BANS: Evaluation of Bystander Awareness Notification Systems for Productivity in VR

Shady Mansour, Pascal Knierim, Joseph O'Hagan, Florian Alt and Florian Mathis

LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN
Universität der Bundeswehr München
University of Glasgow
universität innsbruck
Internet Society

Why?

MetaQuest. (2020, Sep. 17). Infinite Office [Video]. Youtube. https://youtu.be/5_bVkbG1ZCo

Background

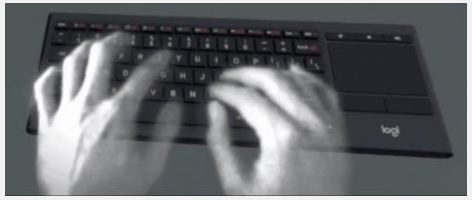
- Introduction of head-mounted displays (HMDs) to the **work** environment
- The demand on **remote** offices increased significantly
- HMDs provide a fully configurable workspace
- Integration of **peripheral input devices** in the VR

Previous Work

Productivity Tasks in VR

- **Pressing Challenge:**
  - Efficient text input.
- **Solution:**
  - Knierim et al. [1] visualized physical keyboards in VR using external sensors and tracking systems

  - Meta's Tracked Keyboard SDK [2]



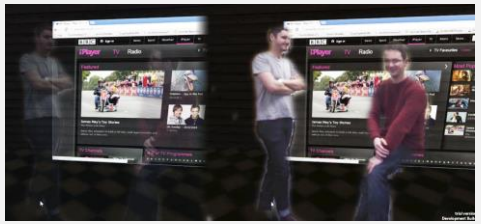
VR In Public Spaces

- **Li et al. [3]:**
  - Productivity tasks in VR in the rear seat of a car
  - Effect of physical constraints in transportation and virtual working spaces on users' performance
- **Ng et al. [4]**
  - Use of multi-display virtual workspaces inside a simulated airplane
  - Effect of public transit on VR users' preferences of multi-display layouts

The near vertical multi-display virtual workspaces tested by Ng et al. [4]

Bystander Awareness

- **McGill et al. [5]:**
  - One bystander awareness system with two states: low and high engagement.
  - Found to be disruptive
- **Gottsacker et al. [6]:**
  - explored how the amount of information a notification depicts affects cross-reality interruptions
  - found users preferred diegetic-based notifications to provide cross-reality interruptions.



The two states of McGill et al's bystander awareness system [5]

Fully diegetic avatar notification system by Gottsacker et al. [6]

Motivation

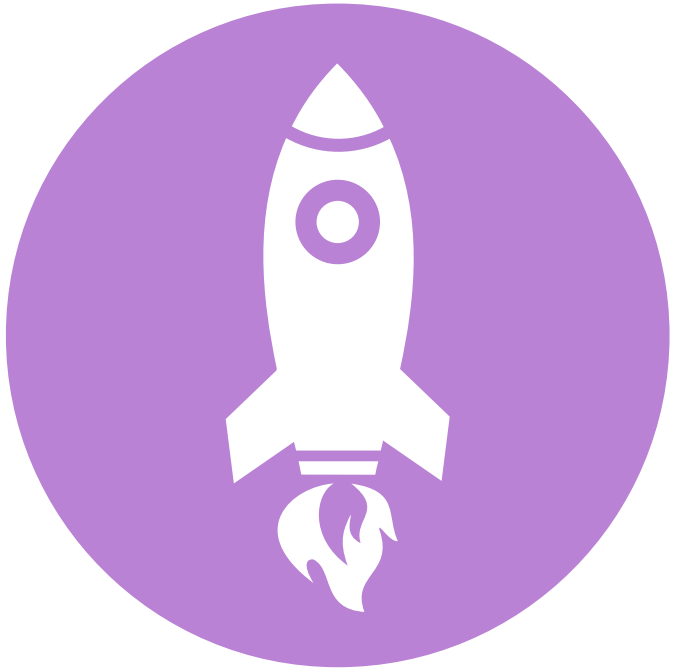
- **Utilization** of bystander awareness notification systems (BANS) to **aid** users in building **awareness** of potential attackers* in their surrounding

- **Usage** of such BANS during realistic VR productivity tasks in **public spaces**

***attack:** shoulder surfing / observation

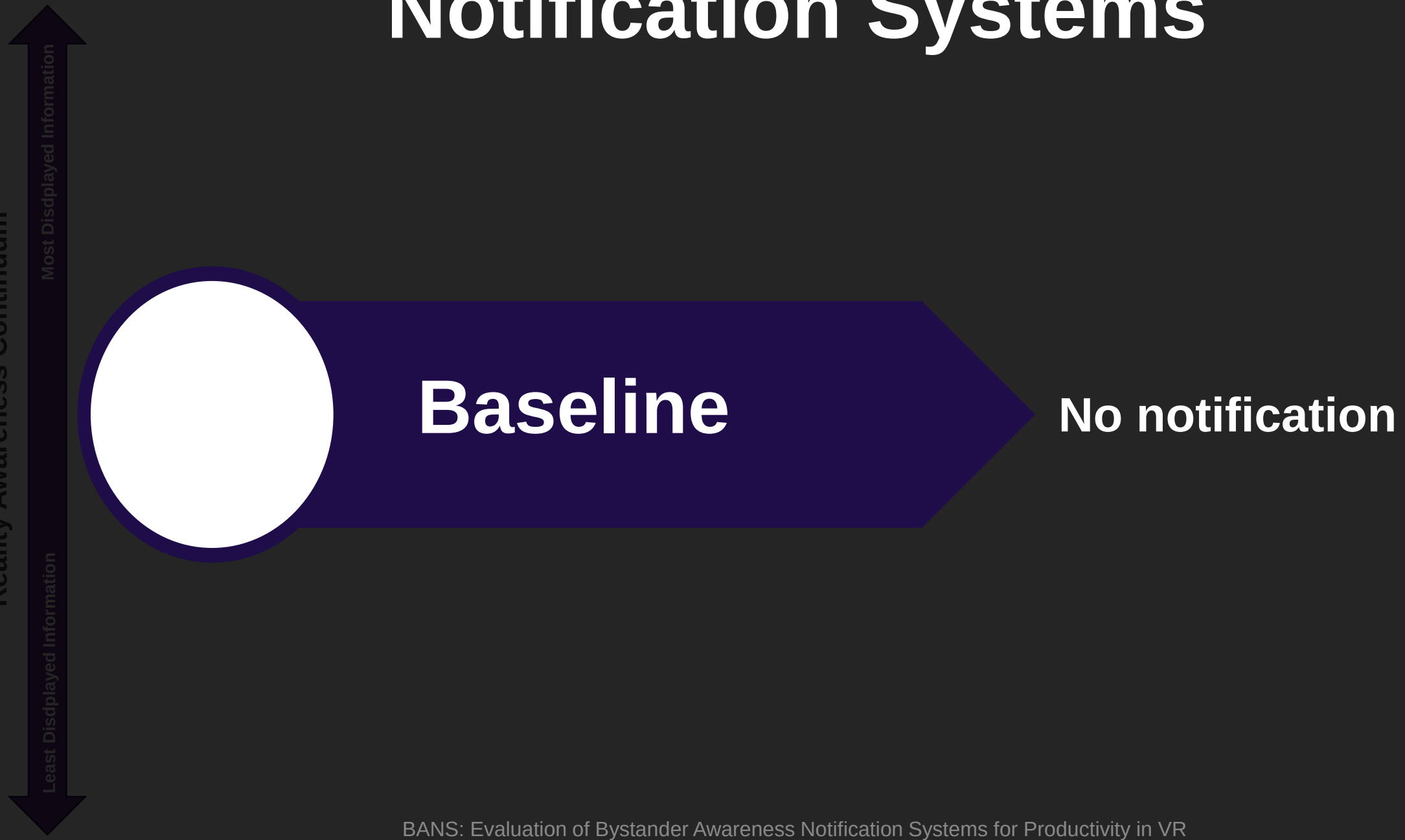
How?

How?



