Human-Computer Interaction

Adaptive & Physiological Computing

Professor Bilge Mutlu

Methods Assignment

Assignment key steps:

» Design a survey

» Collect data

» Construct a scale

Some suggestions:

» If your survey is ready, we can collect data in class on Wednesday

» Post your survey on Piazza

Today's Agenda

- Adaptive computing
- Physiological computing
- Physiological/adaptive computing system example
- Group discussion

Adaptive Computing

*What is an **adaptive system**?*

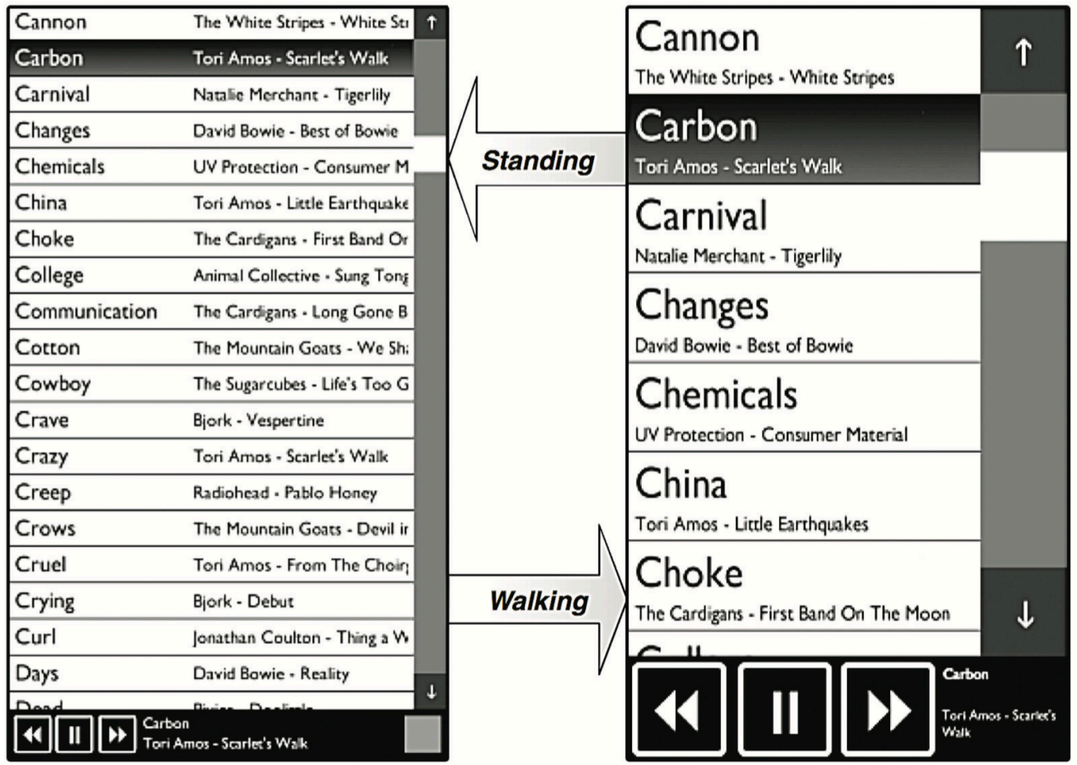
- **Personalization** — Systems tailoring their capabilities or how these capabilities are accessed to the needs, abilities, and preferences of their users.
  - **Example:** A movie streaming service recommending movies a user likes.
- **Adaptation** — Systems dynamically changing components based on user states to maximize accessibility, usability, and/or effectiveness of the system.
  - **Example:** A movie streaming system adjusting volume and screen brightness based on the noise and illumination of the environment.
- **Customization** — Enabling users to choosing what system capabilities to use and how to use them.
  - **Example:** A movie streaming service enabling users to limit recommendations only to movies rated "G."

What are we adapting to?[7]

» Persistent factors (e.g., impairments)

» Near-persistent factors (e.g., user preferences, user needs)

» Situational factors (e.g., user states [e.g., user attention]; situational impairments [e.g., walking vs. sitting])



[7] Gajos et al. (2012). Personalized dynamic accessibility. *Interactions.*

What does this mean for system design?

» Personalization → systems must match persistent user needs, preferences, abilities

» Adaptation → systems must match situational user needs, preferences, abilities

» Customization → systems must allow users to pick and choose what and how of capabilities

How do we adapt to user states?

General approaches include:

» Dynamically prioritizing access to frequently used features

» Offering feature sets grouped under user or task profiles

» Generating interface features to match user abilities

» Switching representations based on situational needs

» Model-based real-time adaptation to user intent

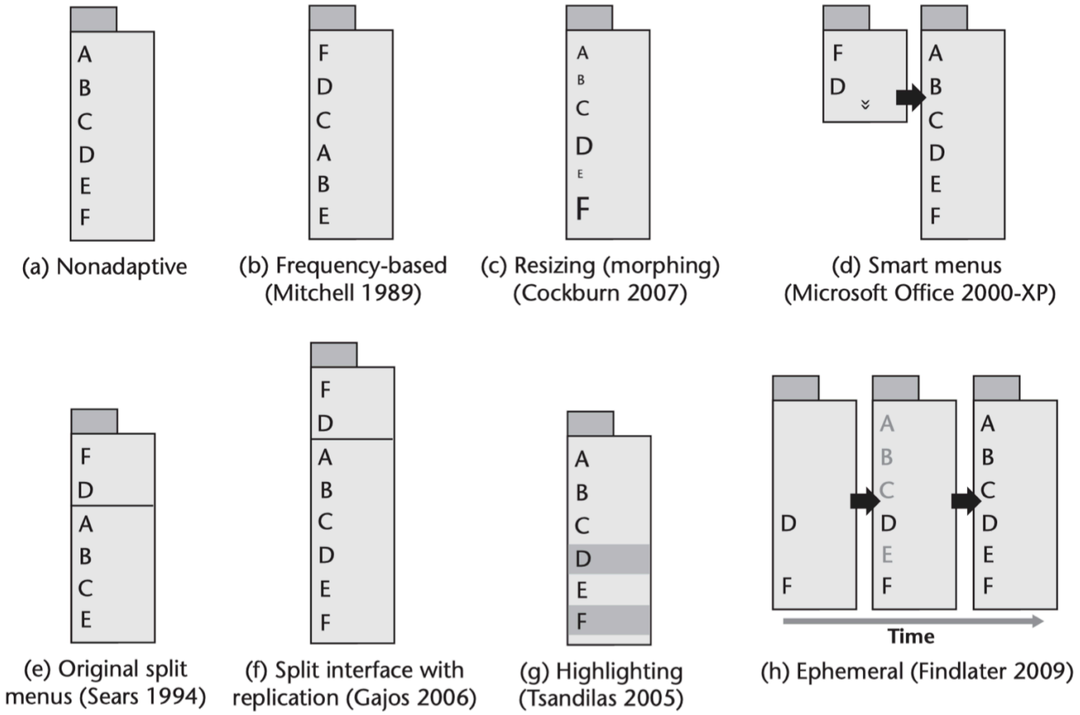
» Real-time adaptation to user states

» And others…

Adaptive approaches: Dynamic Prioritization[8]

Dynamically prioritizing access to frequently used feature

Example: Menu item displays

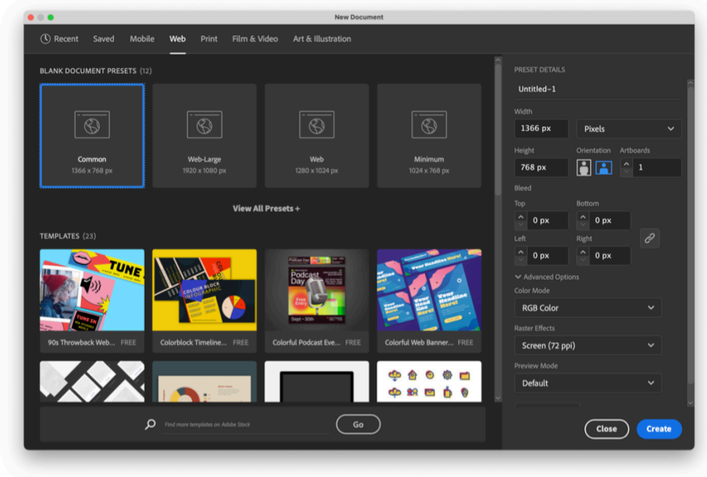


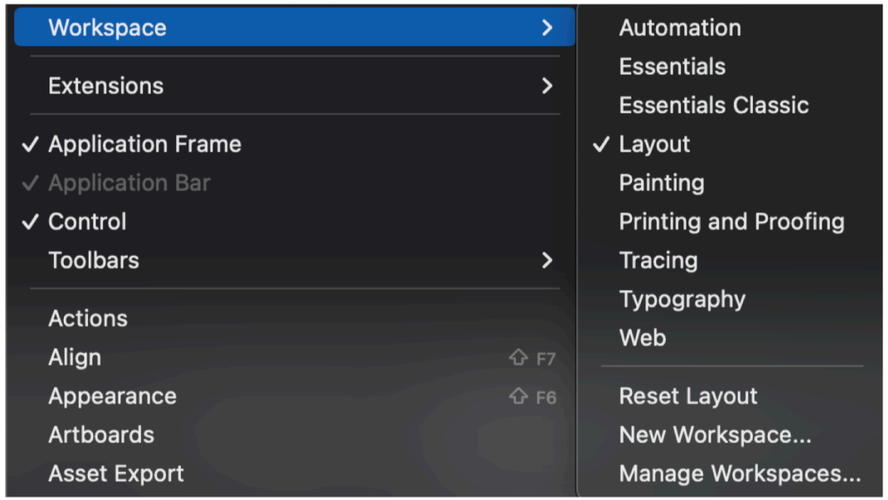
[8] Findlater & Gajos (2009). Design space and evaluation challenges of adaptive graphical user interfaces. *AI Magazine*.

