A Survey on

User Interface Design in Augmented Reality for Real-Time Tasks

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1. Introduction

- Background
- Motivation
- Challenges

2. User Needs
3. Design Practices
4. Design Framework
5. Future Work

Background

Real-time tasks are common in daily life. They need to be finished under certain time constraints.

Teachers monitor students' progress and give timely feedback in an ongoing class.

Athletes need to predict ball trajectories and hit the ball in a proper position.

Background

The real-time tasks have two features:

- They are urgent and require immediate attention or action.
- Finishing them requires information support from the dynamic and complex physical environments.

It is challenging for people to understand the complex environments, capture critical information and respond in a short time.

Background

Augmented Reality (AR) can alleviate the challenges and has been applied to fields such as medicine and maintenance decades ago.

Background

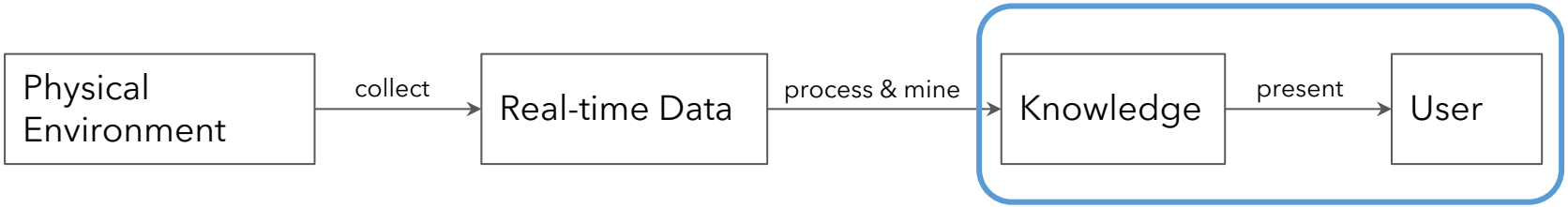
Why can AR facilitate real-time tasks in dynamic environments?

1. AR systems are equipped with cameras and sensors that can
    - enhance human senses and capture key information from the physical environments.
    - reduce explicit manipulations and save time to perform urgent tasks.

2. AR can superimpose information near the corresponding physical objects, which can speed up the process of matching the information to the real world.

Background

Three steps for AR applications to facilitate urgent tasks requiring real-time information support from a dynamic environment.

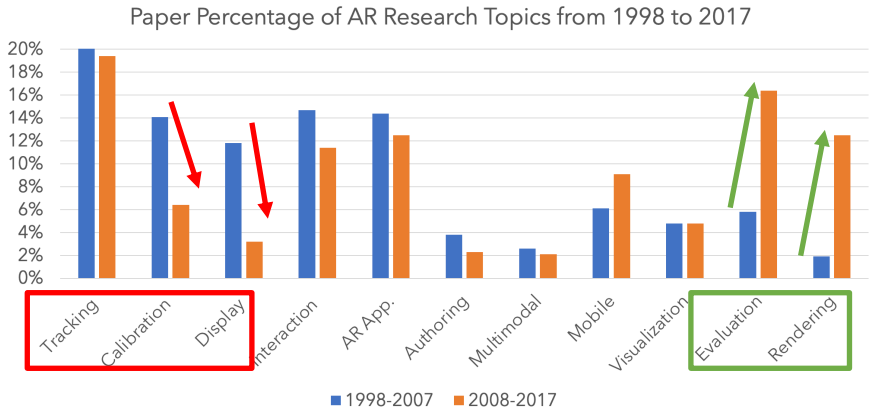


Focus of this survey: the design of effective AR user interfaces to display information properly.

Motivation

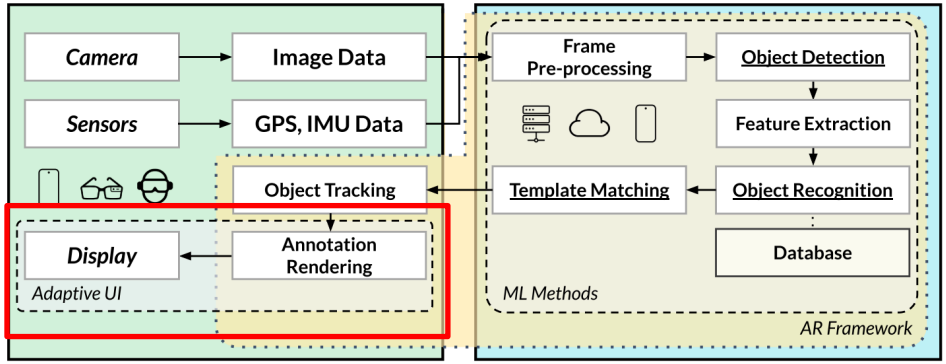
Why focus on AR user interface design for real-time tasks?

1. Researchers are more and more interested in subtopics that are close to real-life and end-users.



(Kim et al., 2018)

2. User interfaces can influence user experiences and the effectiveness of an AR application.



(Cao et al., 2021)

Challenges

The lack of fundamental and intermediate-level design knowledge makes it challenging for novice researchers and designers to design an effective user interface. Many things are unclear:

- **User needs**: when should we use AR?
- **Design dimensions**: what design factors should we consider and what are the possible options for each dimension?
- **Selection criteria**: what are the advantages and disadvantages of each option? How can we make choices among various options?

Scope

- Applications
  - Classroom
  - Sports Training

- Reasons
  - Both contain scenarios where people need to finish real-time tasks under dynamic situations.
  - The user status in the two settings are different, which can give us a better understanding of design practices.

1. Introduction

2. User Needs

- Emotional Needs
- Cognitive Needs
- Social Needs
- Action Needs

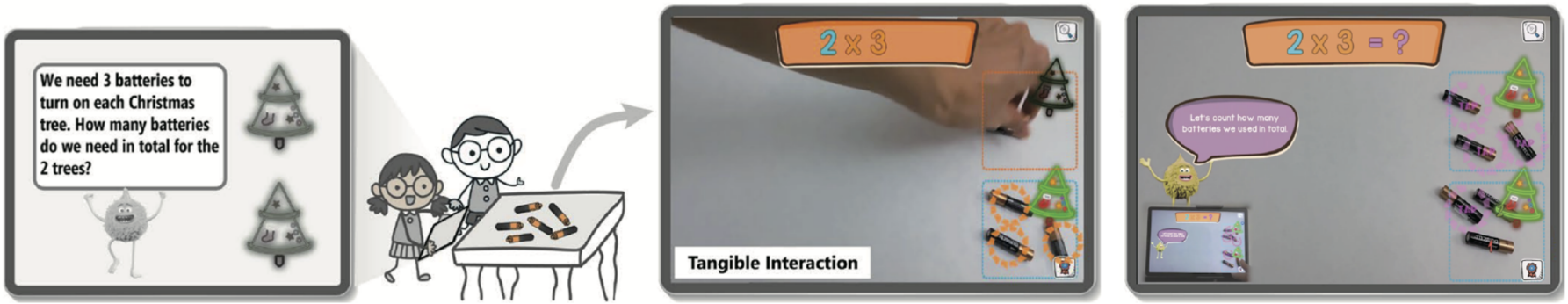
3. Design Practices
4. Design Framework
5. Future Work

User Needs

User Needs		**Papers**
Emotional Needs	Increase Enjoyment and Engagement	(ARMath, Kang et al., 2020), (KickAR, Rogers et al., 2018), (Sports support system, Sano et al., 2016)
	Alleviate Negative Feelings	(Face2Face, Sahin et al., 2018), (AudienceAR, Hartl et al., 2019)
Cognitive Needs	Help be aware of real time invisible process or future events	(Laplacian Vision, Itoh et al., 2016), (Basketball, Lin et al., 2021), (Volleyball, Sato 2018), (Physio@Home, Tang et al., 2015), (SleeveAR, Sousa et al., 2016), (Glassist, Silva et al., 2014), (Lumio, Holstein et al., 2018), (ALF-G, Zarraonandia et al., 2019)
	Help notice physical objects	(Augmented Climbing Wall, Kajastila et al., 2016), (betaCube, 2016)
Social Needs	Help Communication	(StARe, Rivu et al., 2020), (BouldAR, Daiber et al., 2013), (Make it personal, Parmar et al., 2020)
Action Needs	Guide action	(WetLab, Scholl et al., 2016), (LightGuide, Sodhi et al., 2012), (ClimbVis, Kosmalla et al., 2017), (MOSOCO, Escobedo et al., 2012), (Rhema, Tanveer et al., 2015)