- **Develop different notification systems** that aid VR users in establishing bystander awareness
- **Design a 3D simulation** allowing users to test and evaluate the designed notification systems

Notification Systems



Notification Systems

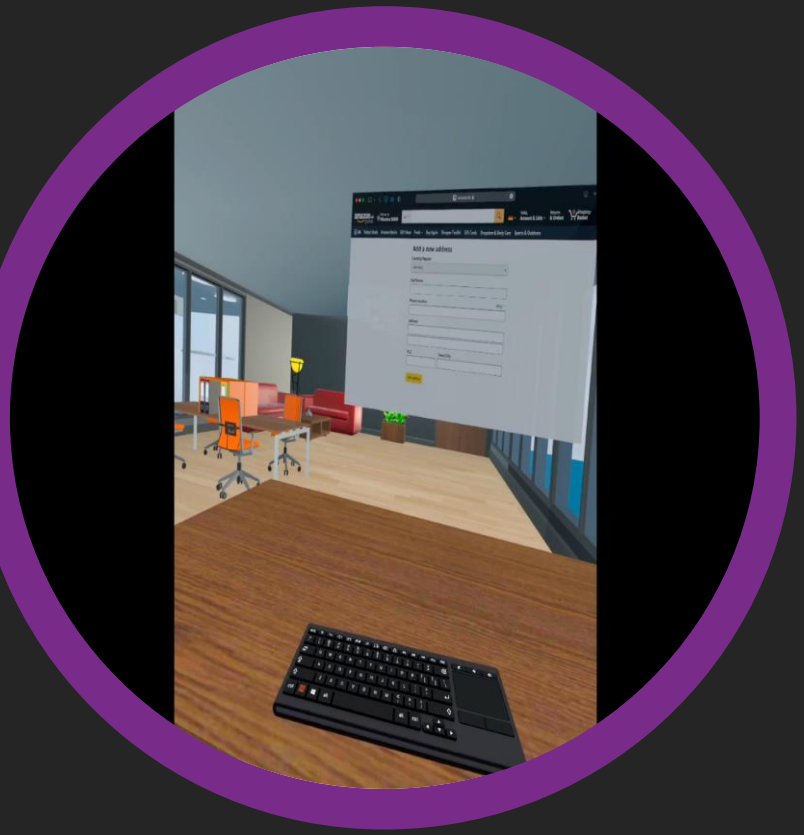
Reality Awareness Continuum

Most Disdplayed Information

Least Disdplayed Information

A text popup informing the user that someone's watching

Text-UI



Baseline

No notification

Notification Systems

Attention Marker

A blinking border augmented on the keyboard that turns on when an attack is detected revealing the observed sector of the keyboard

ng the
omeone's
watching

Text UI

Baseline

No notification

Notification Systems

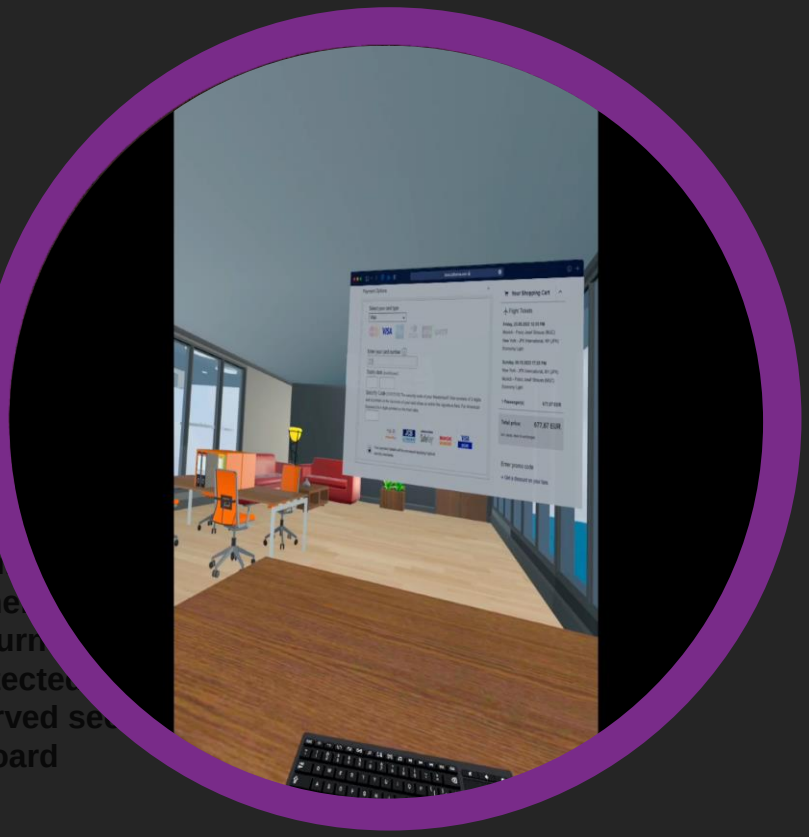
Reality Awareness Continuum

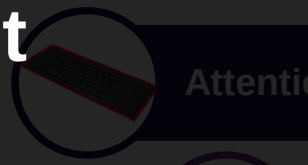
Most Disdplayed Information

Least Disdplayed Information

A 2D Minimap showing the location of all bystanders in a given radius marking attackers with a red dot

2D-Radar

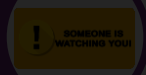




Attention Marker

A blin
augme
that turn
is detecte
observed se
keyboard

Text UI



A test popup informing the user that someone's watching

Baseline

No notification

Notification Systems

Avatar

An avatar showing the user the location and proximity of the attacker

Attention Marker

A blinking border augmented on the keyboard that turns on when an attack is detected revealing the observed sector of the keyboard

Text UI

ing the someone's watching

Baseline

No notification

Notification Systems

Reality Awareness Continuum

Most Disdplayed Information

Least Disdplayed Information

A 3D Scan of the attacker from the real world without contextual information

3D Scan

An ava

2D Radar

location of all bystanders in

attackers with a red dot

Attention Marker

A blin
augme
that turn
is detecte
observed se
keyboard

A test popup informing the user that someone's watching

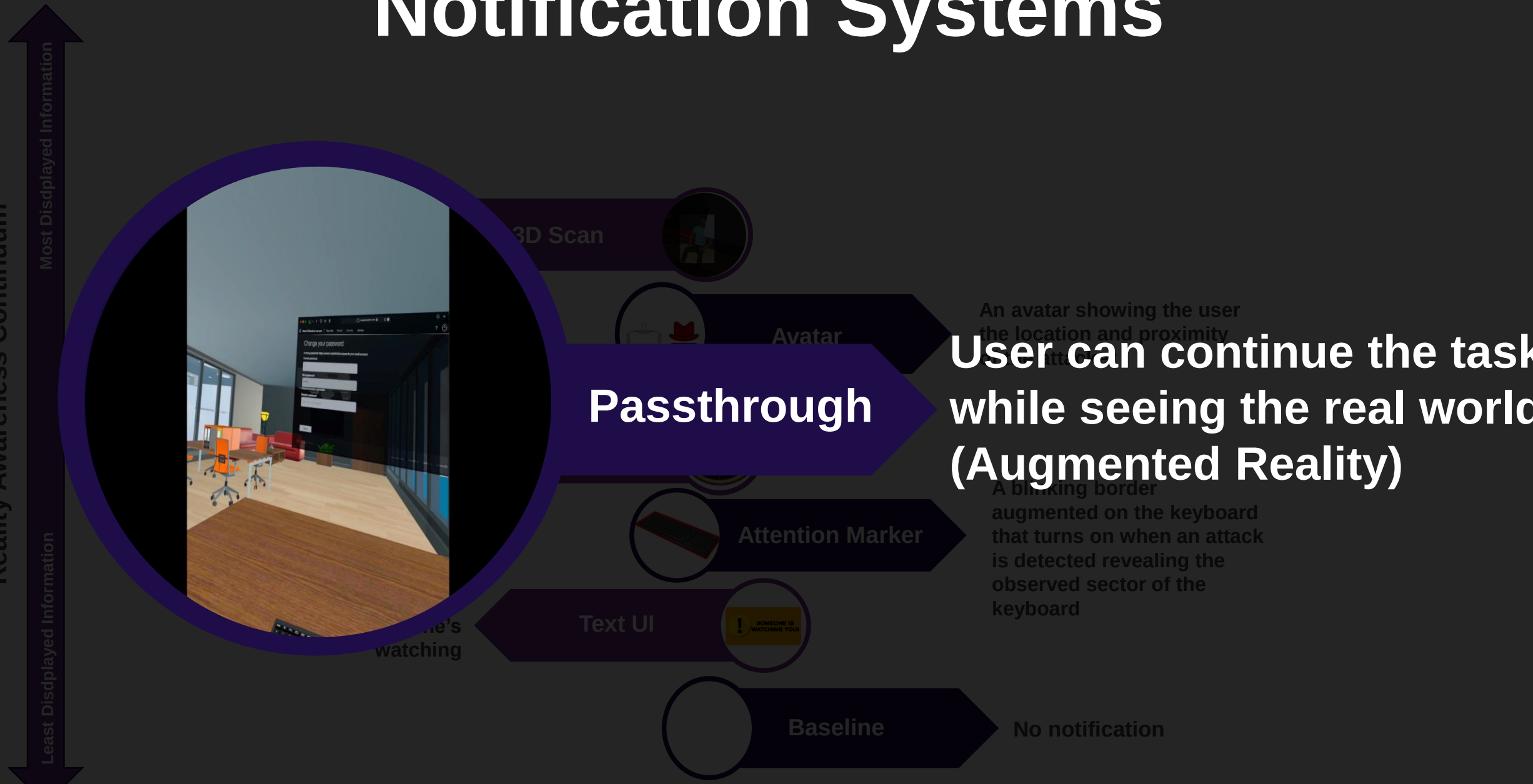
Text UI

SOMEONE IS WATCHING YOU!