Adaptive approaches: User/task profiles

Offering feature sets grouped under user or task profiles

Example: Adobe Illustrator "New Document" dialog, "Workspace" menu

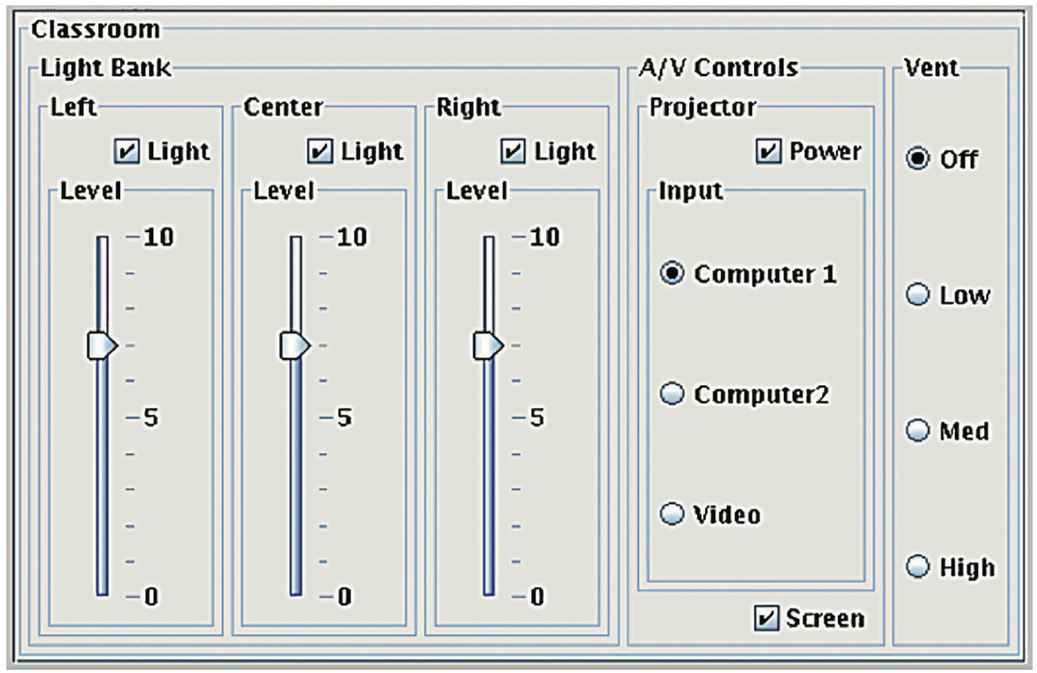


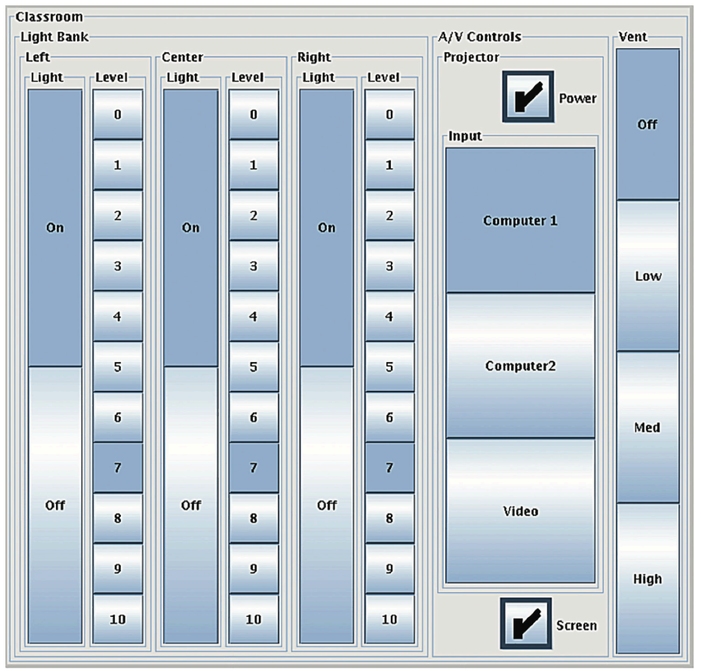


Approaches: Matching User Capabilities[8]

Generating interface features to match user abilities

Example: Adapting interface elements to dexterous abilities





[8] Findlater & Gajos (2009). Design space and evaluation challenges of adaptive graphical user interfaces. *AI Magazine*.

Approaches: Switching Representations[9]

Switching representations based on situational needs

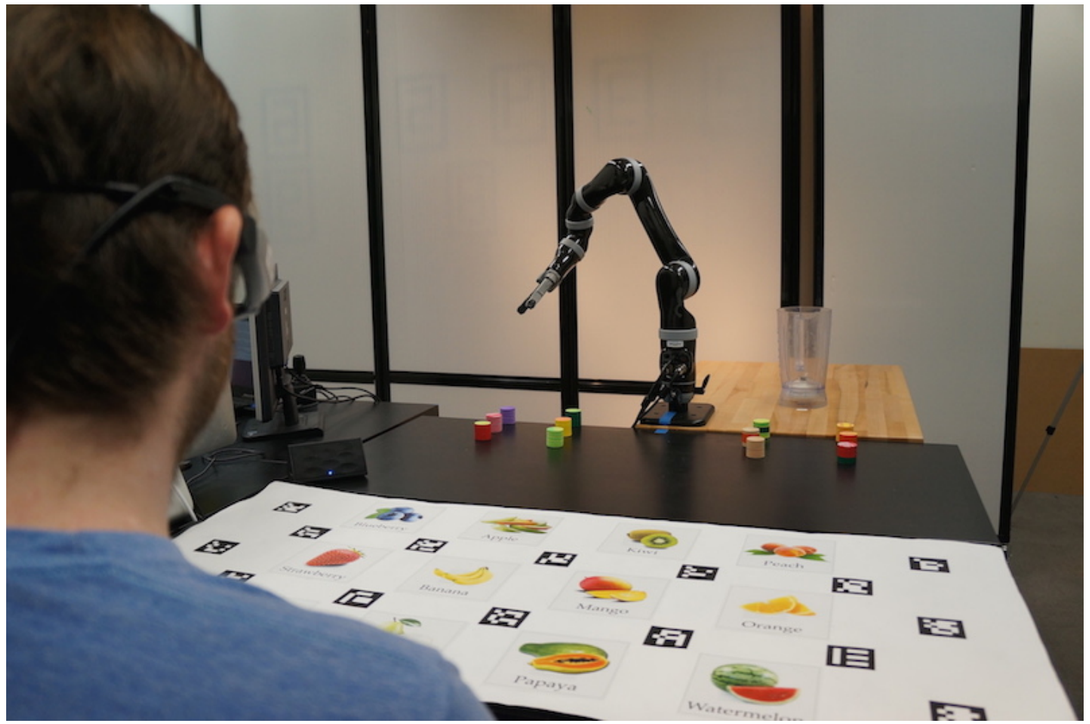
Example: iOS iPhone vs. Carplay interfaces

[9] Image

Approaches: Adapting to User Intent[11]

Model-based adaptation to user intent

Example: Anticipatory robot behavior



[11] Huang, C. M., & Mutlu, B. (2016). Anticipatory robot control for efficient human-robot collaboration. *HRI 2016*.

