Human–Computer Interaction

Physiological Computing

Professor Bilge Mutlu

Today's Agenda

>> Topic overview: *Physiological computing*

>> Discussion: **New format:** *Breakout groups discuss, report back*
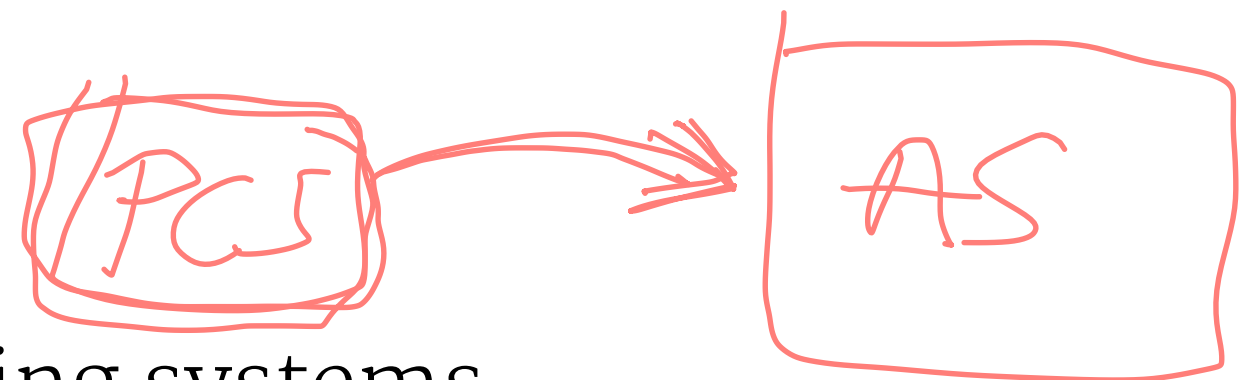
>> Q&A: *Assignment, project next steps & deliverables*

*What is **physiological computing**?*

Definition: physiological computing systems … employ real-time measures of psychophysiology to communicate the psychological state of the user to an adaptive system.[1]

What could the system be communicating?

>> Affective state, e.g., in affective computing systems

>> Cognitive state, e.g., in brain-computer interfaces

>> Physical state, e.g., in prosthetics, driving aids

[1] Fairclough, 2008, Fundamentals of physiological computing

Is physiological computing only about sensing?

The field of ~~affective~~ computing encompasses both the creation of and interaction with machine systems that sense, recognize, respond to, and influence ~~emotions~~.[2]

Systems that…

» Sense ✓

» Recognize ✓

» Respond to ✓

» Influence ✓

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[2] Daily et al., 2017, Affective Computing