Baseline

No notification

Notification Systems

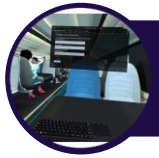


Notification Systems

Reality Awareness Continuum

Most Disdplayed Information

Least Disdplayed Information

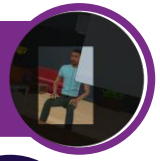


Passthrough

User can continue the task while seeing the real world (Augmented Reality)

A 3D Scan of the attacker from the real world without contextual information

3D Scan



Avatar

An avatar showing the user the location and proximity of the attacker

A 2D Minimap showing the location of all bystanders in a given radius marking attackers with a red dot

2D-Radar

Attention Marker

A blinking border augmented on the keyboard that turns on when an attack is detected revealing the observed sector of the keyboard

A test popup informing the user that someone's watching

Text UI

Baseline

No notification

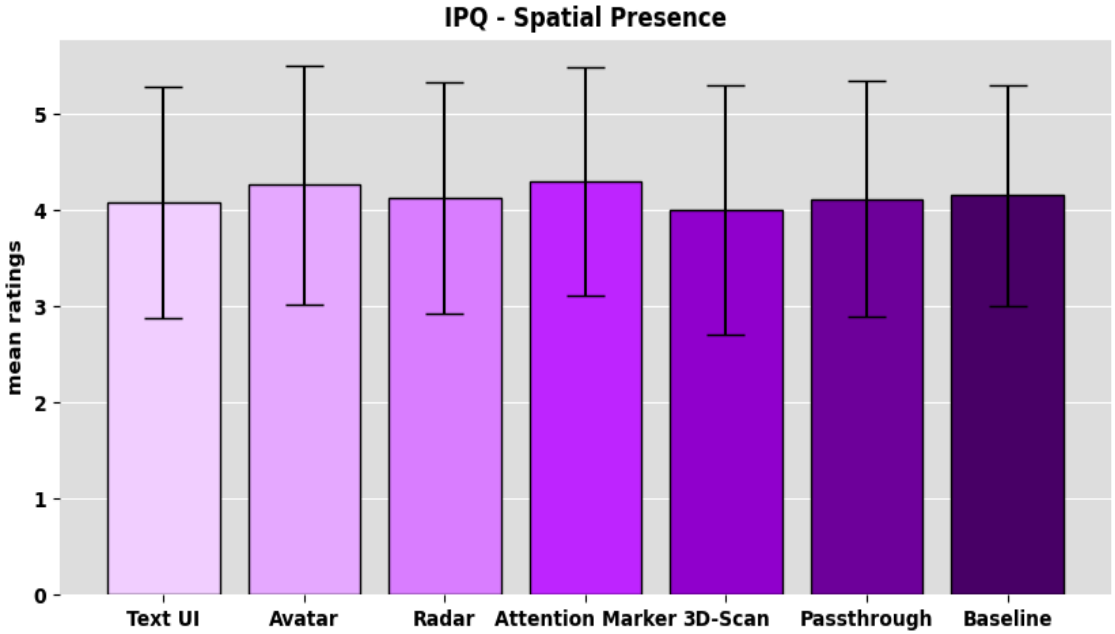
User Study

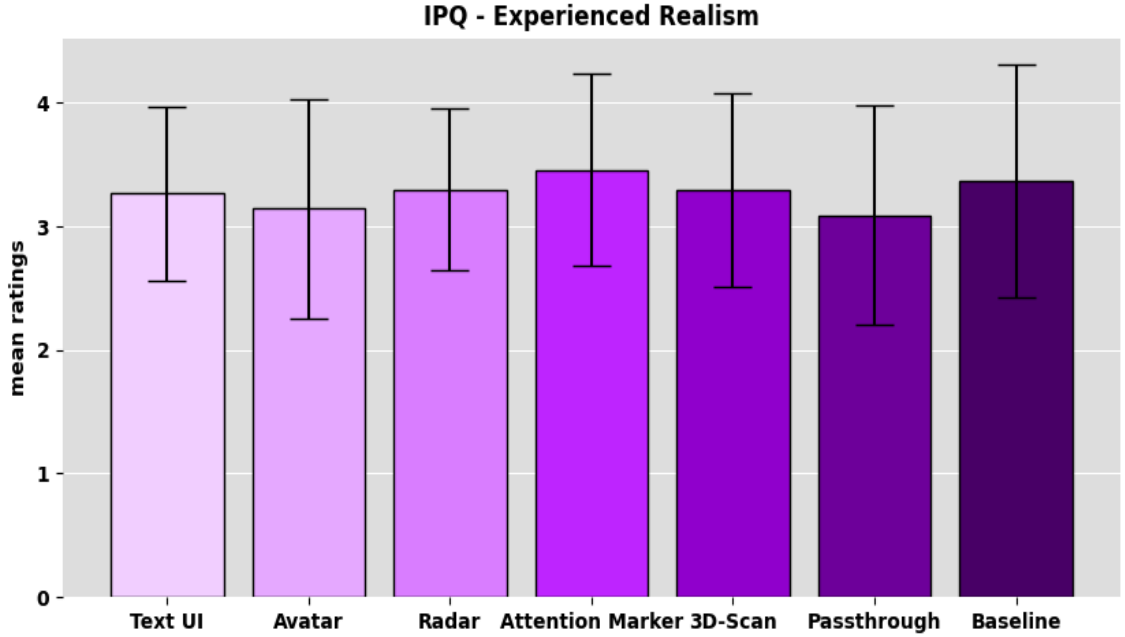
- **Within-subject lab user study**
- **28 participants ensured counterbalancing**
- **We measured:**
  - **Notification's** usability (SUS[1]), noticeability, understandability and intrusiveness
  - **Users'** sense of presence (IPQ[2]) and preference (semi-structured interview)

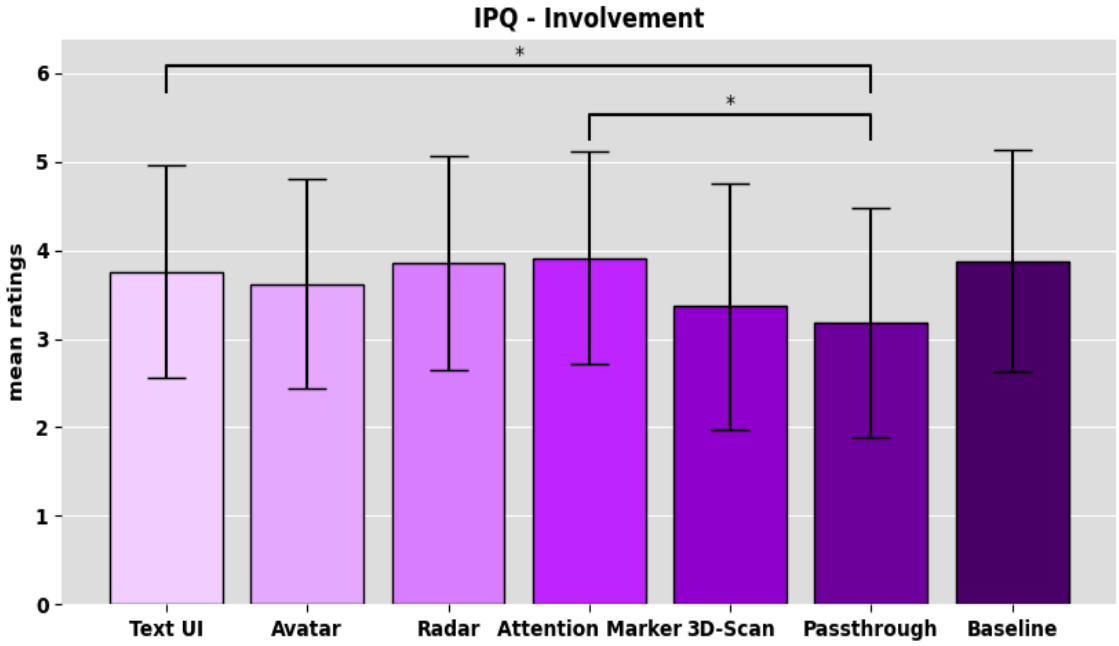
- **Nested Realities:**
  - simulated a plausible real world scenario and virtuality in VR