Approaches: Adapting to User States[10]

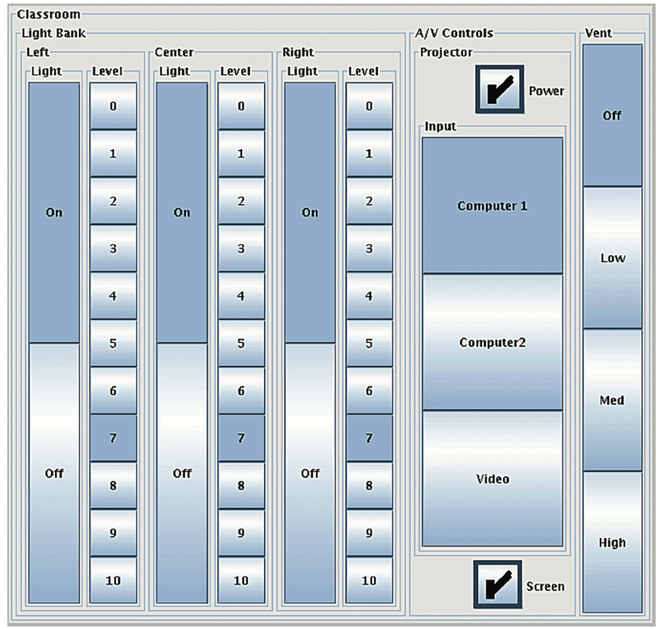
Real-time adaptation to user states (e.g., attention)

Example: Proximity toolkit

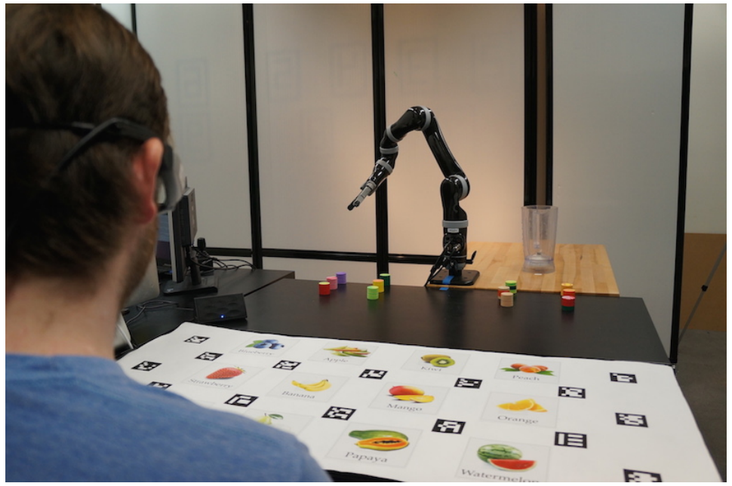
[10] Greenberg et al. (2011). Proxemic interactions: the new ubicomp? *interactions*.

What are common archetypes of adaptive systems?

Design-time adaptation/ personalization
(static, one-time)

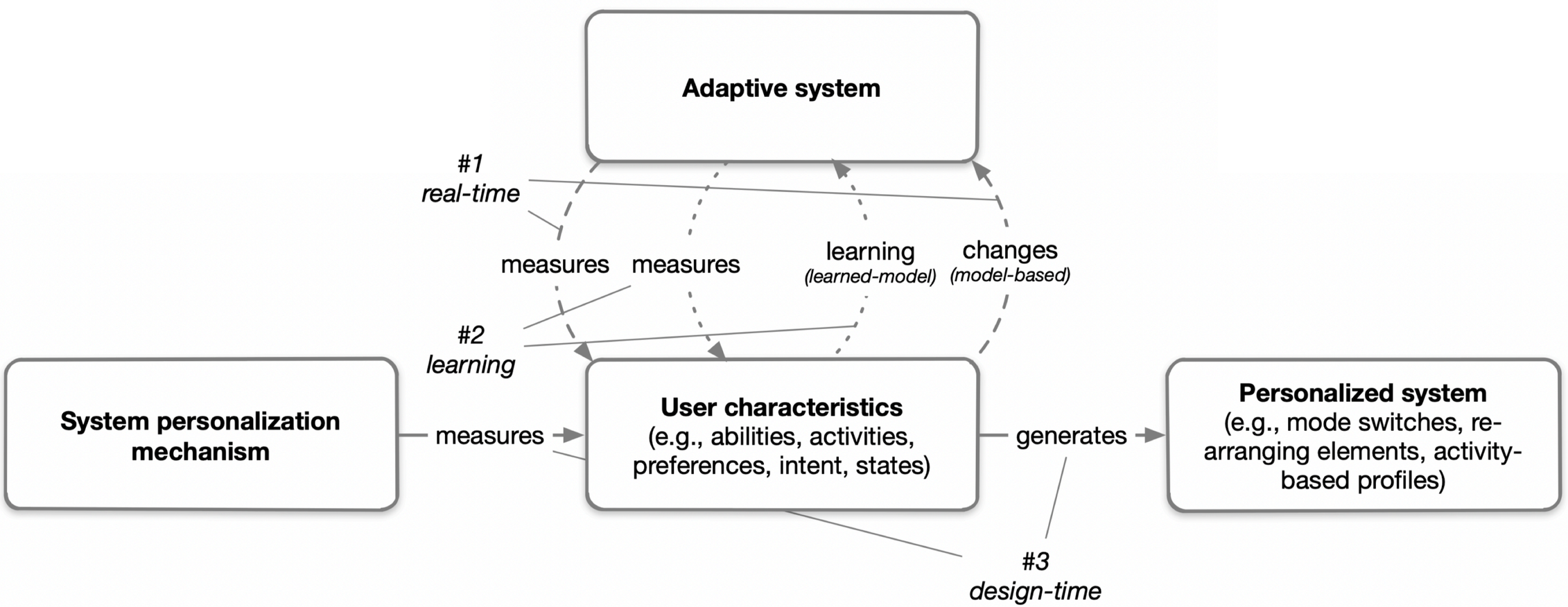


Real-time adaptation
(dynamic, short-term, closed loop)