User Needs -- Emotional Needs

- Emotional needs are related to users' mental states.
  - Increasing engagement and enjoyment
  - Reducing negative emotions such as anxiety and fear

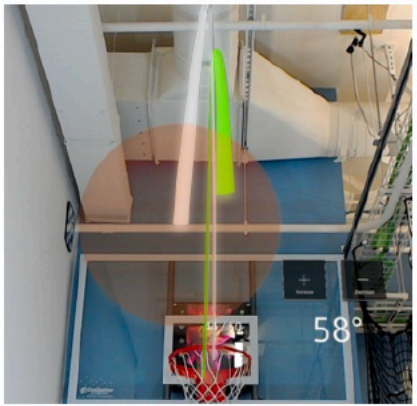


(ARMath, Kang et al., 2020)

User Needs -- Cognitive Needs

Cognitive needs are about enhancing people's perception of the environment and improving their awareness of what is going on.

- Capturing invisible processes
- Noticing important physical objects



(Basketball, Lin et al., 2021)

User Needs -- Action Needs

Social needs are related to improving communication among a group of people.

Action needs are related to giving direct and clear hints to guide users on what to do next.

(MOSOCO, Escobedo et al., 2012)

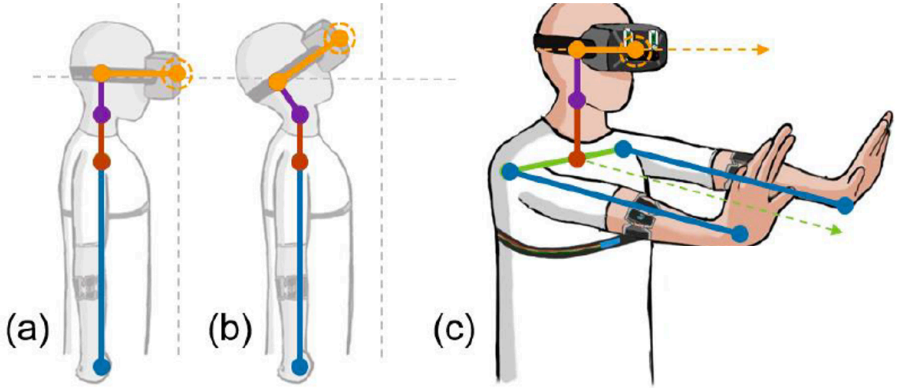
1. Introduction
2. User Needs
3. Design Practices
   - Interface Design Examples
   - Design Dimensions
4. Design Framework
5. Future Work

Interface Design: Example 1

How can AR applications meet users' cognitive and action needs during exercises like weight training and rehabilitation?

Interface Design: Example 1

AR-Arm



(AR-Arm, Han et al., 2016)

Strengths:

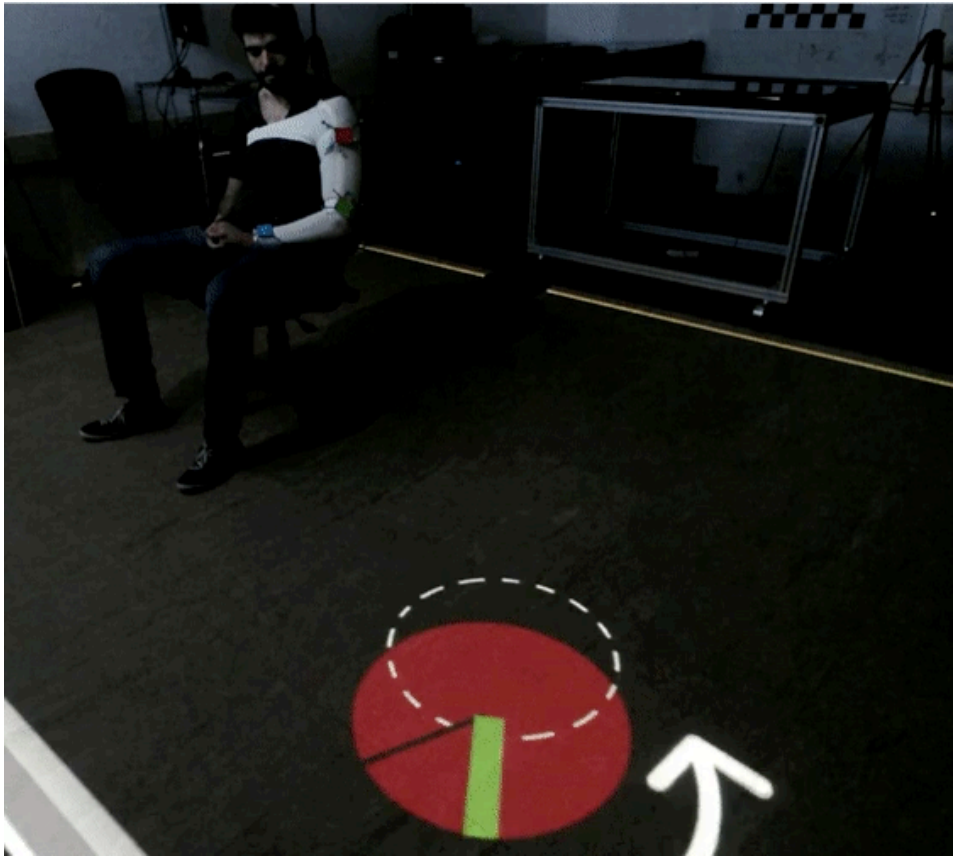
- Easy to understand and follow
- Lightweight and portable

Limitations:

- Limited types of supported movements
- Narrow field of view

Interface Design: Example 1

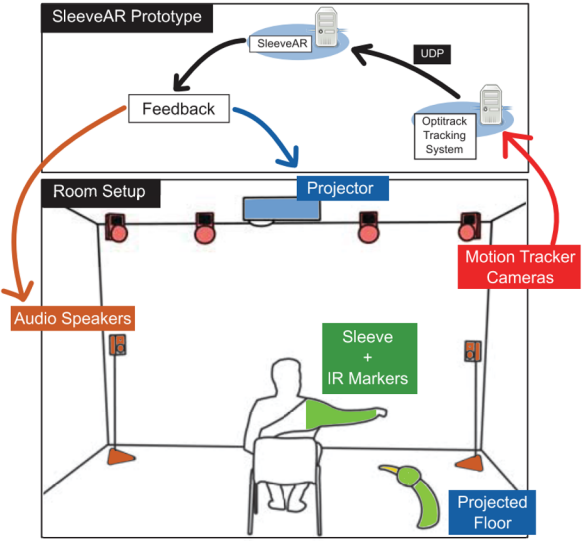
SleeveAR

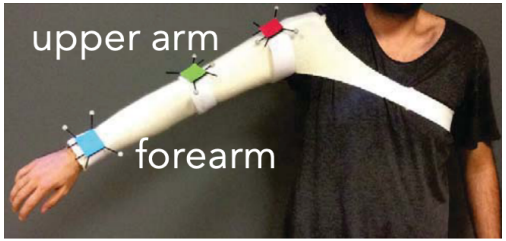


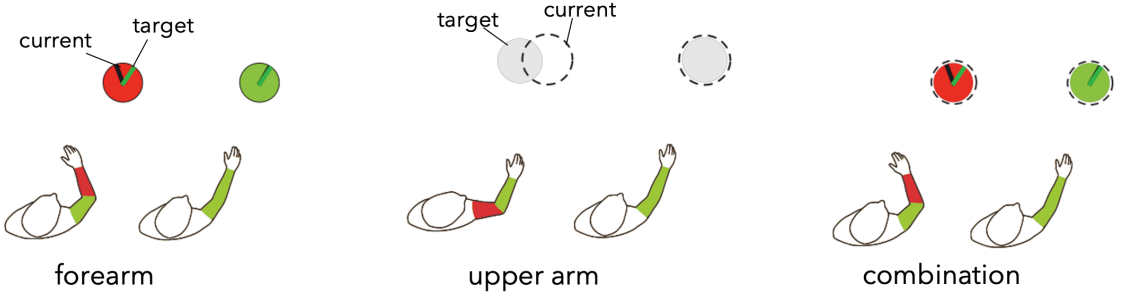
(SleeveAR, Sousa et al., 2016)