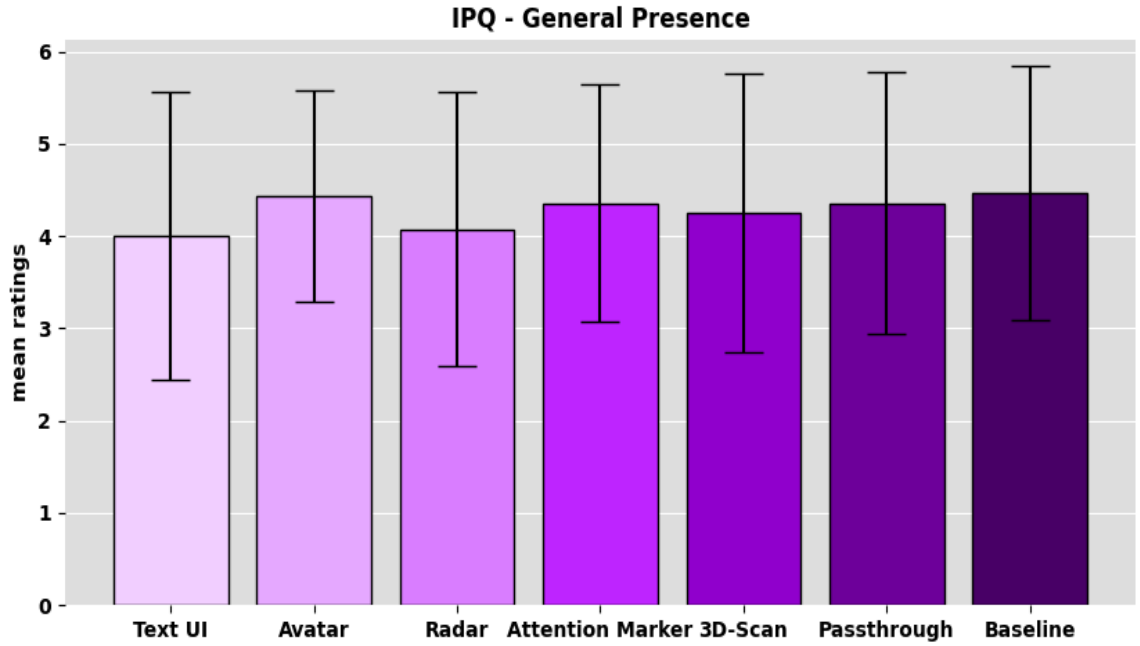
[1] System Usability Scale
[2] iGroup presence questionnaire

Results

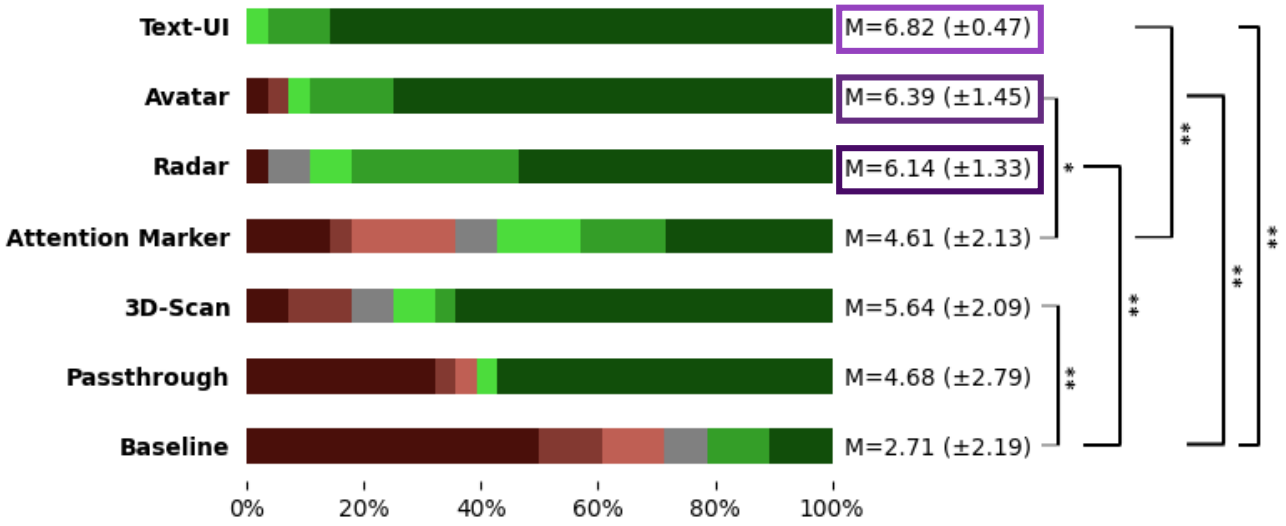

IPQ - Spatial Presence
mean ratings
0
1
2
3
4
5
Text UI
Avatar
Radar
Attention Marker
3D-Scan
Passthrough
Baseline


IPQ - Experienced Realism
mean ratings
0
1
2
3
4
Text UI
Avatar
Radar
Attention Marker
3D-Scan
Passthrough
Baseline

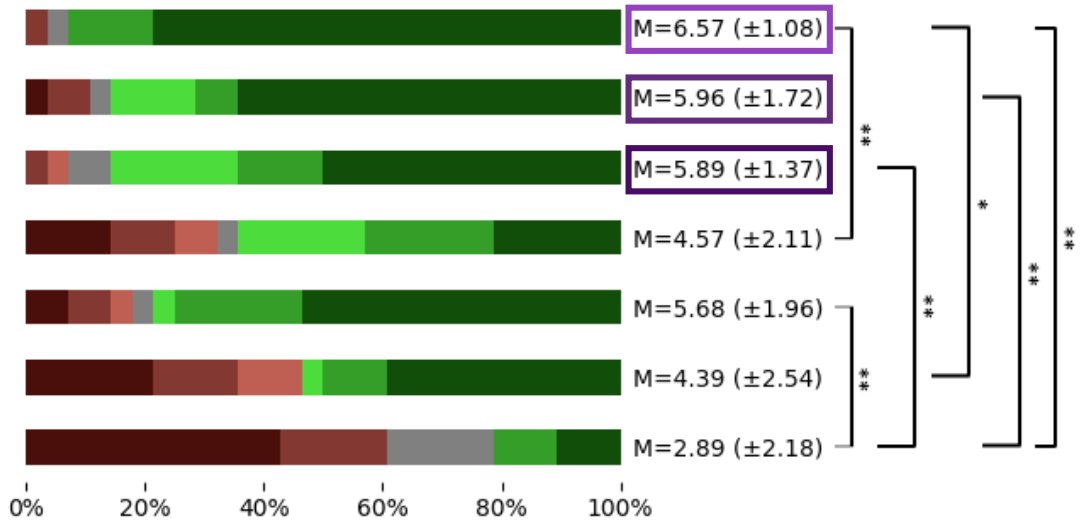

IPQ - Involvement
mean ratings
*
*
0
1
2
3
4
5
6
Text UI
Avatar
Radar
Attention Marker
3D-Scan
Passthrough
Baseline


IPQ - General Presence
mean ratings
0
1
2
3
4
5
6
Text UI
Avatar
Radar
Attention Marker
3D-Scan
Passthrough
Baseline