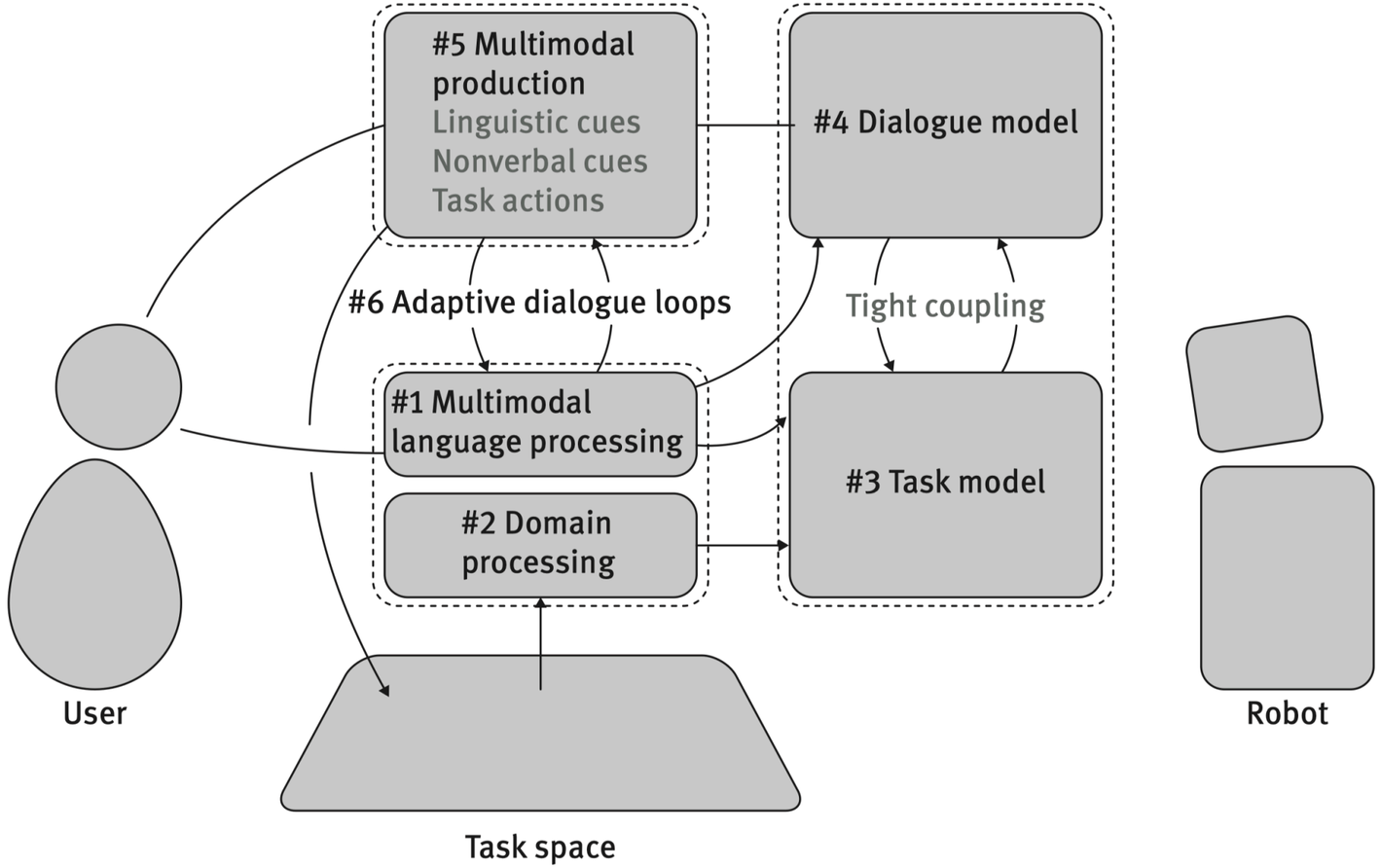


Learning-based adaptation
(dynamic, long-term, open loop)[12]

[12] Spotify image


Adaptive system
#1
real-time
measures
measures
learning
(learned-model)
changes
(model-based)
#2
learning
System personalization mechanism
measures
User characteristics
(e.g., abilities, activities, preferences, intent, states)
generates
Personalized system
(e.g., mode switches, re-arranging elements, activity-based profiles)
#3
design-time