A broader definition of physiological computing

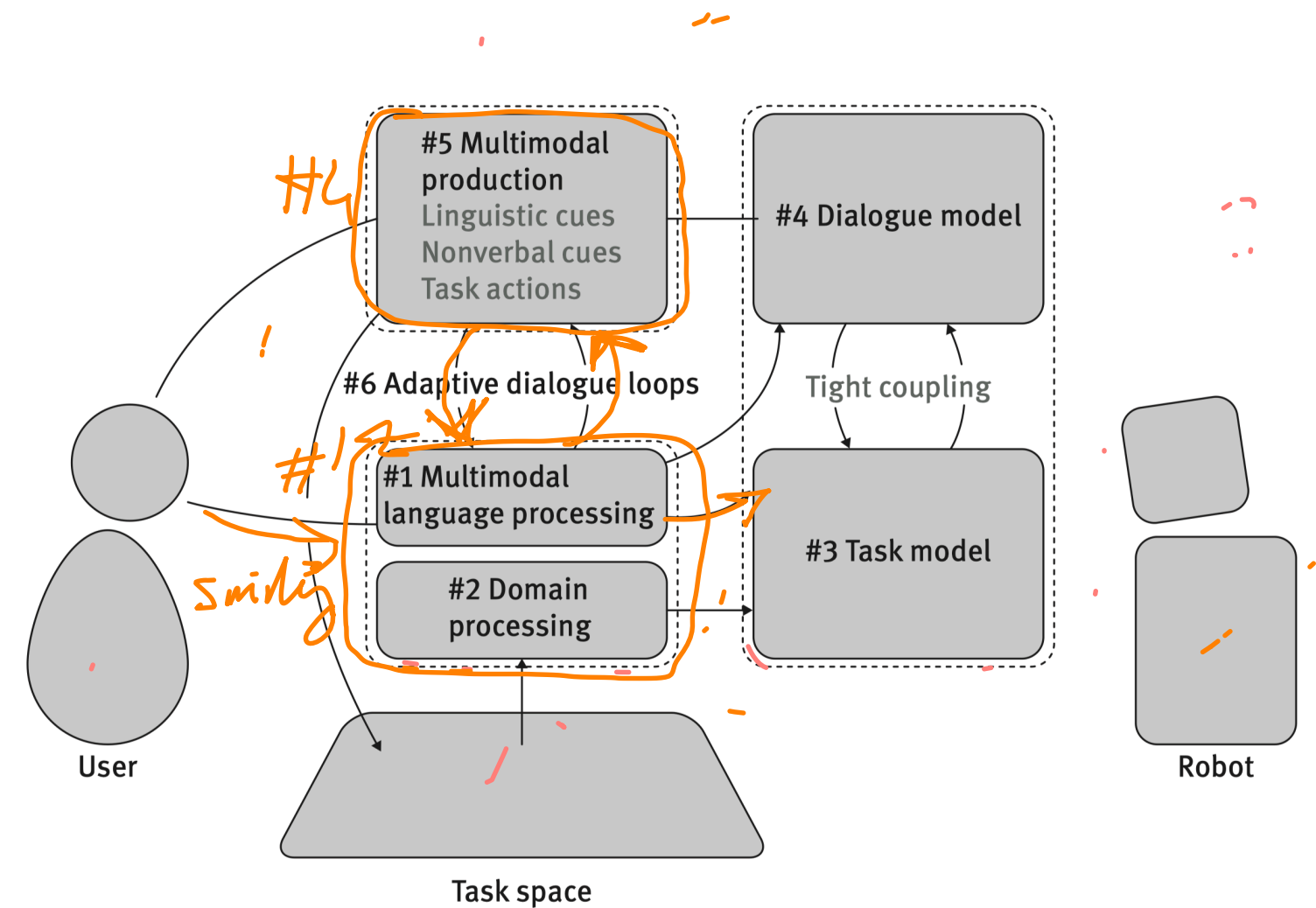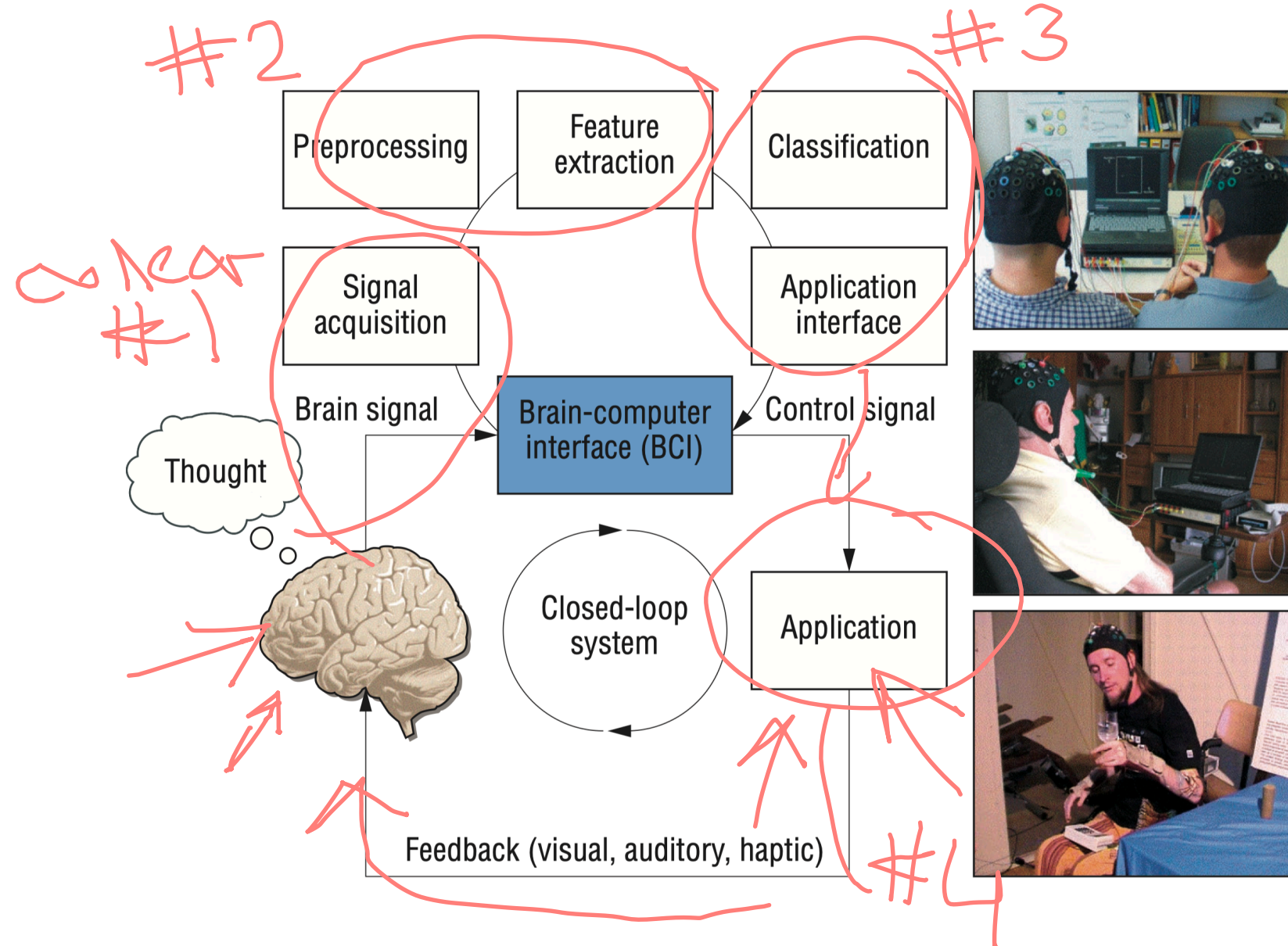Physiological computing enables adaptive systems to sense, recognize, and respond to user affective, cognitive, and cognitive states.