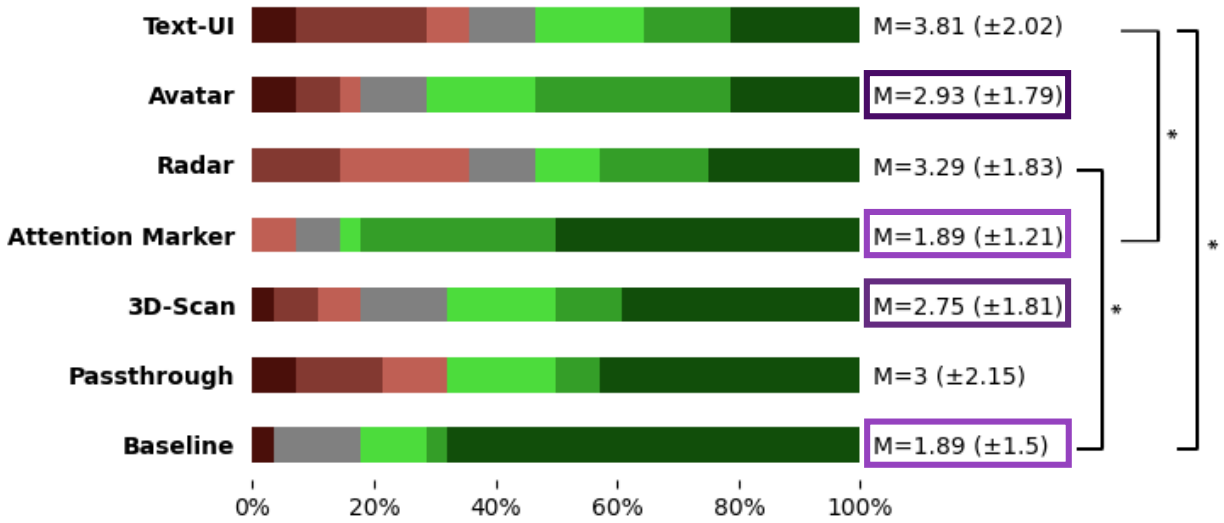
Noticeability



Understandability

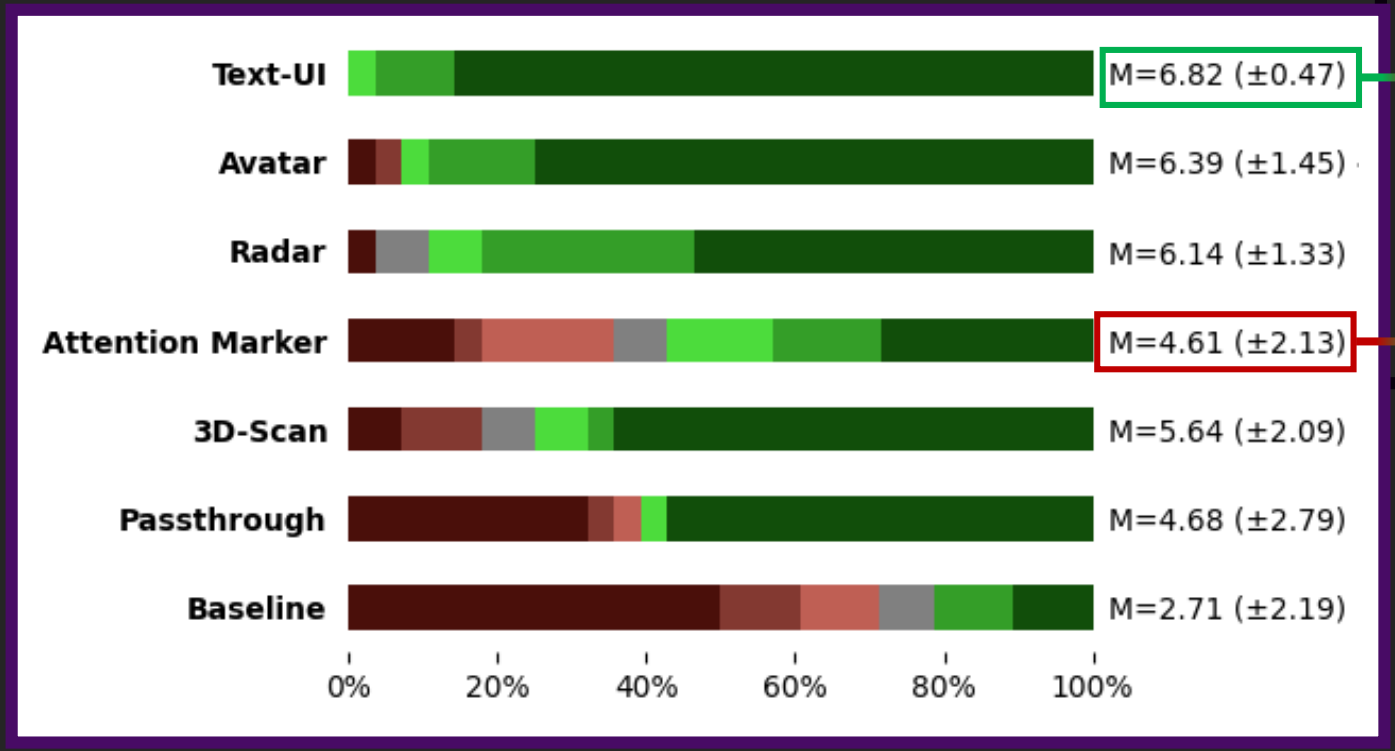


Perceived Intrusiveness

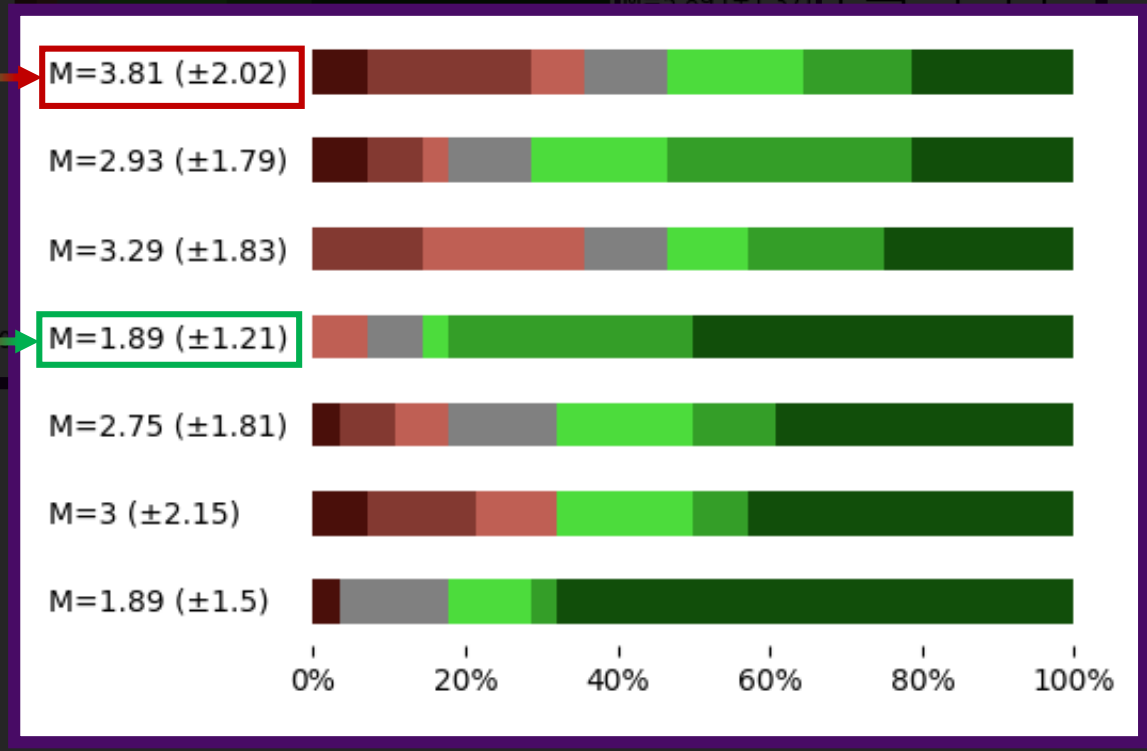


Extremely Difficult/Intrusive | Difficult/Intrusive | Somewhat Difficult/Intrusive | Neither Difficult/Intrusive nor Easy/Unintrusive | Somewhat Easy/Unintrusive | Easy/Unintrusive | Extremely Easy/Unintrusive