5



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

Physiological Computing

*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

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

A broader definition of physiological computing

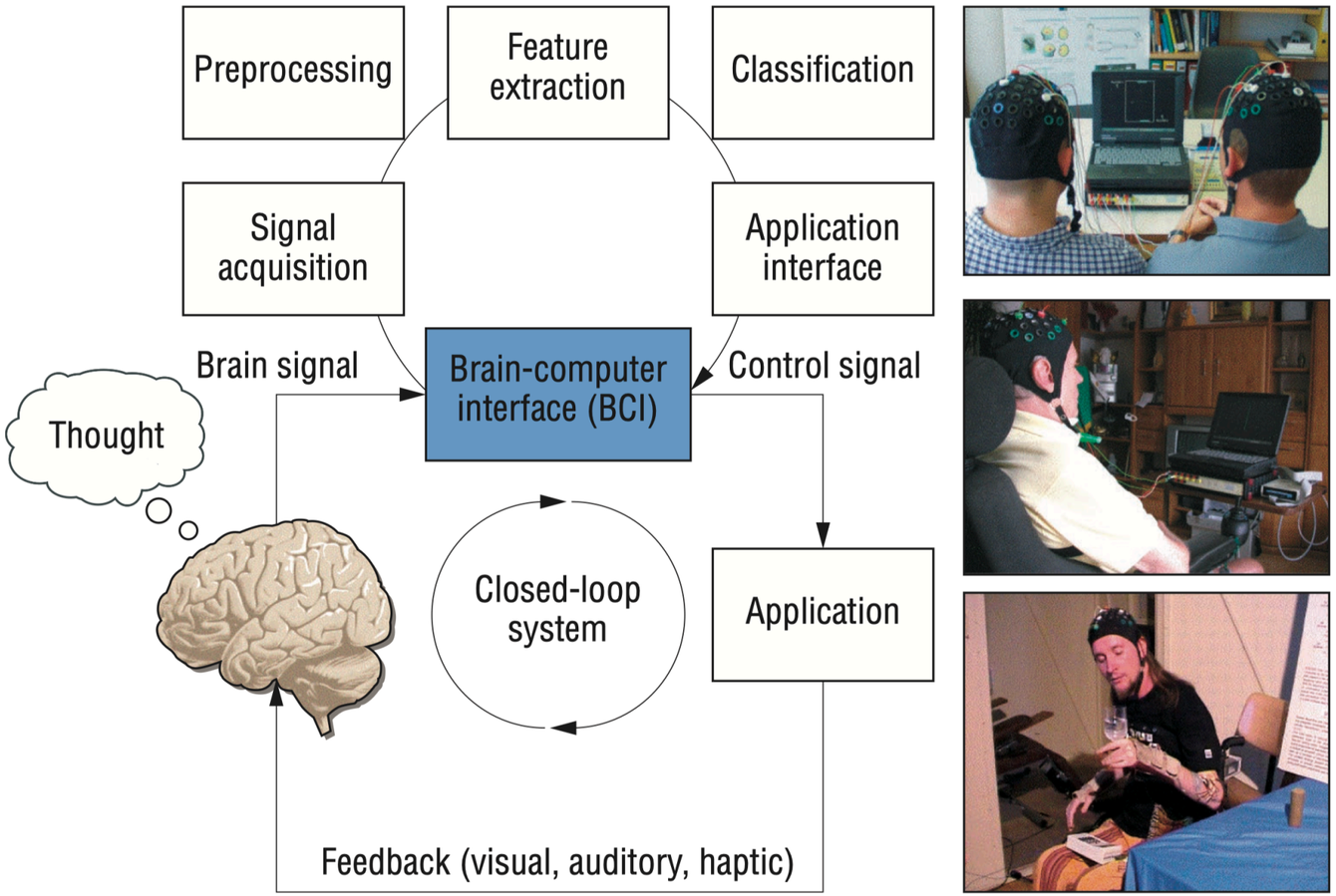
Physiological computing enables adaptive systems to sense, recognize, and respond to user affective, cognitive, and cognitive states.

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

1. Collect psychophysiological data from users
2. Filter, 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

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

4



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

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]

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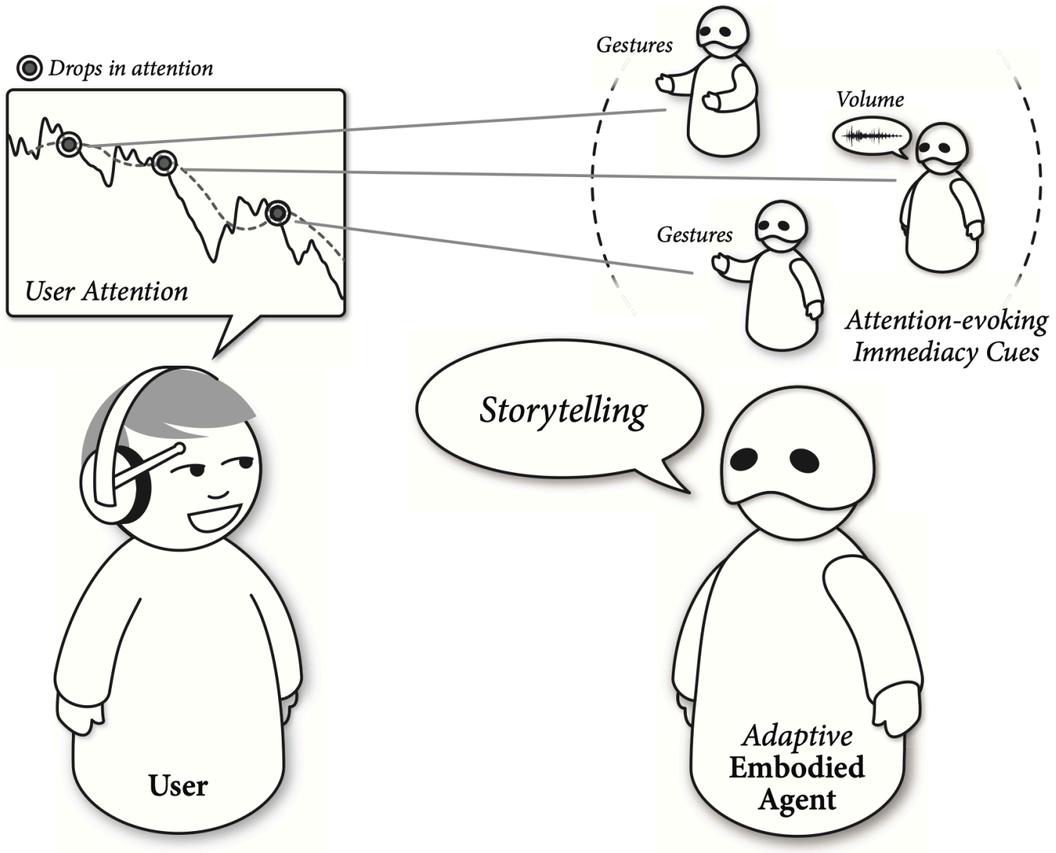
[4] Nijholt et al., 2008, Brain-computer interfacing for intelligent systems