Interface Design: Example 1

SleeveAR





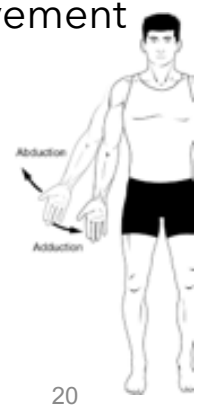


Strengths:

- Support larger arm's range of motion
- Reduce eye shift between a video screen and the movement

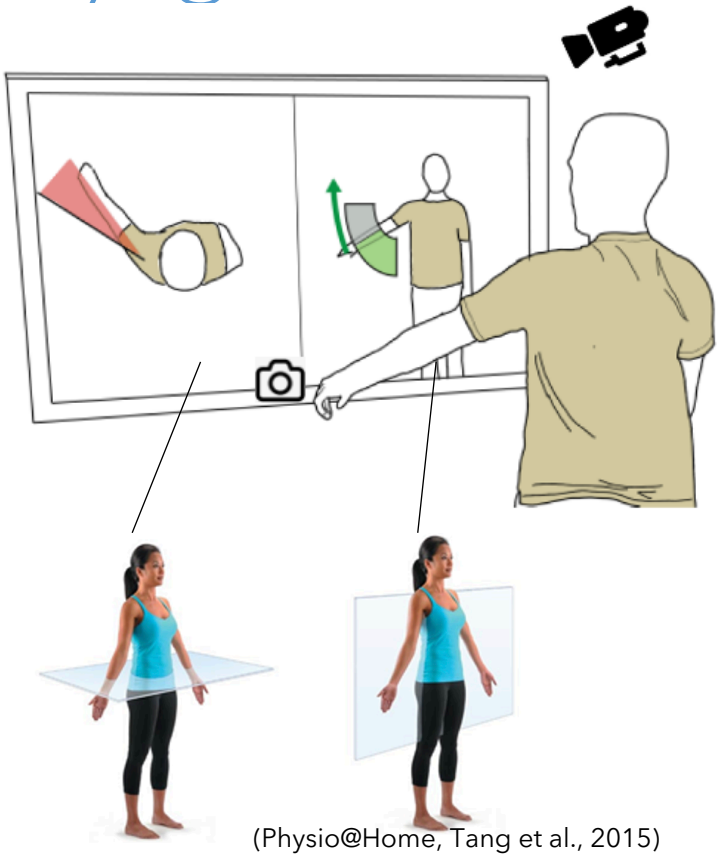
Limitations:

- Suffer from occlusion
- Do not support movements along a vertical plane

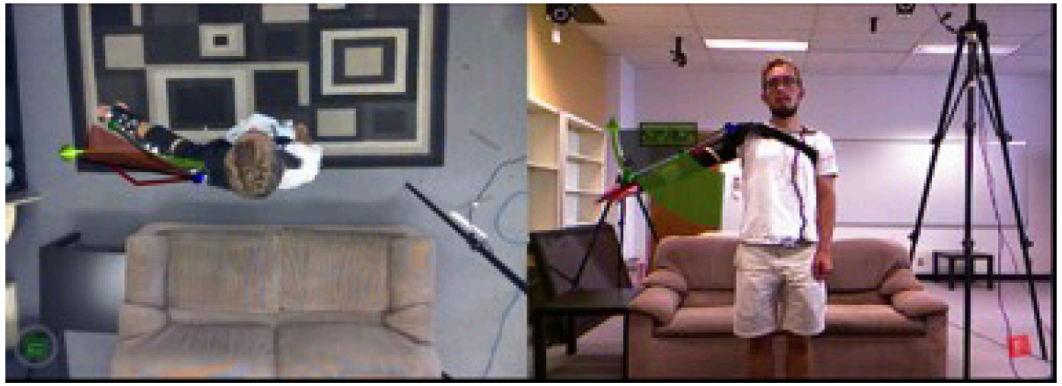


Interface Design: Example 1

Physio@Home



(Physio@Home, Tang et al., 2015)



Strength:

- Provide more details

Limitation:

- Be Less intuitive because of an extra matching process

Interface Design: Example 1

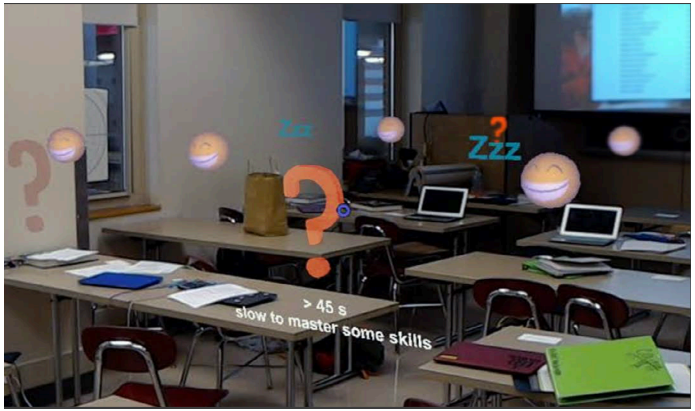
Summary

Similarities : providing real-time feedback or guidance to facilitate arm rehabilitation exercises

Differences: displays, visual design, and underlying data

		Portable	On-body hints	Multiple-view	Easy matching	Large size
AR-Arm	HMD	✓	✓		✓	
SleeveAR	Projector		✓		✓	✓
Physio@Home	TV Screen			✓		✓

Interface Design: Example 2



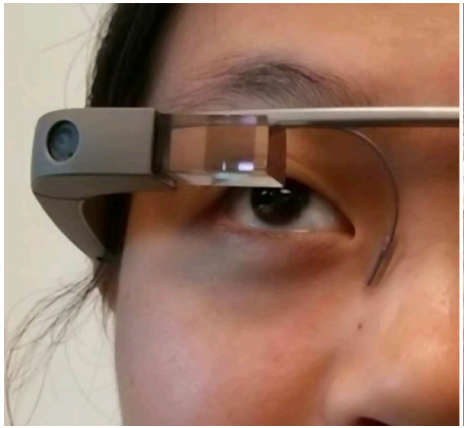
(Lumio, Holstein et al., 2018) The icons indicate students' status in a self-pace class.

- Can help teachers spend more time with students who need help.
- May cause visual clutter.

(ALF-G, Zarraonandia et al., 2019) The charts show students' overall comprehension levels in a normal lecture.

- Can help teachers adjust teaching pace.
- Need time to interpret.

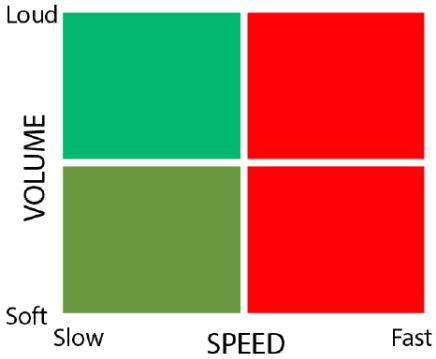
Interface Design: Example 2



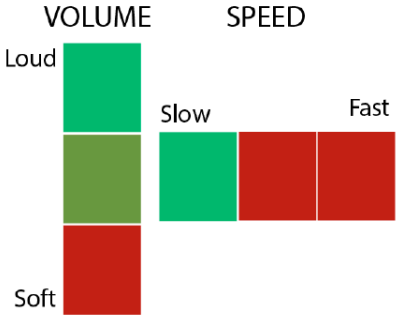
(Rhema, Tanveer et al., 2015)

✗ Plotting volume and speed values requires presenters' interpretation and judgement.