Noticeability



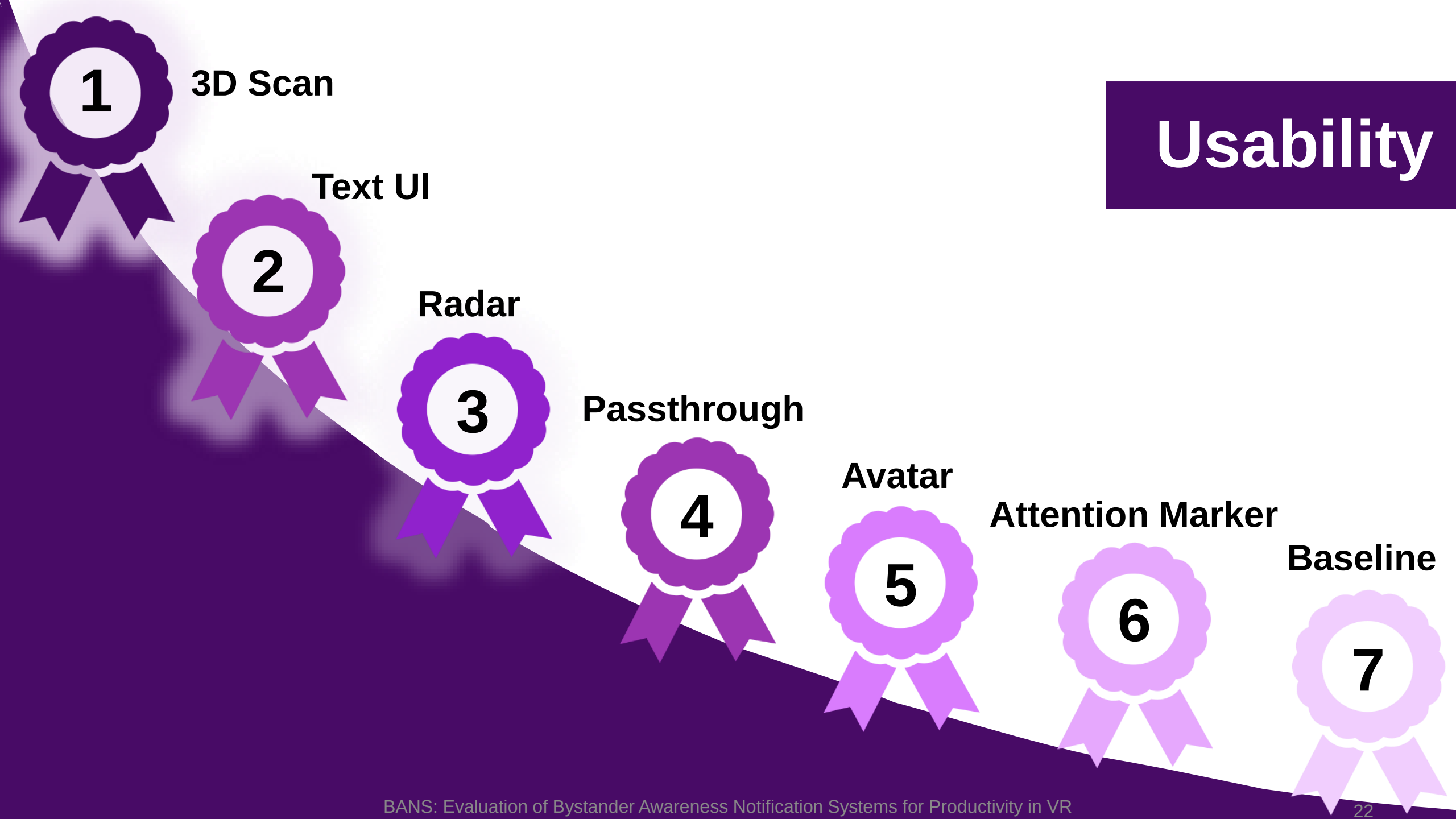
Perceived Intrusiveness



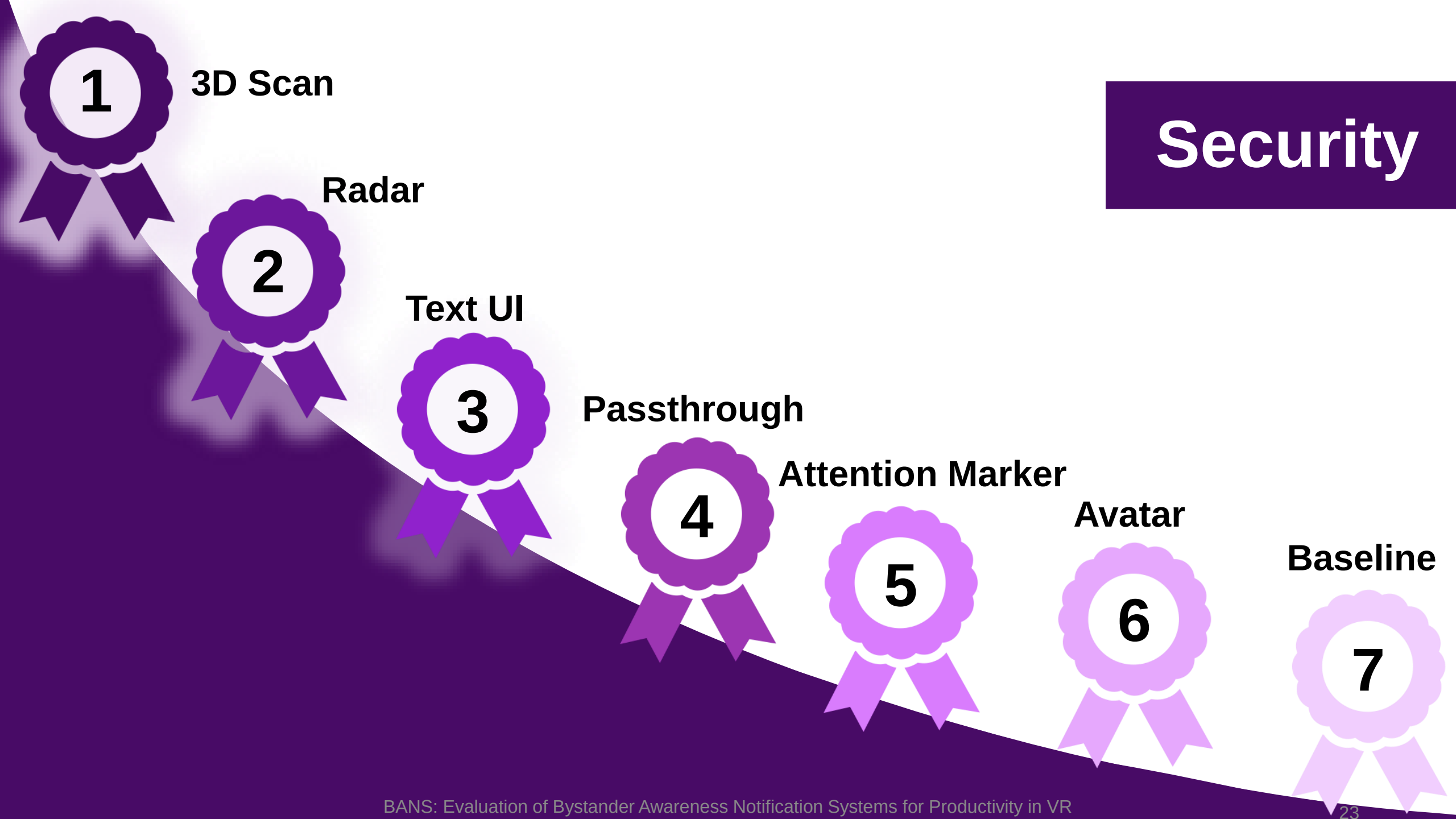
Understandability

Extremely Difficult/Intrusive | Difficult/Intrusive | Somewhat Difficult/Intrusive | Neither Difficult/Intrusive nor Easy/Unintrusive | Somewhat Easy/Unintrusive | Easy/Unintrusive | Extremely Easy/Unintrusive

Usability


1
3D Scan
2
Text UI
3
Radar
4
Passthrough
5
Avatar
6
Attention Marker
7
Baseline

Security


1
3D Scan
2
Radar
3
Text UI
4
Passthrough
5
Attention Marker
6
Avatar
7
Baseline

“BANS increase VR users’ bystander awareness and help them preserve their privacy without negatively impacting their sense of presence ”

Questions

Recommendations

1

Consider how VR users can best be transitioned between realities when their bystander reality awareness is of relevance due to privacy or safety reasons.

2

HMDs equipped with BANS should be designed and implemented to support both VR users and bystanders in preserving their privacy.

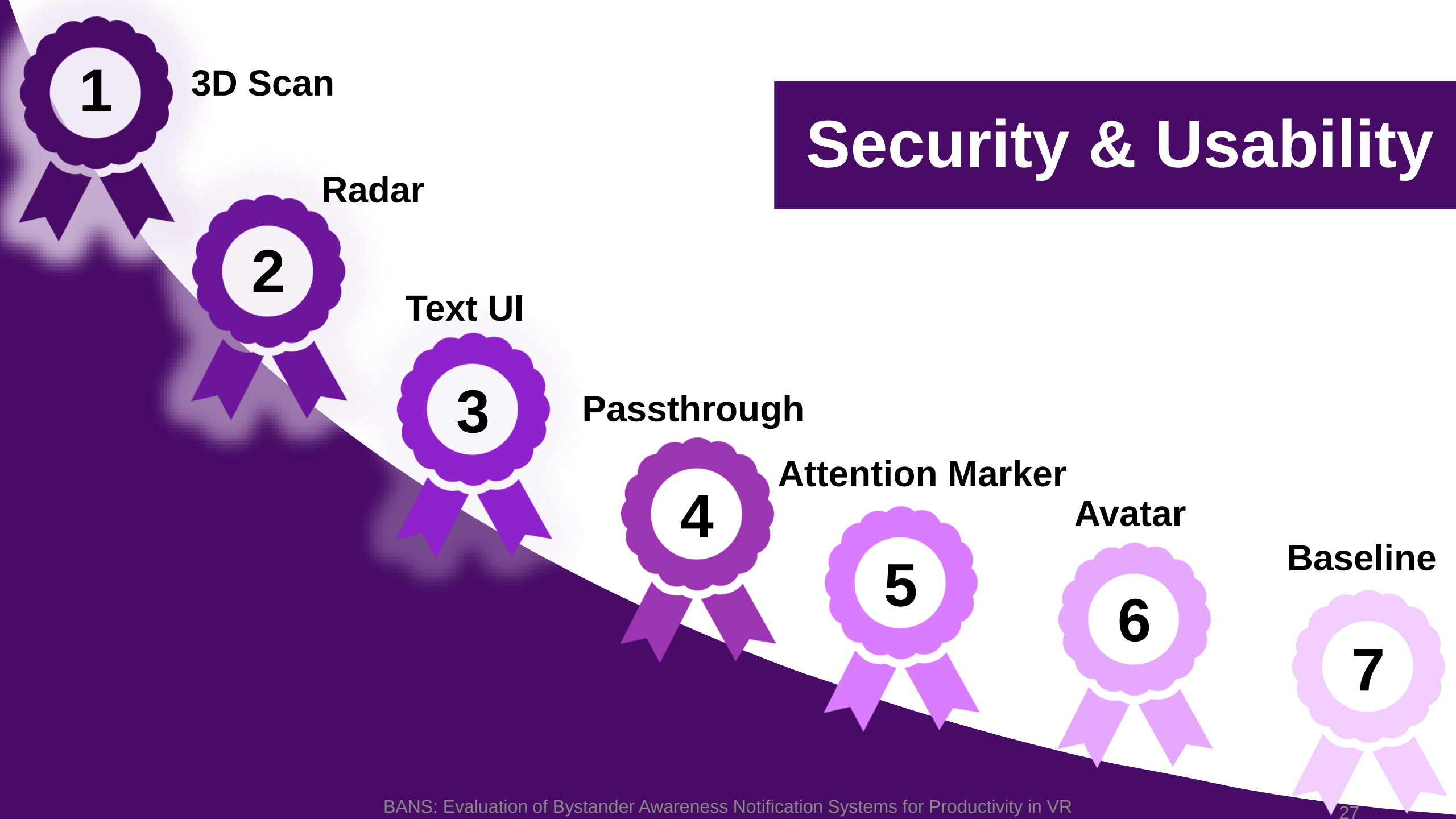
3

Notification systems should use different modalities, to support VR users in noticing out-of-view notifications.