[1] Fairclough, 2008, Fundamentals of physiological computing

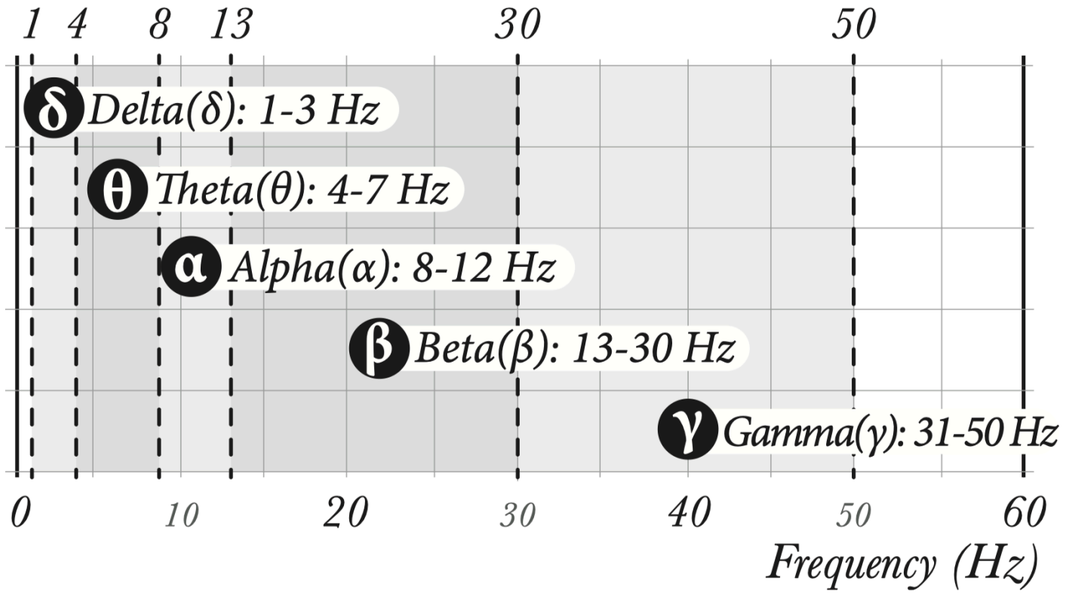
Physiological Computing System Example

Physiological Computing System Example[6]