These systems integrate the **biocybernetic loop**:[3]

1. Collect psychophysiological data from users
2. Filtering, quantify data to operationalize psychological constructs
3. Analyze data to quantify or label the state of the user
4. Determine an appropriate response based on the magnitude or label

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[3] Pope et al., 1995, Biocybernetic system evaluates indices of operator engagement in automated task

What do these systems look like?[4] [5]

Preprocessing · Feature extraction · Classification · Signal acquisition · Application interface · Brain signal · Brain-computer interface (BCI) · Control signal · Thought · Closed-loop system · Application · Feedback (visual, auditory, haptic)

#5 Multimodal production — Linguistic cues, Nonverbal cues, Task actions · #4 Dialogue model · #6 Adaptive dialogue loops · Tight coupling · #1 Multimodal language processing · #3 Task model · #2 Domain processing · User · Task space · Robot

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[4] Nijholt et al., 2008, Brain-computer interfacing for intelligent systems

[5] Mutlu et al., 2014, Enabling Human-Robot Dialogue

What are challenges in physiological computing?

1. **Justification:** Applications can be limited, poorly justified[4]

2. **Technology:** Sensors, systems need development, refinement[4]

3. **Inference:** Difficulty of inferring psychological states[1]

4. **Validity:** Content, concurrent validity; reliability [1]

5. **User representation:** Sophisticated, operationalizable, appropriate[1]

6. **Design:** How should adaptivity be conveyed to users?[1]