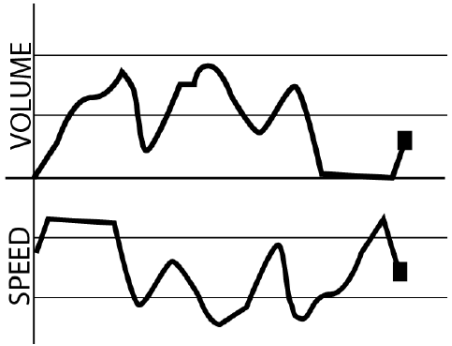
✓ Using short words to tell presenters how to adjust the volume and speed directly.



(a) Quadrants



(b) Bars



(c) Plots

(d) Words

Interface Design: Example 2

Summary

Similarity : head-mounted displays

Difference: visual forms

		Easy to Interpret	Show aggregation information	Support sensemaking	Draw direct conclusion
Lumilo	Icons	✓		✓	
ALF-G	Charts		✓	✓	
Rhema	Text	✓			✓

Design Dimensions

There are four types of design dimensions frequently considered by researchers:

- Display Devices
- Visual Forms
- Availability Over Time
- Attention

Design Dimensions
Display Devices

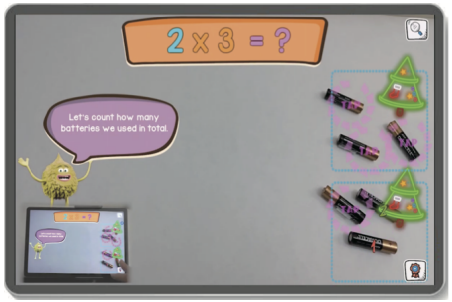
Head-mounted display

(ALF-G, Zarraonandia et al., 2019)

Projector

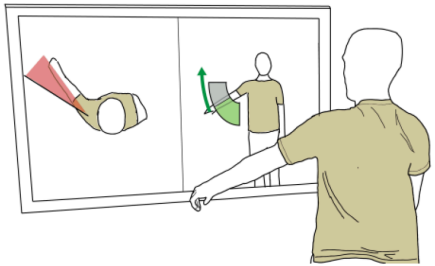
(SleeveAR, Sousa et al., 2016)

Hand-held display



(ARMath, Kang et al., 2020)

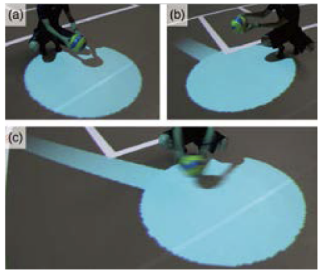
TV Screen



(Physio@Home, Tang et al., 2015)

Design Dimensions
Visual Forms

Shapes



(Volleyball, Sato 2018)

Text

(WetLab, Scholl et al., 2016)

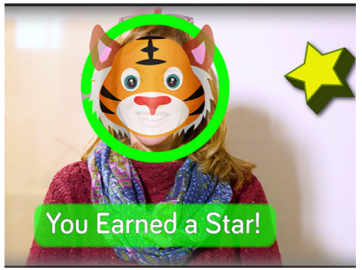
Icons

(Lumilo, Holstein et al., 2018)

Charts

(Zarraonandia et al., 2019)

Clip arts



(MOSOCO, Escobedo et al., 2012)

Design Dimensions

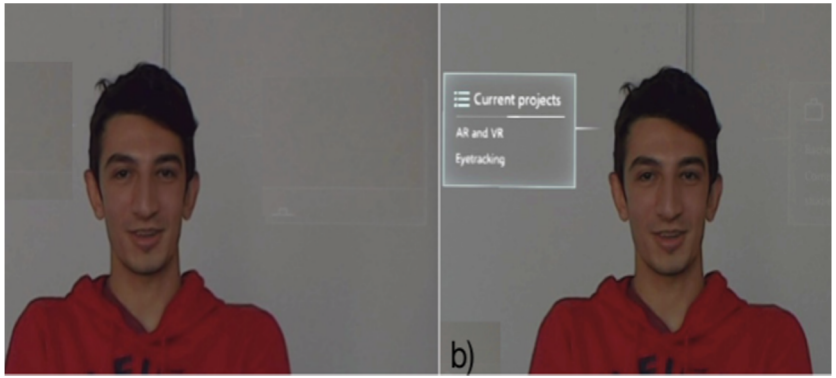
Availability Over Time

Describe how the superimposed information appears and how continuously it is available to the target users.

Always Available

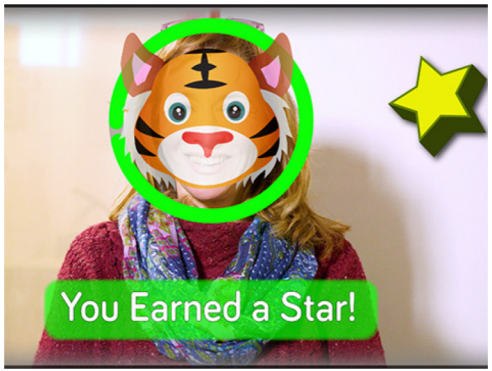
(SleeveAR, Sousa et al., 2016)

Available on Request



(StARe, Rivu et al., 2020)

Available by Trigger

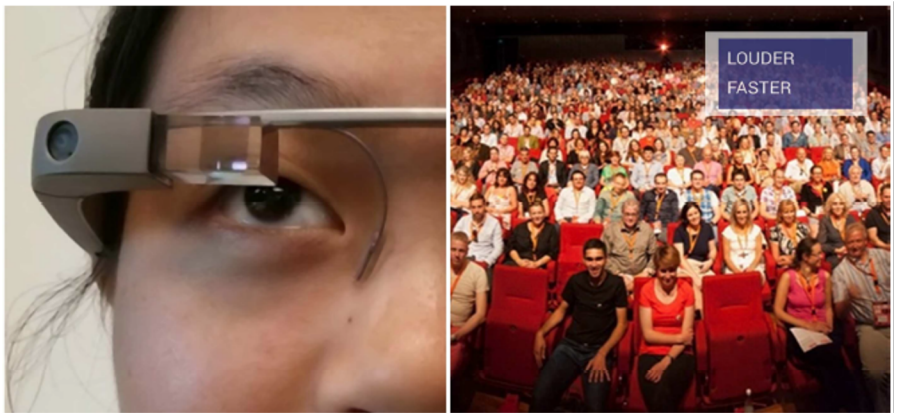


(MOSOCO, Escobedo et al., 2012)

Design Dimensions
Attention

Refer to how much attention people have paid when reading the information.

Peripheral Attention



(Rhema, Tanveer et al., 2015)

Focal Attention

(Physio@Home, Tang et al., 2015)

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Design Steps

Step 1: Understand tasks and user needs.

Step 2: Select a proper option for each design dimension.

The framework that is about to introduce aims to guide the second step.

