Odorama (scratch and sniff cards)
- Used in *Polyester* (1981)
Smell in HCI

• Tagging images with smell


Other “Senses”

• Sense of urgency
• Sense of direction
• Sense of balance
• Sense of timing
• Musical sense
• Intuitive sense
• Moral sense
• etc.
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Limbs
Hand Dominance

• Are you left-handed or right-handed?
• Is hand dominance an either-or condition? (no)
• Level of hand dominance assessed using the Edinburgh Handedness Inventory\(^1\) (next slide)

Voice

• Yes, the voice is a “responder”
• Vocalized sounds by exhaling air through the larynx
• Speech (with automatic recognition)
  • Works best with…
    1. Limited vocabulary
    2. Speaker dependence
    3. Discrete words
• Non-speech
  • Acoustic parameters of the sound signal (pitch, volume, timbre, etc.) measured over time
  • Data stream interpreted as an input channel
  • Particularly useful to specify analog parameters
    • “volume up, aahh” (volume increases while aahh sustained)

CHANTI1 and NVVI

• Text input method using 5 “keys” (ambiguous keyboard)
• CHANTI = voCally enHanced Ambiguous Non-standard Text-Input
• NVVI = non-verbal voice interaction
• 5 sounds → 5 “keys” (4 sets, user selectable)

The Eye

• Yes, the eyes are also “responders”
• Eye tracking (next three slides)

Eye Tracking (for computer control)


Eye Tracking Model

Human

Interface

Computer

Sensory Stimuli

Displays

Motor Responses

Controls


Face Tracking

Note: The Jellyfish is moved horizontally either by device tilt or by face tracking

Other Responders

- Facial expressions
- Body movement
- Tongue
- Breath
- etc.

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Memory

- There are three types of memory, by function:

Sensory memories

- Short-term memory or working memory

- Long-term memory

Sensory Memory

- Buffers in memory for stimuli received through senses
- Buffer types
  - Iconic (for visual stimuli)
  - Echoic (for aural stimuli)
  - Haptic (for tactile stimuli)
- Examples
  - “Sparkler” trail
  - Stereo sound
  - Continuously overwritten
Short-term Memory (STM)

- Scratch-pad for temporary recall
  - Rapid access $\sim 70$ ms
  - Rapid decay $\sim 200$ ms
- Limited capacity
  - Miller’s $7 \pm 2$ chunks
  - “chunking” helps

Magical Number 7 ± 2

- Can you remember the following digit sequences

```
7 4 9 2
3 0 5 8 2
9 3 7 1 4 6
3 6 5 0 7 2 4
2 1 9 7 8 5 4 3
3 7 5 6 2 5 4 5 0
3 5 2 7 0 8 9 3 2 5
0 8 7 3 9 1 2 3 5 1 6
3 5 2 4 9 0 6 5 8 2 0 4
7 5 3 9 1 8 4 5 1 3 4 3 0
```

Results

![Memory Limit Experiment Graph]

Chunking

416736210040631
416 736 2100 40631

HEC ATR ANU PTH ETR EET

? Move last character to front

THE CAT RAN UP THE TREE
Blackjack (aka 21)

Another card? (dealer has 18)
(What cards have already been dealt?)

Long-term Memory (LTM)

• Repository for all our knowledge
  • Slow access: ~ 1/10 second
  • Slow decay, if any
  • Huge or unlimited capacity
• Two types
  • Episodic
    • Serial memory of events
  • Semantic
    • Structured memory of facts, concepts, skills
    • Semantic LTM derived from episodic LTM
LTM – Retrieval

• Recall
  • Information reproduced from memory
  • Assisted by cues; e.g., categories, imagery
  • UI example: command-line interface
• Recognition
  • Information known to be seen or understood before
  • Less complex than recall, because of visual cues
  • UI example: items in a menu

Recognition vs. Recall

• UI principle: Recognition is better than recall
• Recall example
  • Gee! What’s that command to change my password?
• Recognition example:
  • I’ll look in this menu to see if I can find the command to change my password
HCI Context

- I can’t remember how to…
  - Can you think of examples from your own experience?
  - Can you think of ways to measure or quantify this?
  - Can you think of a research project on, say, *retention of skill*?

For an example of HCI research involving memory of an interaction technique, see

http://www.yorku.ca/mack/GI97a.html

Cognition (Thinking)

- Reasoning
  - Deduction, induction, abduction
- Problem solving
  - Models, issues
Deductive Reasoning

• Definition:
  • Derive logical conclusion from premises
  • E.g., If it is Friday, then she will go to work.
    It is Friday.
    Therefore, she will go to work.

Inductive Reasoning

• Definition:
  • Generalize from cases seen to cases unseen
  • E.g., All elephants we have seen have trunks.
    Therefore all elephants have trunks.
Abductive Reasoning

- Definition:
  - Reasoning from event to cause
  - E.g., Sam drives fast when drunk. If I see Sam driving fast, assume drunk.