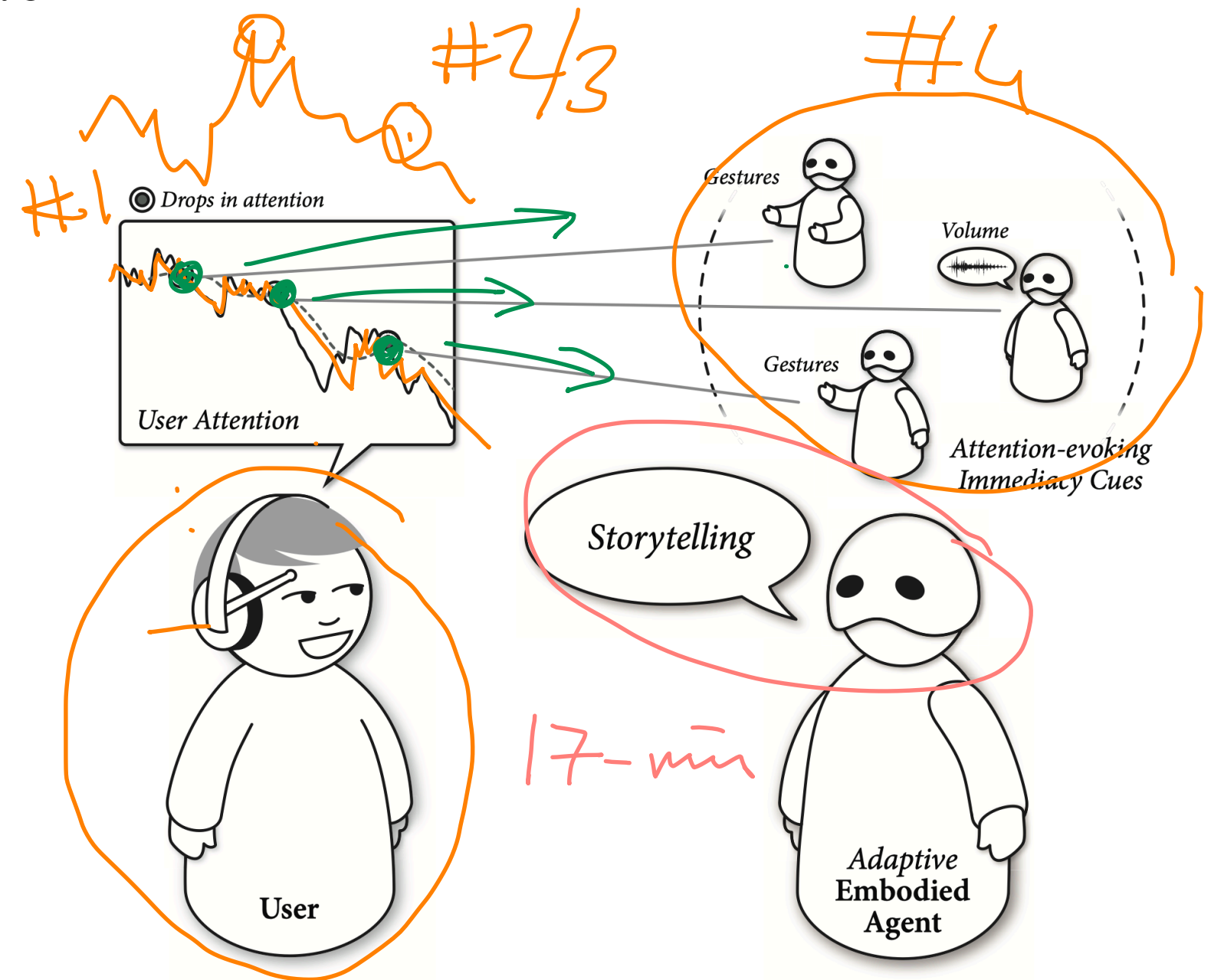7. **Ethical issues:** Privacy, user autonomy, transparency[1]
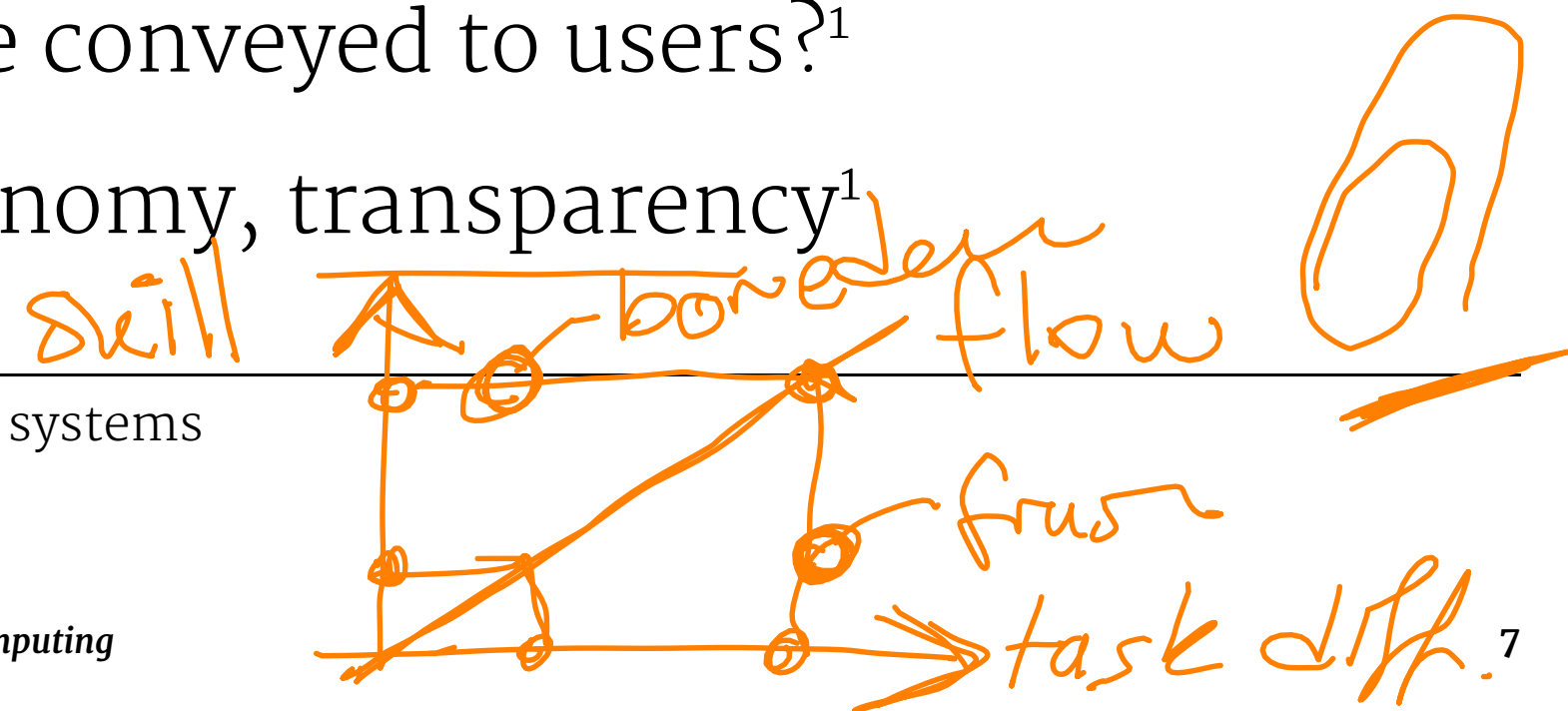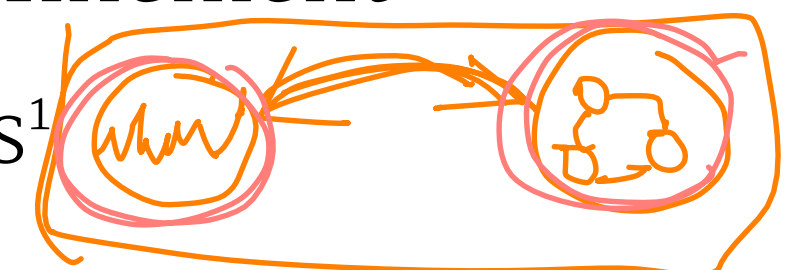
[4] Nijholt et al., 2008, Brain-computer interfacing for intelligent systems