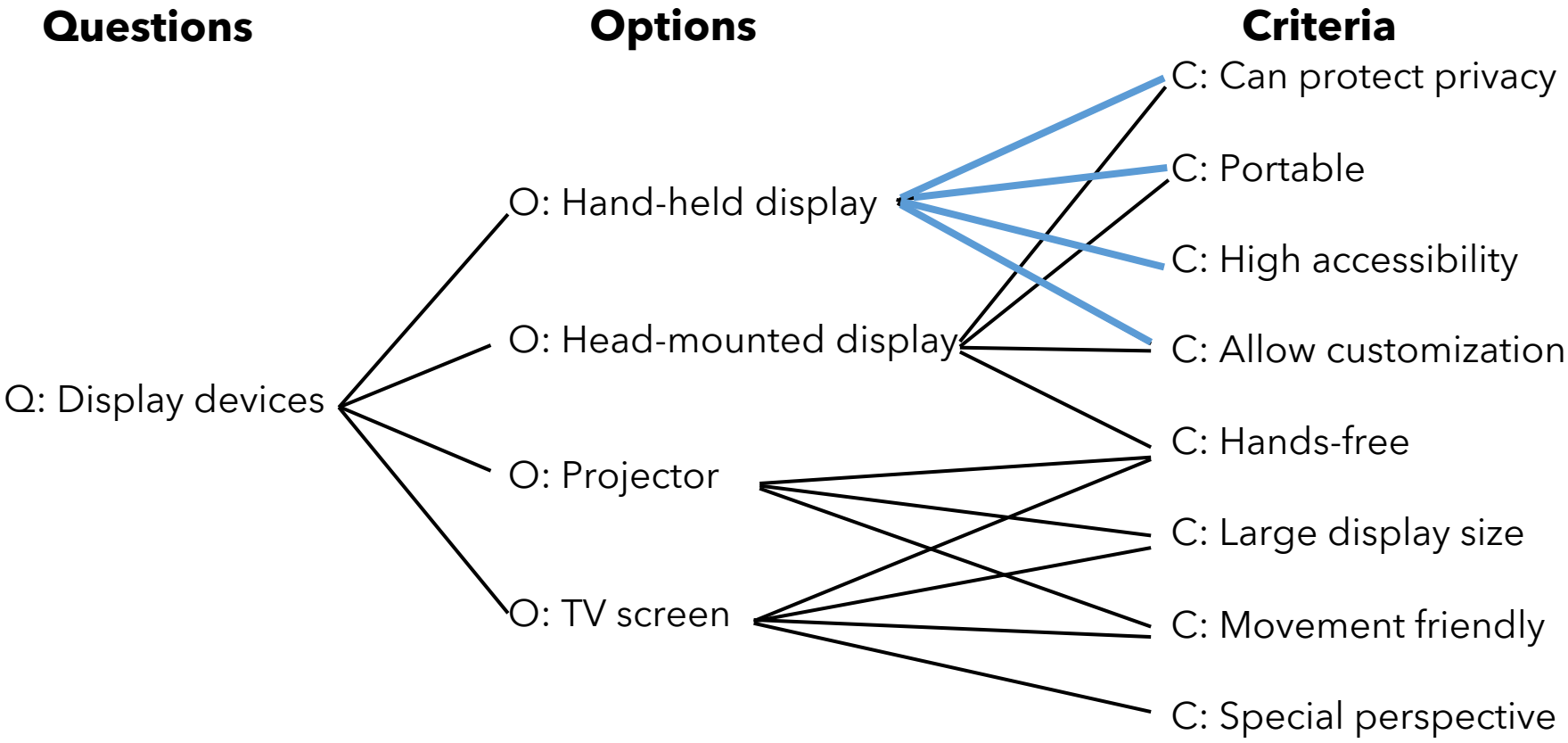
QOC Analysis

Questions, Options, and Criteria (QOC) Analysis for Selection

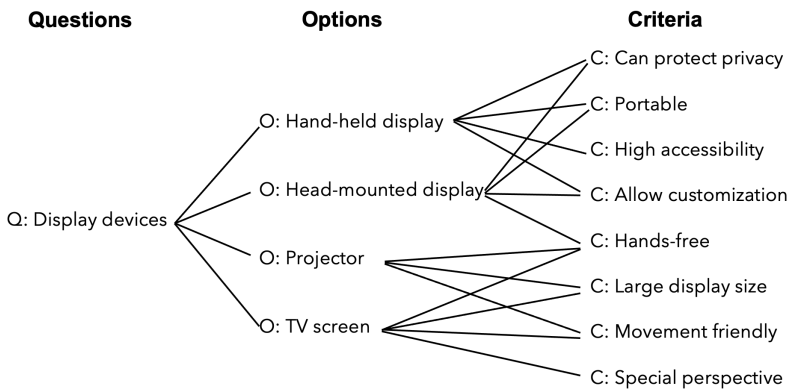
Ask questions about the design of specific elements	List available options to the questions	Establish criteria to assess and compare each option
Questions	**Options**	**Criteria**
• **Which kind of display devices?**	• Hand-held Display	• Hands-free
• Which kind of visual forms?	• Head Mounted Display	• Portable
• Which kind of availability?	• Projector	• High accessibility
• Which level of attention?	• TV Screen	• Movement friendly
		• Large display size
		• Can protect privacy

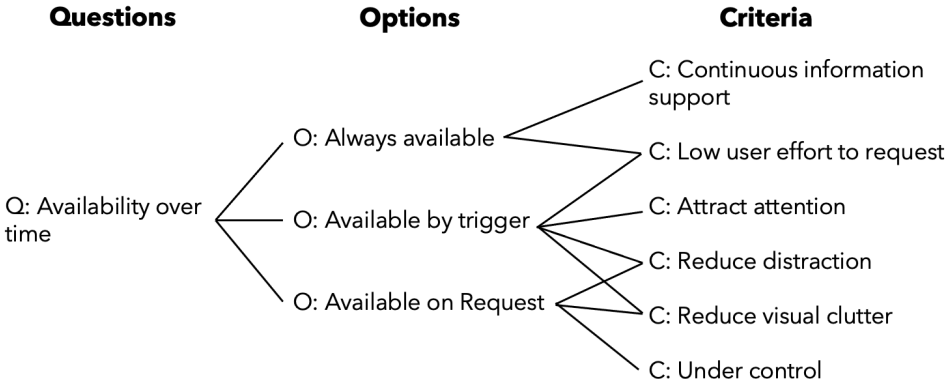
Allan MacLean, Richard M. Young, Victoria Bellotti, Thomas P. Moran: Questions, Options, and Criteria: Elements of Design Space Analysis. HCI 6(3-4): 201-250 (1991)