Problem Solving

- Process of finding a solution to an unfamiliar task using knowledge
- Many theories, for example
- Gestalt $\rightarrow$ tendency of the brain to form whole forms from self-organizing tendencies. Involves two component processes...
  - Production $\rightarrow$ drawing on insight and restructuring of problem
  - Reproduction $\rightarrow$ drawing on previous experience
Problem Solving (continued)

- Process of finding a solution to an unfamiliar task using knowledge
- Analogy
  - Analogical mapping
    - Novel problems in new domains
    - Use knowledge of similar problem from similar domain
    - Analogue mapping difficult if domains are semantically different
- Skill acquisition
  - Skilled activity characterized by chunking
    - Lot of information is chunked to optimize STM
    - Conceptual rather than superficial grouping of problems

For an example of HCI research using analogy or metaphor, see http://www.yorku.ca/mack/IJHCS.html

Errors and Mental Models

- Types of errors
  - Slips
    - Right intention, but failed to do it right
    - Causes: poor physical skill, inattention, etc.
    - Change to aspect of skilled behaviour can cause slip
  - Mistake
    - Wrong intention
    - Cause: incorrect understanding
      - Humans create mental models to explain behaviour, if wrong
        (different from actual system errors can occur)
Language

“Humankind is defined by language; but civilization is defined by writing.” ¹

• Speech → learned naturally by all humans
• Writing → learned with great difficulty
• Language includes…
  • Redundancy (what we inherently know)
  • Entropy (what we don’t know)
  • (Note: entropy = information)
• HCI Context – text entry (primarily)


Redundancy in English Text

• We can infer meaning from text, even if parts are missing
• Demo:

![Image of text manipulation demonstration]
Entropy in English Text

- Read API (*Entropy.html*)
- Demo

```java
PROMPT>java Entropy dl-letterfreq.txt 27 0
Entropy = 4.0810 bits

PROMPT>java Entropy dl-digamfreq.txt 27 1
Entropy = 3.2876 bits

PROMPT>java Entropy dl-trigramfreq.txt 27 2
Entropy = 2.3452 bits

PROMPT>java Entropy dl-quadgramfreq.txt 27 3
Entropy = 1.5050 bits
```

Note:
\[ \log_2(27) = 4.75 \]

Files: `d1-letterfreq.txt` | `coins.txt` | `coins2.txt`

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Shannon’s Letter-guessing Experiment

- Instructions:
  - Top line: hidden initially
  - Participant guesses letters one at a time
  - Top line revealed letter-by-letter as guessing continues
  - Bottom line: “-” = correct guess, letter = incorrect guess

```
THE ROOM WAS NOT VERY LIGHT
-----ROO------NOT-V-----I---

A SMALL OBLONG READING LAMP ON THE DESK
--SM----OBL--- REA---------O------D---
```

Letter-guessing Experiment Demo

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Human Performance

- Humans differ – we are...
  - young, old, male, female, experts, novices, left-handed, right-handed, English-speaking, Chinese-speaking, from the North, from the South, tall, short, strong, weak, fast, slow, able-bodied, disabled, sighted, blind, motivated, lazy, creative, bland, tired, alert, and on and on

- Human performance will vary...
  - From person to person
  - From trial to trial, task to task
  - With amount of practice, etc.

- Human performance is...
  - Speed in doing a task
  - Accuracy in doing a task
  - Other quantifiable properties of human interaction with computing systems

Measuring Human Performance

- External apparatus needed
- Observe and log events and time of events
- Difficult to observe cognitive operations separate from sensory input and response output:
Simple Reaction Time

- Simplest embodiment of human performance
- Time taken to respond to stimulus; e.g.,
  - Sensory stimulus = a light turns on
  - Motor response = a button is pushed
  - (see previous slide)
- Movement time dependent on age, fitness, etc.
- Reaction time dependent on stimulus type:
  - Auditory ~ 150 ms
  - Visual ~ 200 ms
  - Pain ~ 700 ms
Cognitive Operations in Reacting

- Simple reaction
  - Stimulus $\rightarrow$ response
- Physical matching
  - Deduce equivalence, same presentation
- Name matching
  - Deduce equivalence, presentation may vary
- Class matching
  - Deduce membership in a class
- Visual search
  - Locate code in search space

Movement - Fitts’ Law

- A model for rapid-aimed movements

$$ID = \log_2(D/S + 1)$$

$$MT = a + b \cdot ID$$

- where:
  - $ID$ is the Index of Difficulty (bits)
  - $MT$ is movement time (seconds)
  - $D$ is the distance to the target (cm)
  - $S$ is the size of the target (cm)
  - $a$ and $b$ are empirically determined constants
- $MT$ can be reduced using large targets or small distances
Fitts’ Law Demo

prompt>java FittsTaskTwo

Skilled Behaviour

- With practice, performance improves according to the *Power Law of Practice*
Skilled Behaviour: New vs. Current

- A “new” interaction technique may require practice to out-perform a “current” technique

![Graph showing the performance of new vs. current techniques over time.]


Attention, Motivation, Fatigue, etc.

- Performance suffers in the presence of a secondary task
- Performance affected by attention, motivation, fatigue.
- Attention example (click to play video)

[Video link: http://www.youtube.com/watch?v=JG698U2Mvo]
Thank You