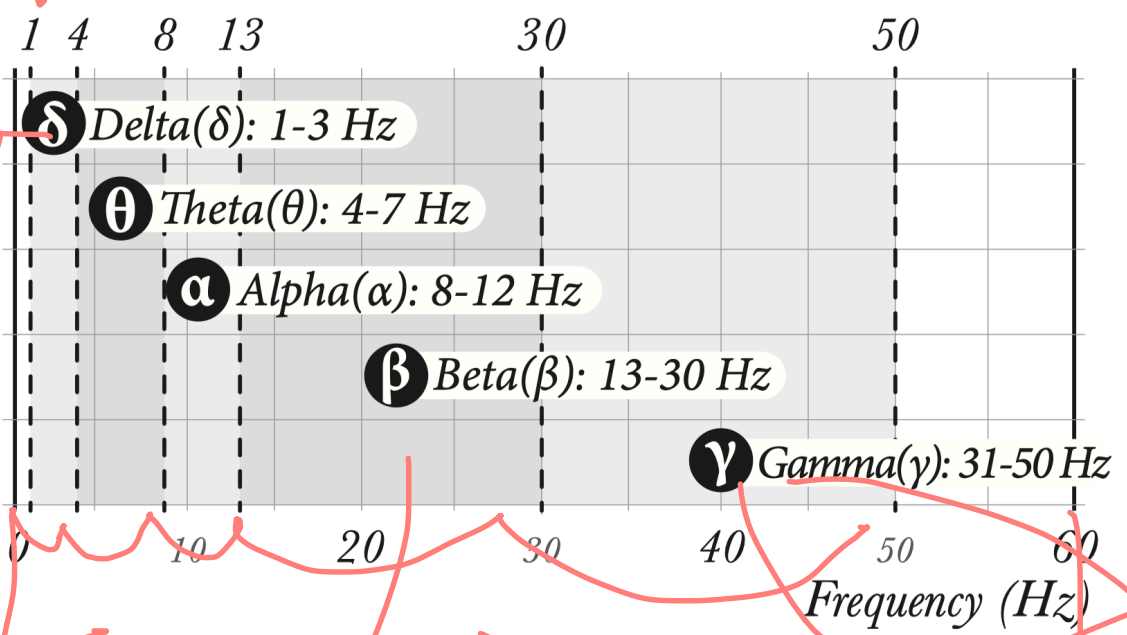[1] Fairclough, 2008, Fundamentals of physiological computing

Physiological Computing System Example[12]

Research Question: How can adaptive agents monitor changes in student *attention* in real time and regain diminished attention?