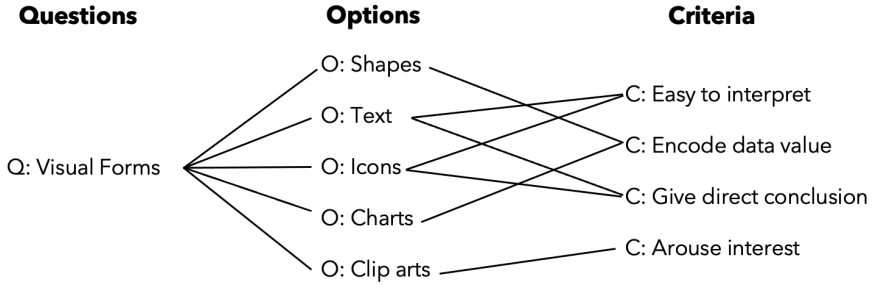
QOC Analysis

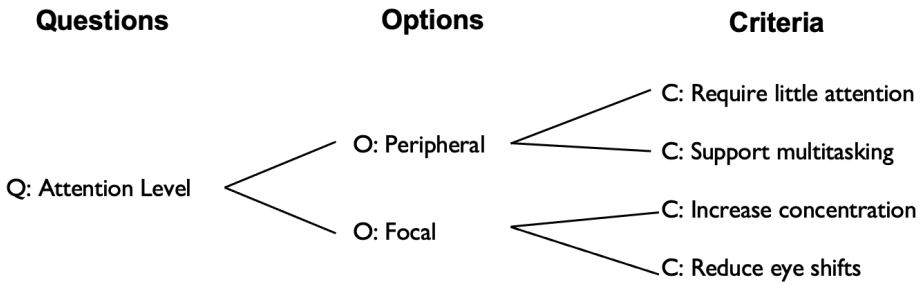


QOC Analysis



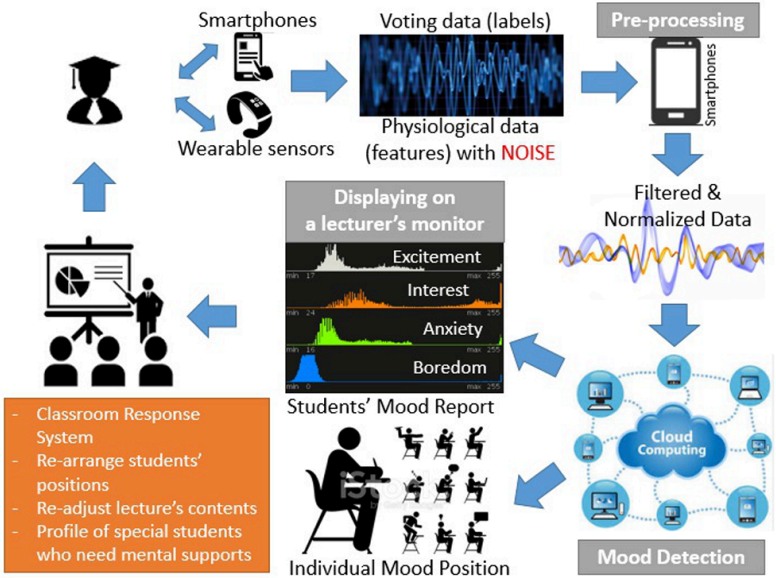




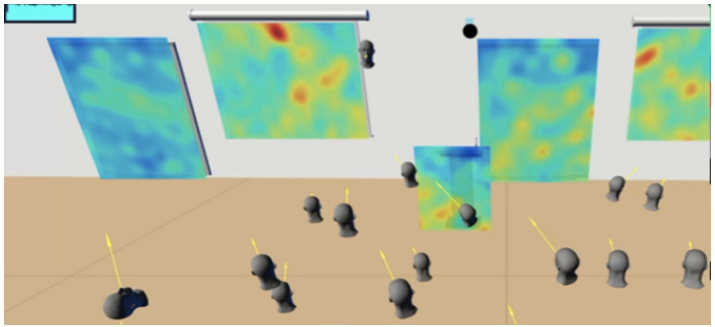


Example

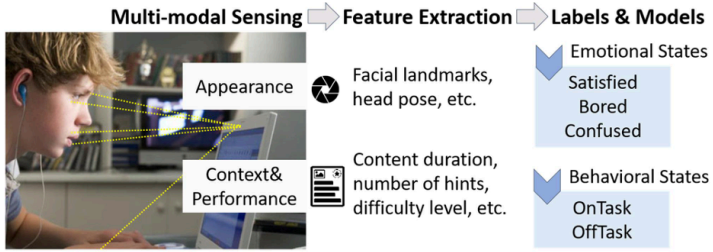
Students' in-class activities, emotions, and engagement can be captured with sensors nowadays.



(Dao et al., 2018)

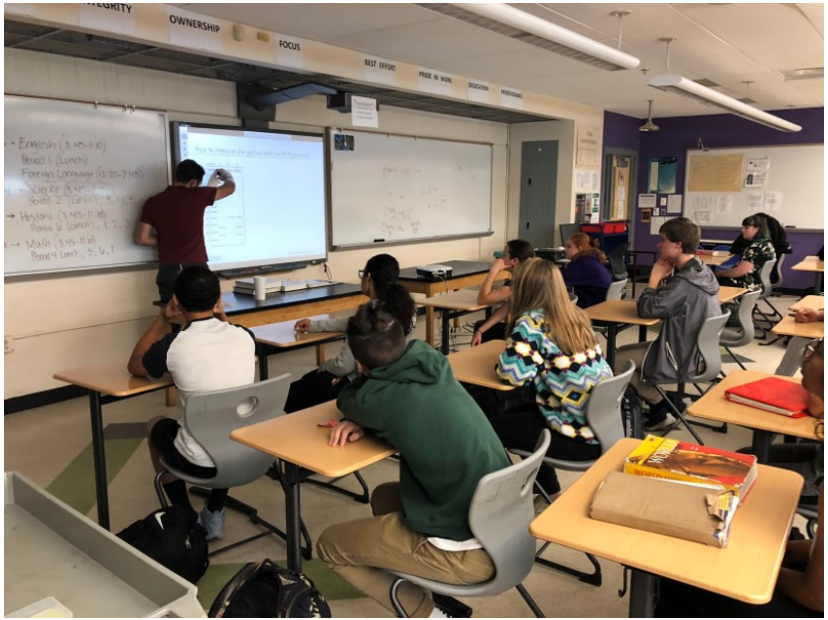


(Ahuja et al., 2021)



(Aslan et al., 2019)

Example



Task: Adjust the teaching pace according to students' comprehension levels.

Needs: cognitive needs to know

- whether students are confused
- which parts they are confused about

Captured Data: Emotion, Gaze

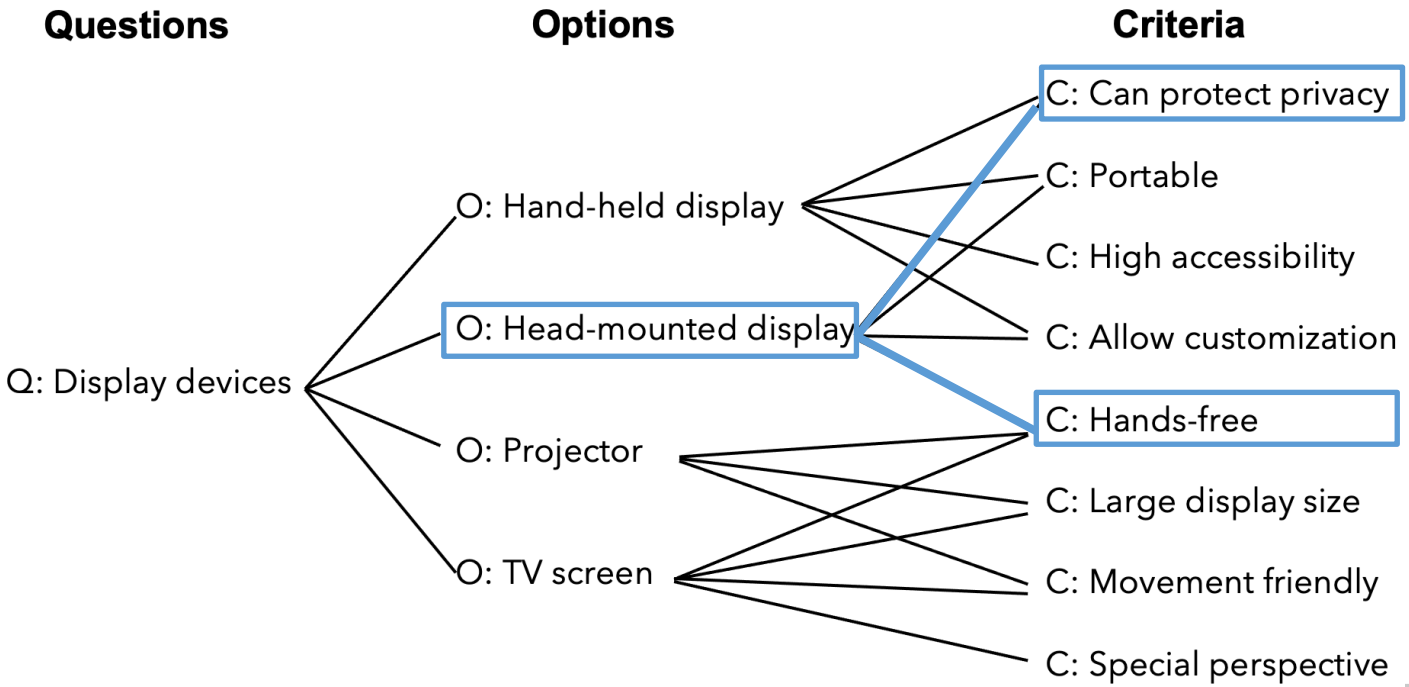
Example

User requirements:

- R1: Reserve body language.
- R2: Keep the virtual content only visible to the teacher.
- R3: Notice in-time notification when detecting confusion and react in a short time.
- R4: Take charge of whether to pause and repeat some content.
- R5: Allow to analyze and identify which parts need to be repeated.
- R6: Minimize distractions caused by the virtual content, such as not obstructing vision and distracting attention during talking.