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

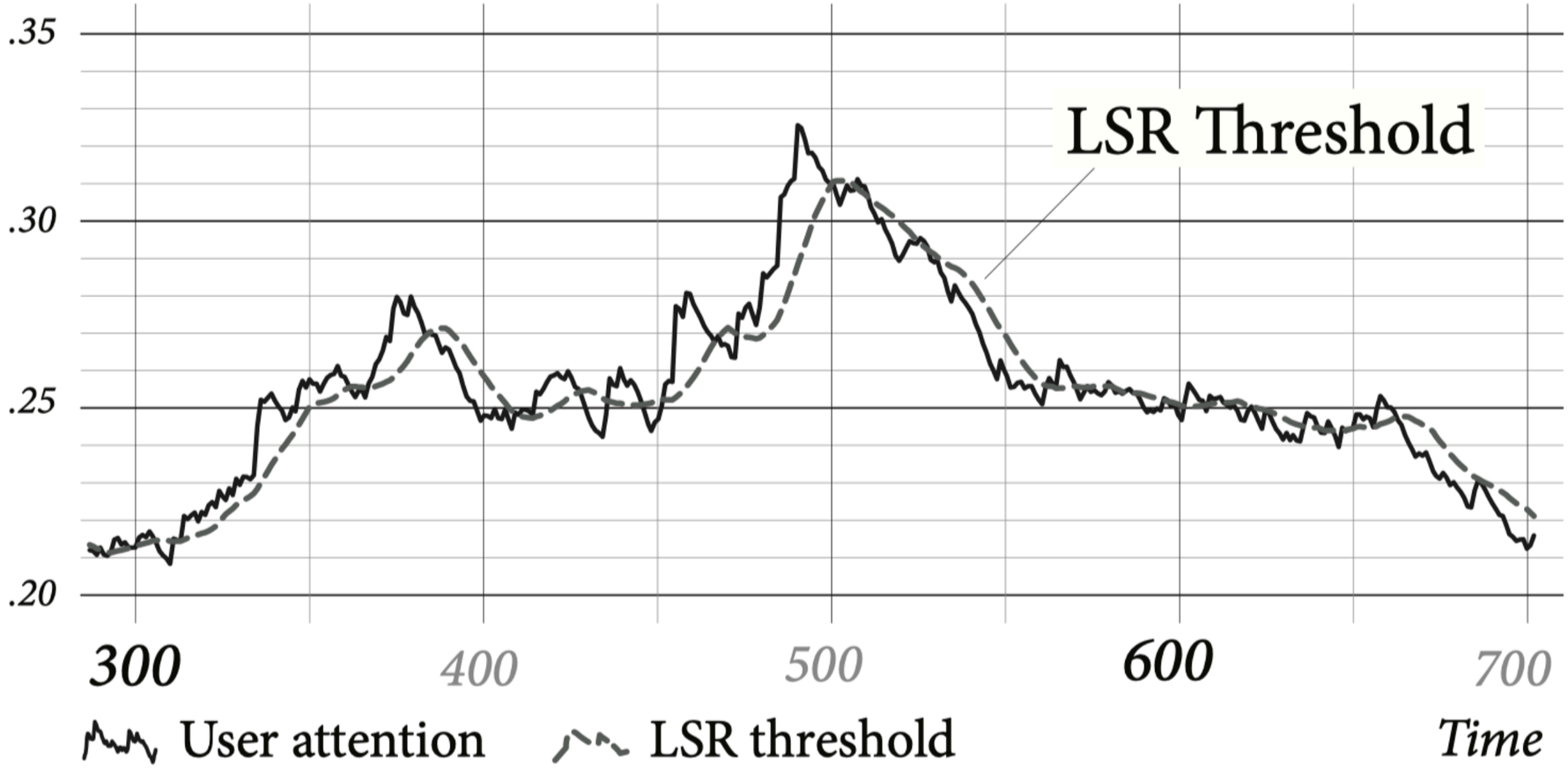


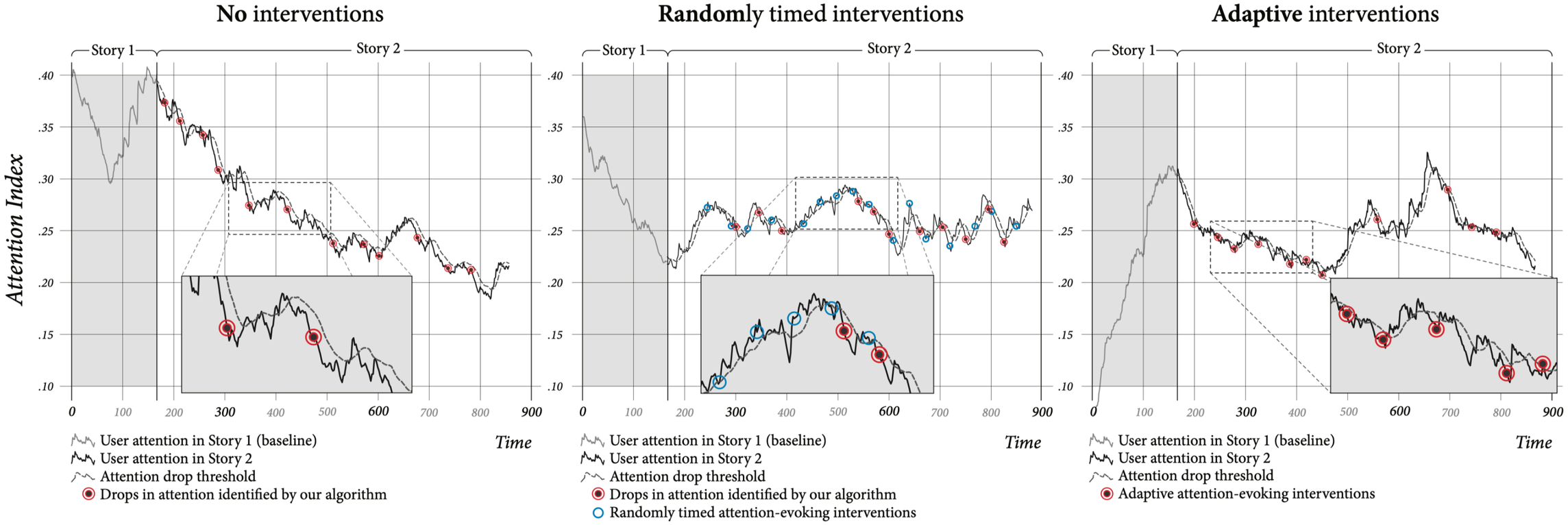
[6] Szafir & Mutlu, 2012, Pay Attention! Designing Adaptive Agents that Monitor and Improve User Engagement



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

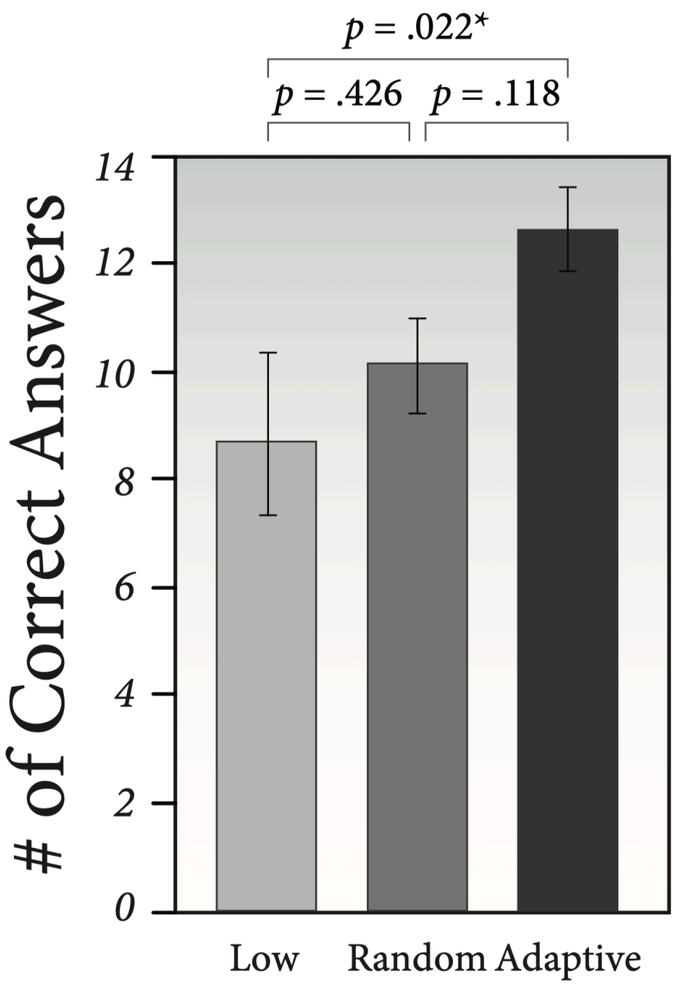
Band	Function	Example activities
Delta	Instinct	Survival, deep sleep, coma, repair, complex problem solving
Theta	Emotion	Drives, feelings, dreams, creativity, insight, deep states
Alpha	Consciousness	Aware of the body, integration of feelings, alert and peaceful, reading, meditation
Beta	Thought	Perception,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


.35
.30
.25
.20
LSR Threshold
300
400
500
600
700
User attention
LSR threshold
Time


No interventions
Randomly timed interventions
Adaptive interventions
Story 1
Story 2
Attention Index
.40
.35
.30
.25
.20
.15
.10
0
100
200
300
400
500
600
700
800
900
Time
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
Adaptive attention-evoking interventions

Summary

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 Format

- We'll let AI randomly pick 3-5 names
- In the selected order, students:
  - Present their provocation/critical artifact/policy or design recommendation (30 secs)
  - Lead class discussion (5-8 min)