4

VR users should be provided with full control over the BANS and their functionality.

Security & Usability



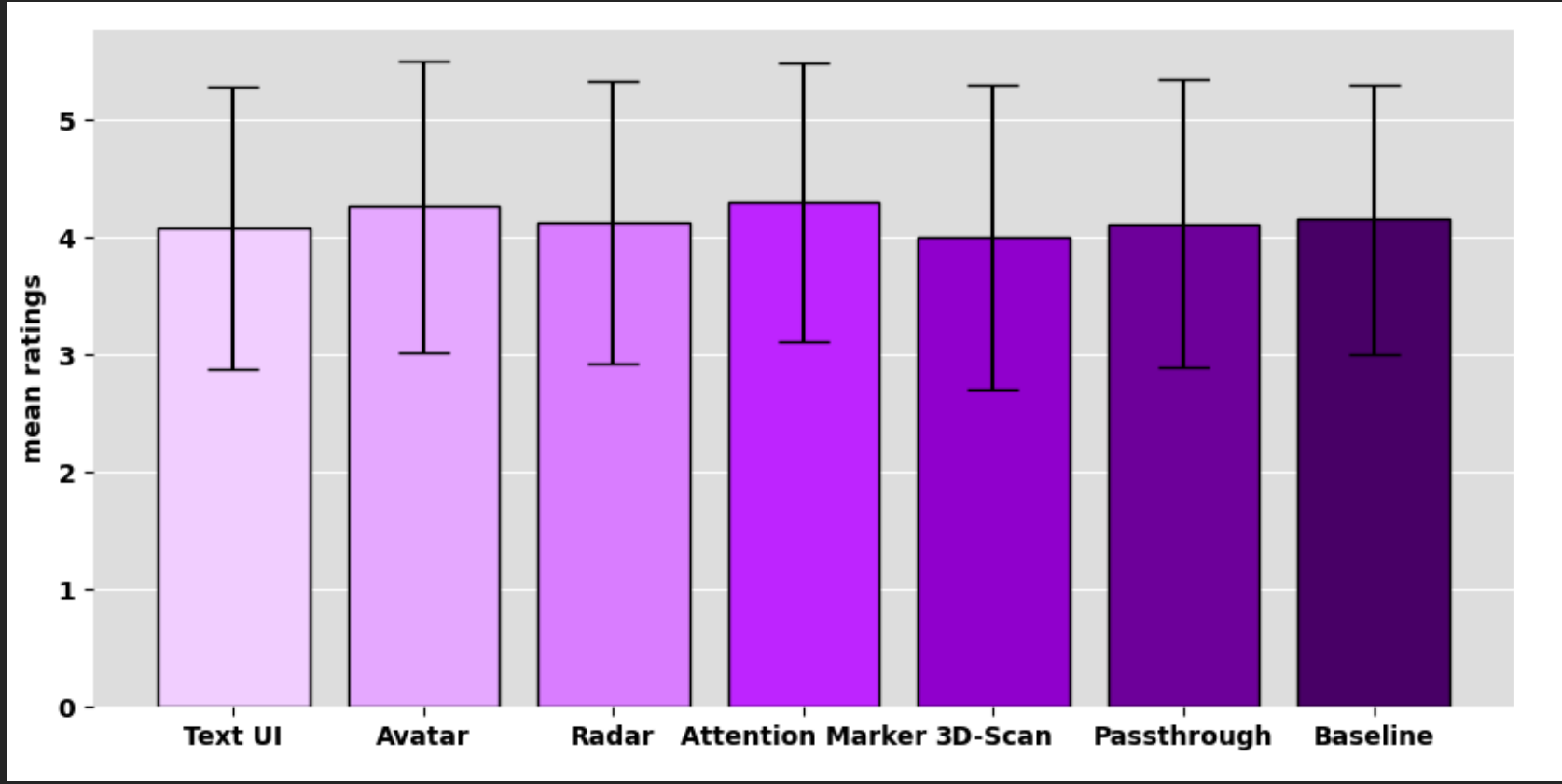
Results

	(1) Baseline	(2) Text UI	(3) Avatar	(4) 2D-Radar	(5) Attention Marker	(6) 3D-Scan	(7) Passthrough	Friedman Test		Nemenyi *Post-hoc*
IPQ	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	χ^2	$p-value$	**Significant Pairs**
Spatial Presence	4.15 (1.14)	4.08 (1.21)	4.26 (1.24)	4.12 (1.20)	4.30 (1.19)	4.00 (1.30)	4.12 (1.22)	5.95	0.43	NA
Involvement	3.88 (1.25)	3.76 (1.20)	3.62 (1.18)	3.86 (1.21)	3.91 (1.20)	3.37 (1.39)	3.18 (1.29)	17.29	0.008	2-7, 5-7
Realism	3.37 (0.94)	3.27 (0.70)	3.14 (0.89)	3.29 (0.65)	3.46 (0.78)	3.29 (0.79)	3.09 (0.89)	4.53	0.61	NA
General Presence	4.46 (1.38)	4.00 (1.56)	4.43 (1.15)	4.07 (1.49)	4.36 (1.29)	4.25 (1.50)	4.36 (1.42)	4.07	0.67	NA
	M (SD)	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	χ^2	$p-value$	**Significant Pairs**
SUS	63.04 (31.26)	80.80 (15.38)	78.12 (17.82)	77.86 (17.61)	77.14 (18.73)	83.57 (17.82)	72.59 (25.32)	12.19	0.058	NA
7-point Likert Scale	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	χ^2	$p-value$	**Significant Pairs**
Noticeability	2.71 (2.19)	6.82 (0.47)	6.39 (1.45)	6.14 (1.33)	4.61 (2.13)	5.64 (2.09)	4.68 (2.79)	59.75	< 0.001	1-2, 1-3, 1-4, 1-6, 2-3, 2-5
Understandability	2.89 (2.18)	6.57 (1.08)	5.96 (1.72)	5.89 (1.37)	4.57 (2.11)	5.68 (1.96)	4.39 (2.54)	55.44	< 0.001	1-2, 1-3, 1-4, 1-6, 2-5, 2-7
Perceived Intrusiveness	1.89 (1.50)	3.61 (2.02)	2.93 (1.79)	3.29 (1.83)	1.89 (1.21)	2.75 (1.81)	3.00 (2.15)	26.97	< 0.001	1-2, 1-4, 1-5

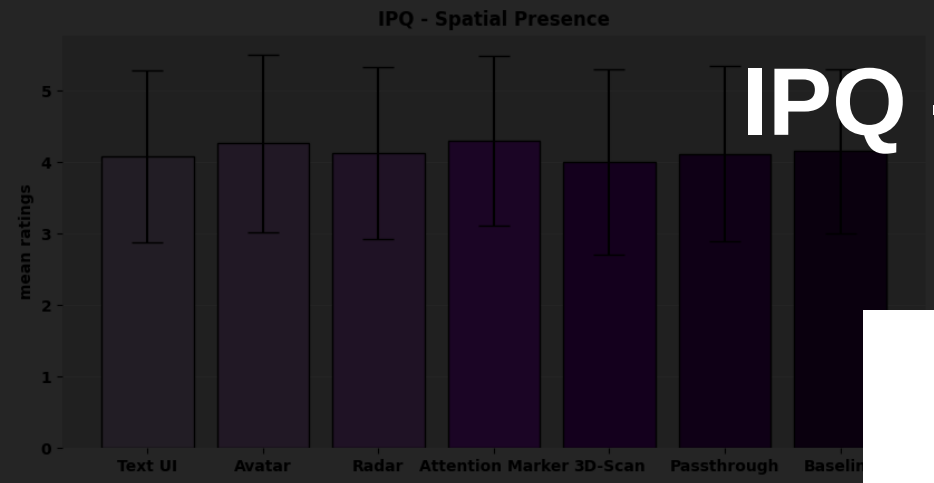
**Green denotes greatest mean, Yellow second greatest, and Orange third greatest. Red highlights the lowest mean. Blue denotes $p < 0.005$

IPQ – Spatial Presence

- Highest: **Attention Marker**
- Lowest: **3D Scan**
- No significant differences
- Users' sense of spatial presence wasn't affected