Example

Display devices

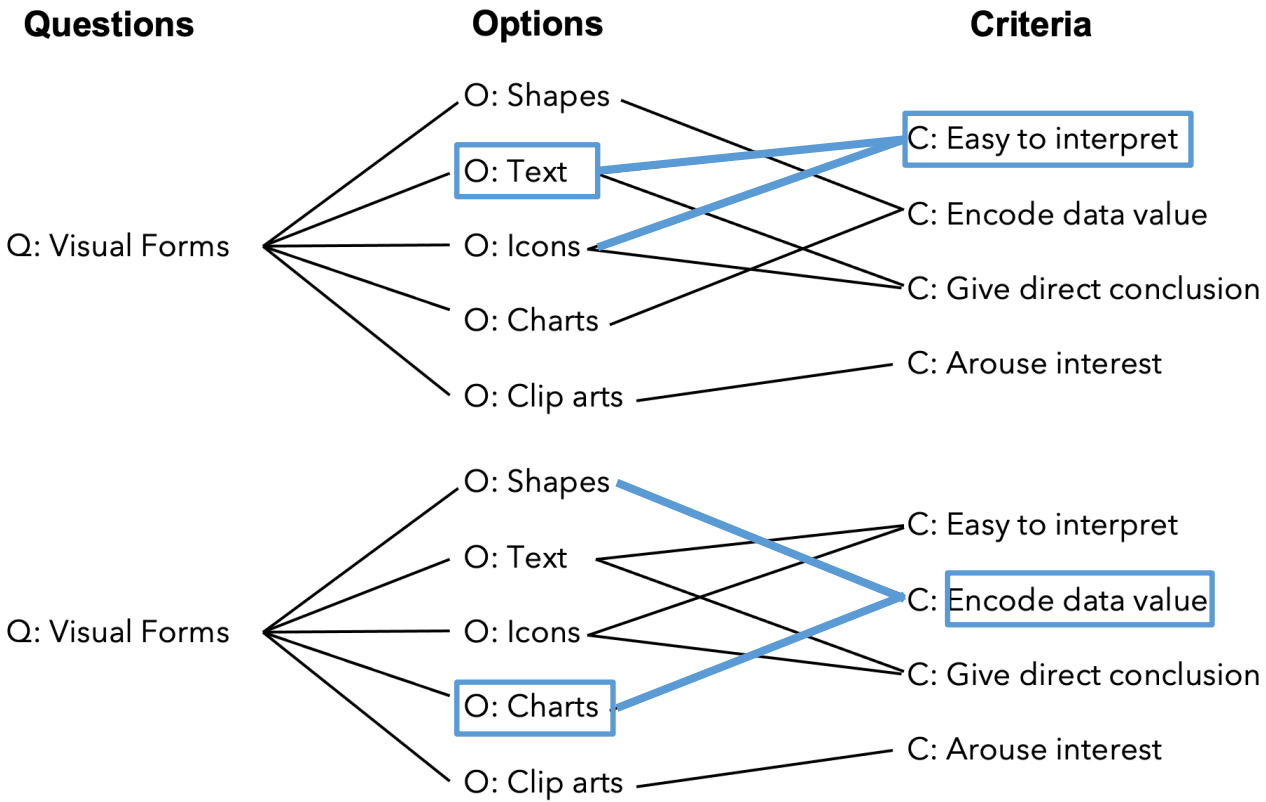


R1: Reserve body language.

R2: Keep the virtual content only visible to the teacher.

Example

Visual Forms



Emotion

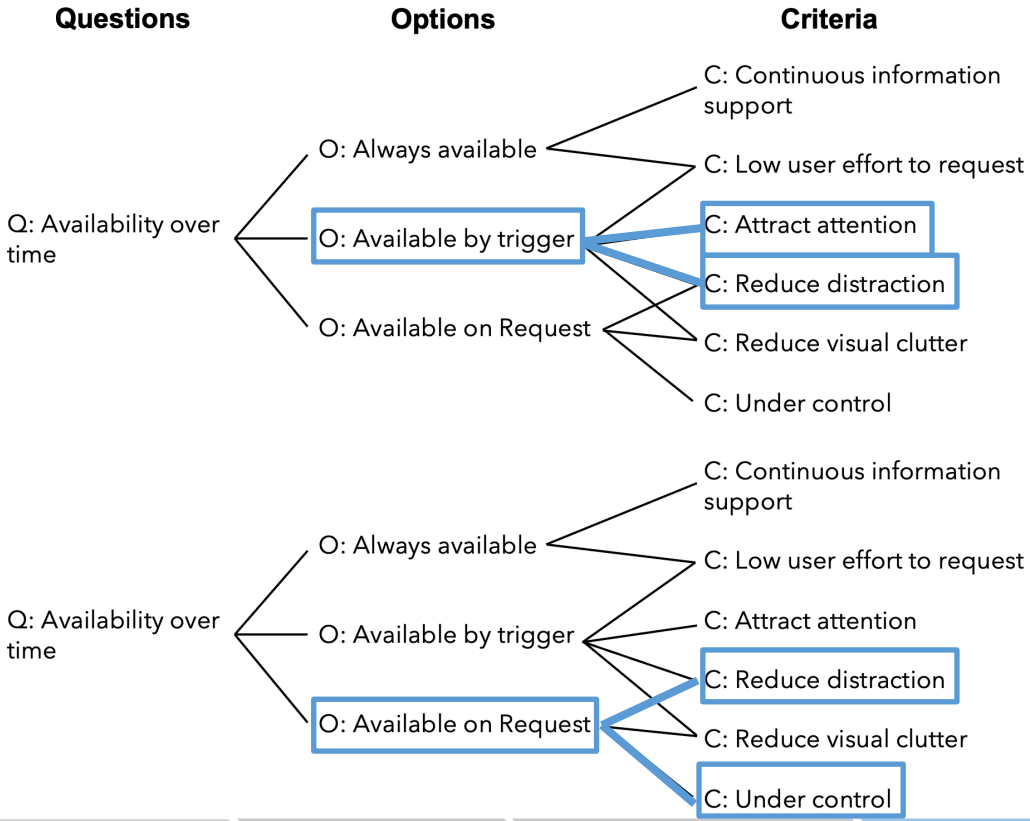
R3: Notice in-time notification when detecting confusion and react in a short time.

Gaze

R5: Allow to analyze and identify which parts need to be repeated.

Example

Availability over time



Emotion

R3: Notice in-time notification when detecting confusion and react in a short time.

R6: Avoid distracting attention during talking.

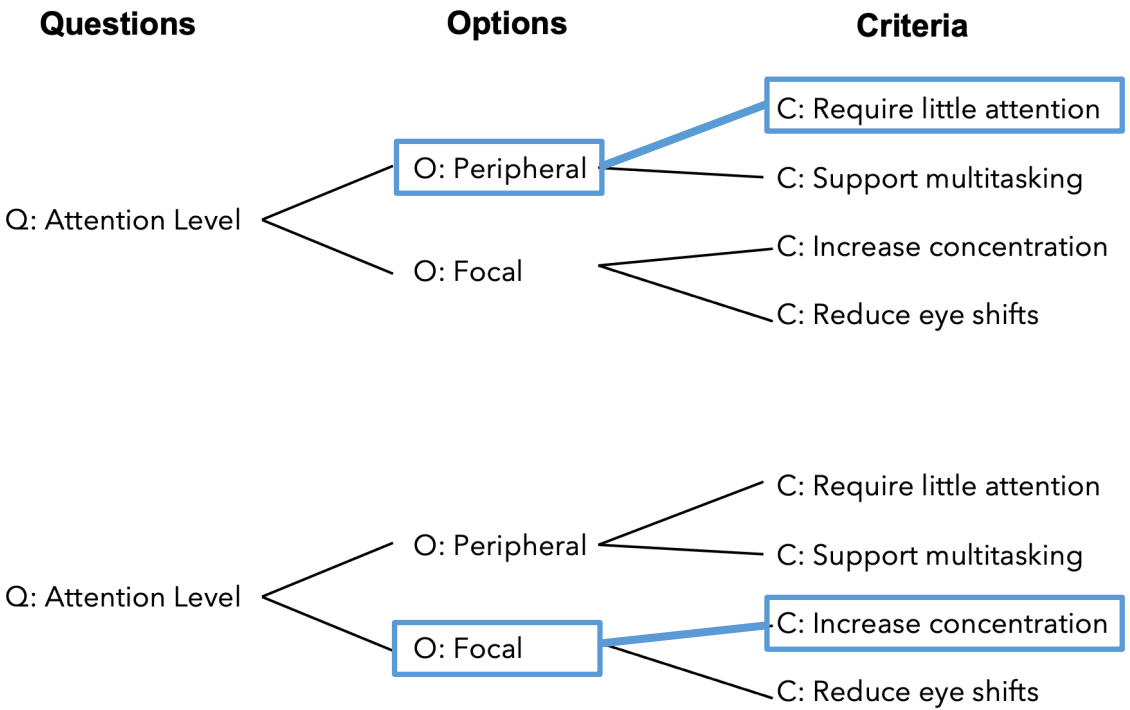
Gaze

R4: Take charge of whether to pause and repeat some content.