Drops in attention
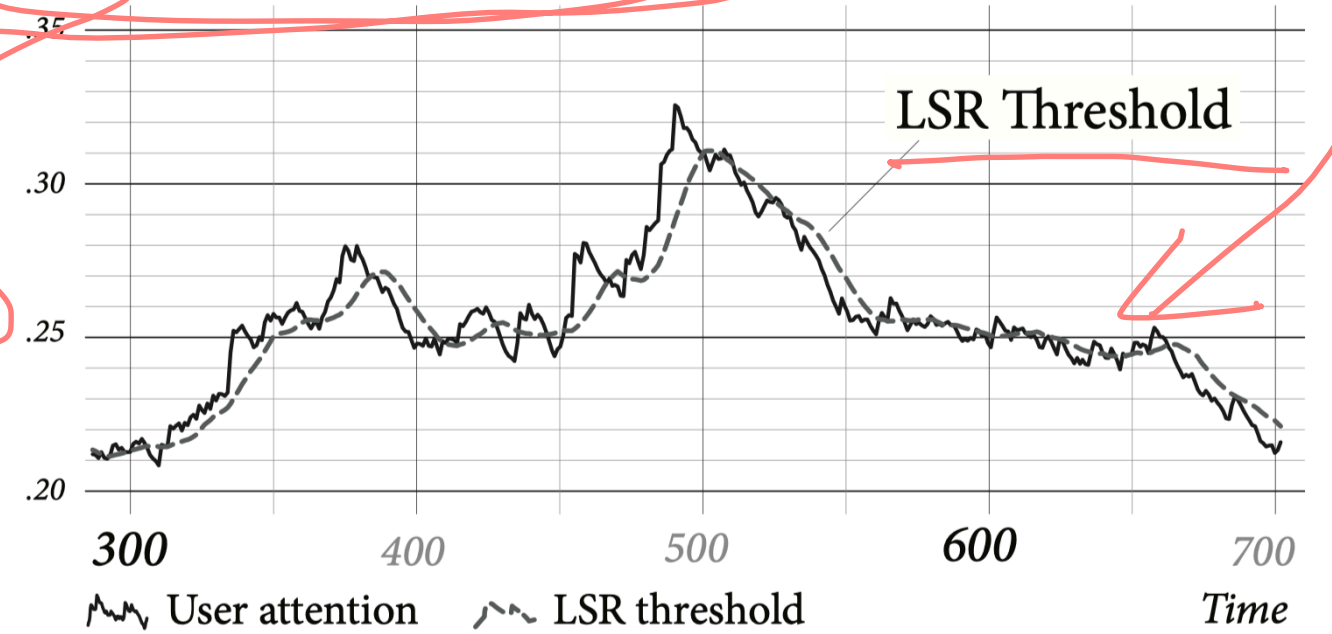
User Attention

Gestures

Volume

Gestures

Attention-evoking
Immediacy Cues

Storytelling

User

Adaptive
Embodied
Agent

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[12] Szafir & Mutlu, 2012, Pay Attention! Designing Adaptive Agents that Monitor and Improve User Engagement

EEG

Delta(δ): 1-3 Hz
Theta(θ): 4-7 Hz
Alpha(α): 8-12 Hz
Beta(β): 13-30 Hz
Gamma(γ): 31-50 Hz

Frequency (Hz)

$$E = \frac{\beta}{(\alpha + \theta)}$$

LSR Threshold

Band	Function	Example activities
Delta	Instinct	Survival, deep sleep, coma, repair, complex problem solving
Theta	Emotion	Drives, feelings, dreams, creativity, insight, deep states
Alpha	Consciousness	Aware of the body, integration of feelings, alert and peaceful, reading, meditation
Beta	Thought	Perception, mental activity, thinking, focusing, sustained attention
Gamma	Will	Extreme focus, energy, ecstasy, learning, cognitive processing

∿ User attention   ∿ LSR threshold   Time

No interventions — Randomly timed interventions — Adaptive interventions

Legend (left panel):
- User attention in Story 1 (baseline)
- User attention in Story 2
- Attention drop threshold
- ● Drops in attention identified by our algorithm

Legend (middle panel):
- User attention in Story 1 (baseline)
- User attention in Story 2
- Attention drop threshold
- ● Drops in attention identified by our algorithm
- ○ Randomly timed attention-evoking interventions