R6: Avoid obstruction.

Example

Attention



Emotion

R6: Minimize distractions caused by the virtual content, such as not obstructing vision and distracting attention during talking.

Gaze

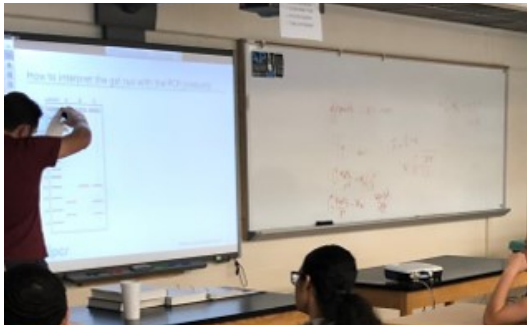
R5: Allow to analyze and identify which parts need to be repeated.

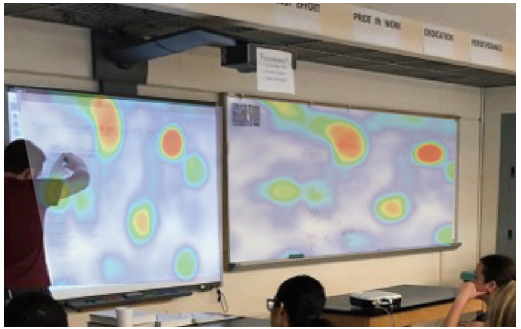
Example

Initial Design

Emotion is used to determine whether students are confused.

Text
Available by trigger
Peripheral attention





Gaze is used to determine which parts they are confused about.

Heatmap
Available on request
Focal attention

Discussion

- The initial design is a starting point, which reduces the barriers for designers to get started and provides a baseline for improvements.

- The framework is not exhaustive.
  - Other dimensions: how much data to encode; show raw or processed data
  - Other options: head-up displays

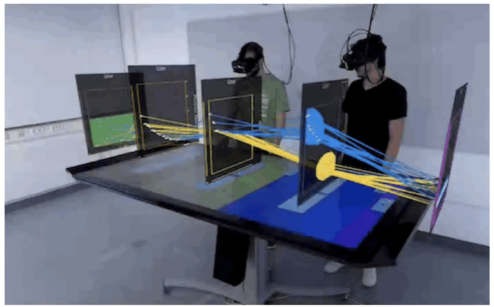
- The framework is extendable.

Future Work

- Adaptive UI
  - How to show details of different levels?
  - How to switch in different views?

- Dealing with big data
  - How to adapt general visualization techniques to solve real-time tasks?

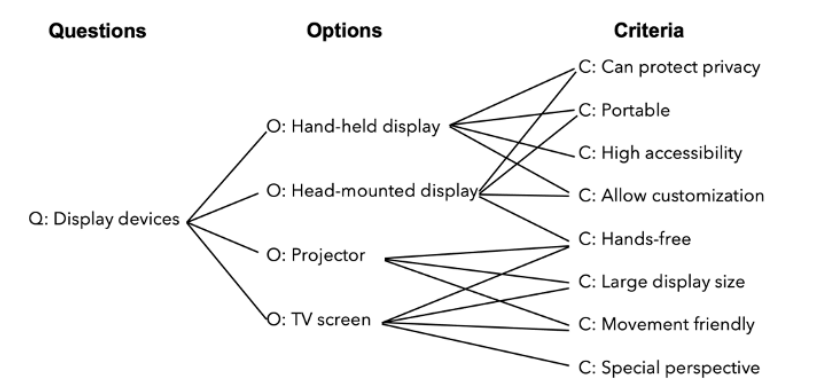
(Langner et al., 2021)

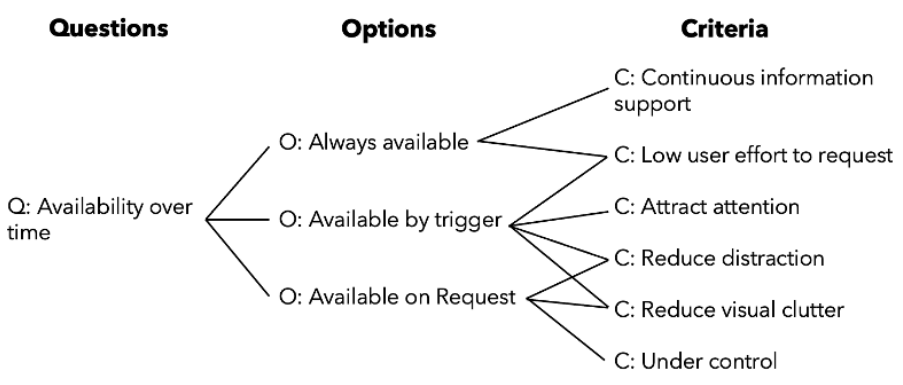


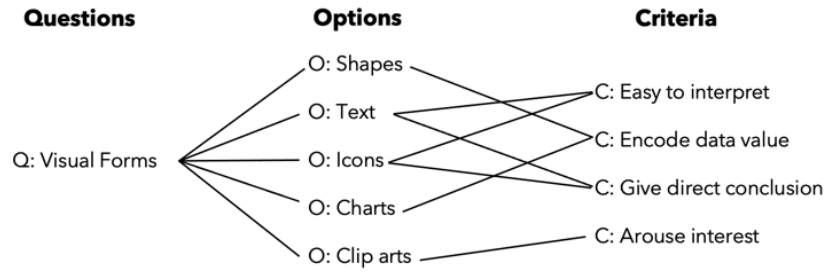
(Butscher et al., 2018)

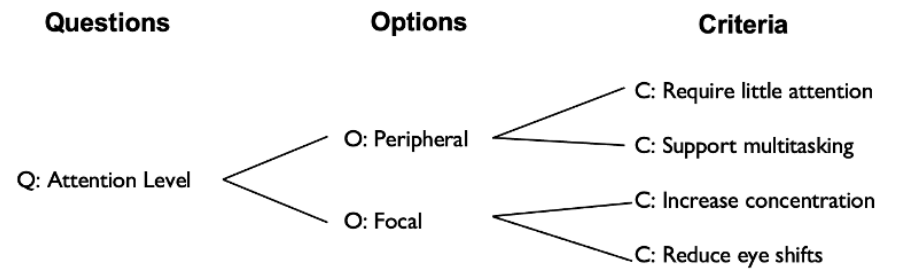
(Satriadi et al., 2021)

Thank You!


Questions
Options
Criteria
Q: Display devices
O: Hand-held display
O: Head-mounted display
O: Projector
O: TV screen
C: Can protect privacy
C: Portable
C: High accessibility
C: Allow customization
C: Hands-free
C: Large display size
C: Movement friendly
C: Special perspective


Questions
Options
Criteria
Q: Availability over time
O: Always available
O: Available by trigger
O: Available on Request
C: Continuous information support
C: Low user effort to request
C: Attract attention
C: Reduce distraction
C: Reduce visual clutter
C: Under control


Questions
Options
Criteria
Q: Visual Forms
O: Shapes
O: Text
O: Icons
O: Charts
O: Clip arts
C: Easy to interpret
C: Encode data value
C: Give direct conclusion
C: Arouse interest


Questions
Options
Criteria
Q: Attention Level
O: Peripheral
O: Focal
C: Require little attention
C: Support multitasking
C: Increase concentration
C: Reduce eye shifts