Legend (right panel):
- User attention in Story 1 (baseline)
- User attention in Story 2
- Attention drop threshold
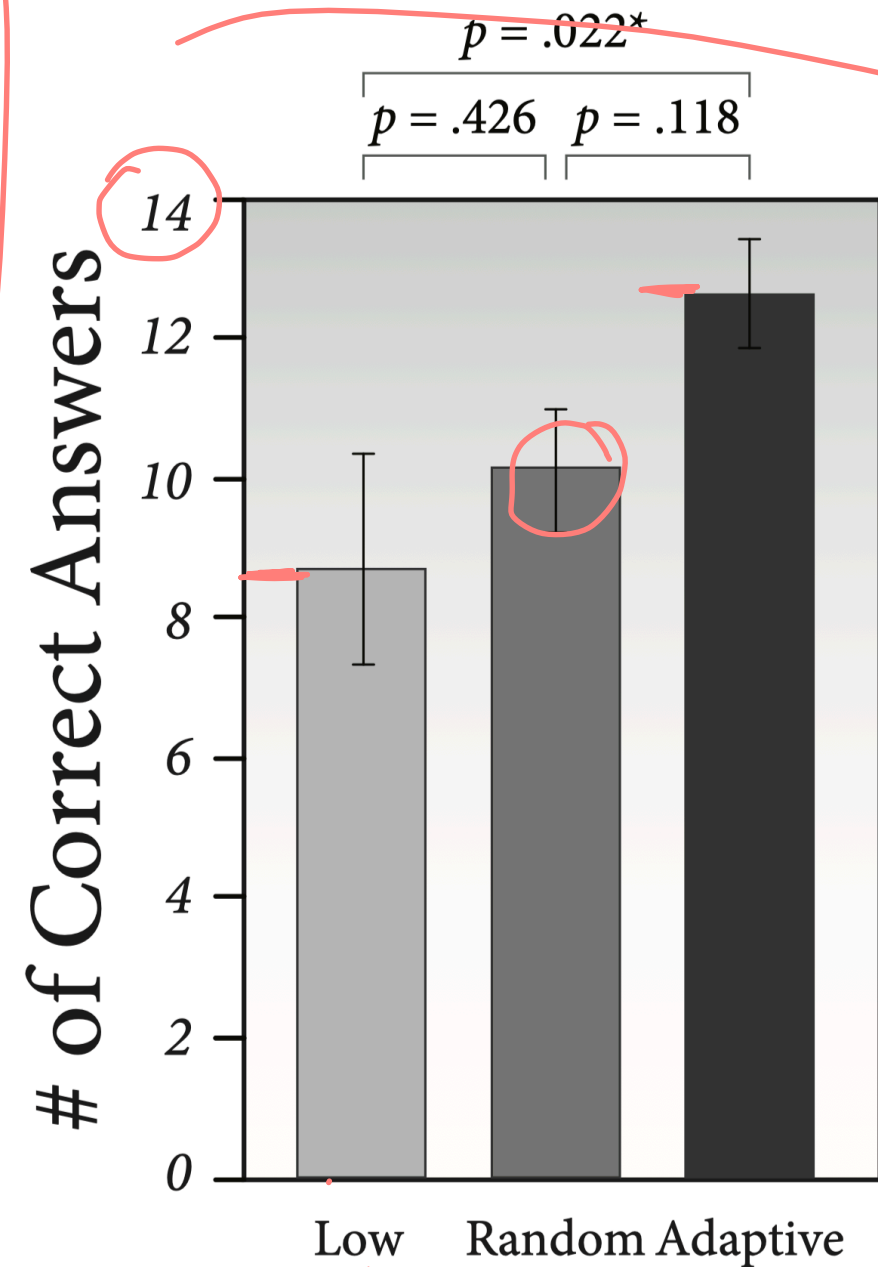- ● Adaptive attention-evoking interventions

Conclusions

1. We can detect loss in attention in real time with a non-invasive method;

2. Lost attention has a negative effect on information recall;

3. By recapturing attention, we can mitigate some of this effect

Discussion Questions

» How do we overcome the challenges in designing physiological computing systems?

» What are application areas where physiological computing is well-justified and promising?

» What physiological computing systems do you use?

» What external resources did you find?