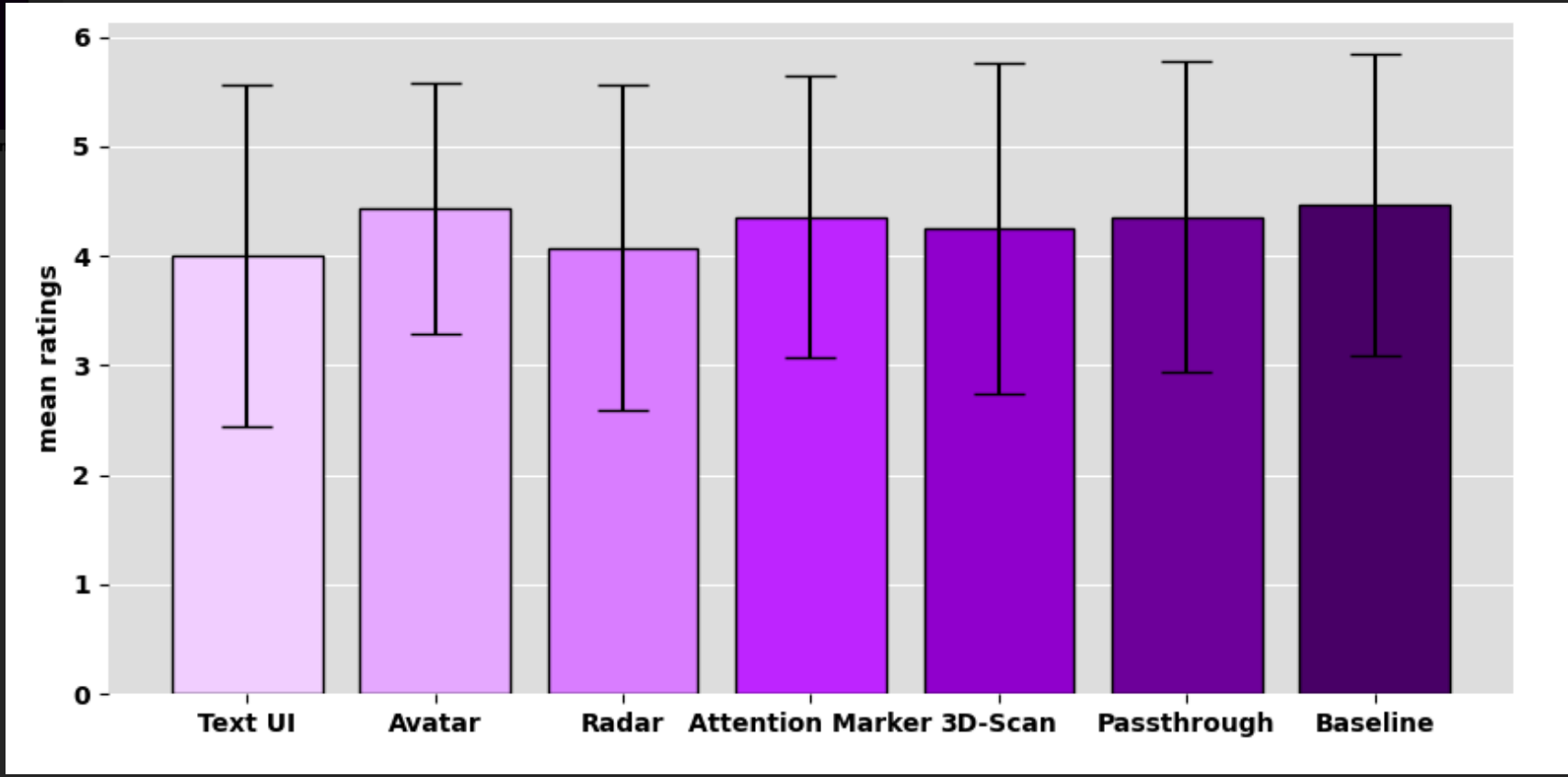


***Error bars denote standard deviation**



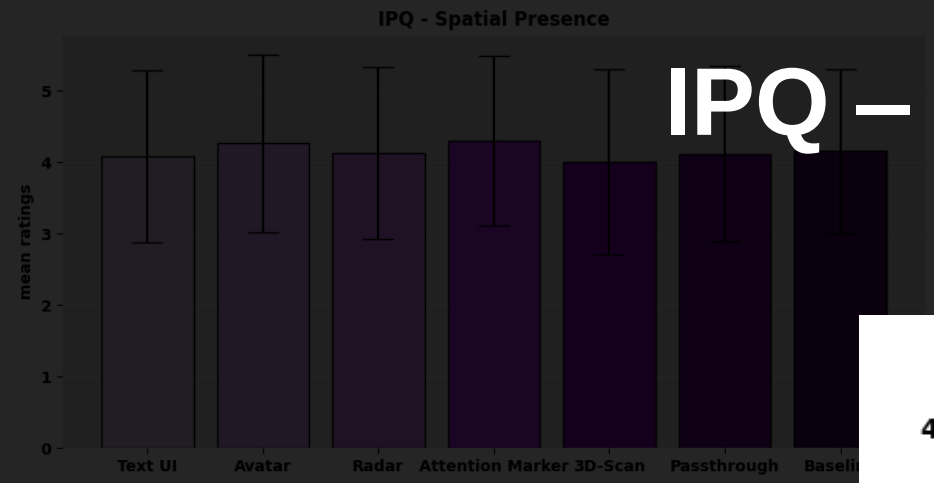
IPQ – General Presence

- Highest: **Baseline**
- Lowest: **Text UI**
- No significant differences
- Users’ general sense of presence wasn’t affected

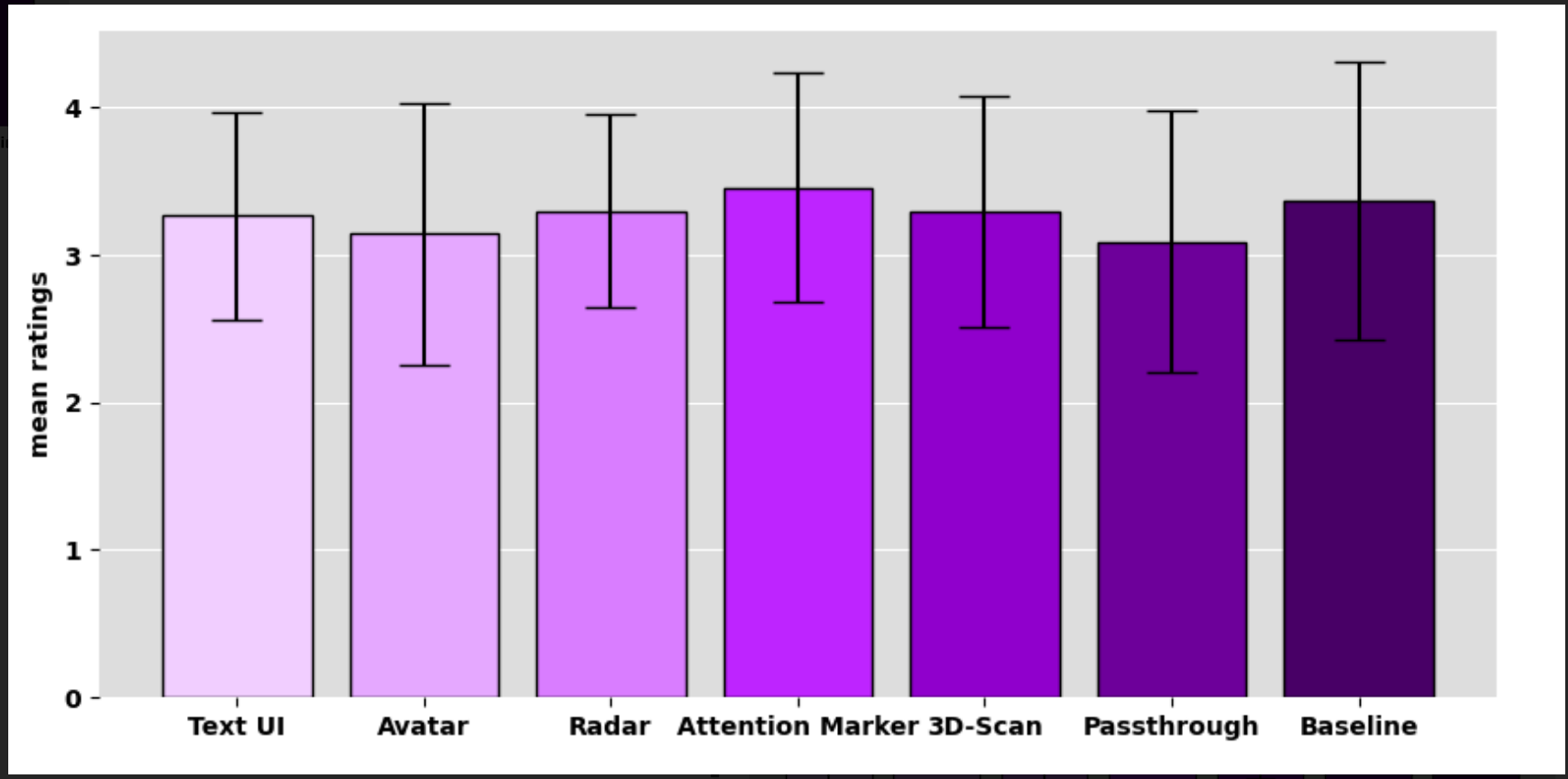


***Error bars denote standard deviation**

IPQ – Experienced Realism



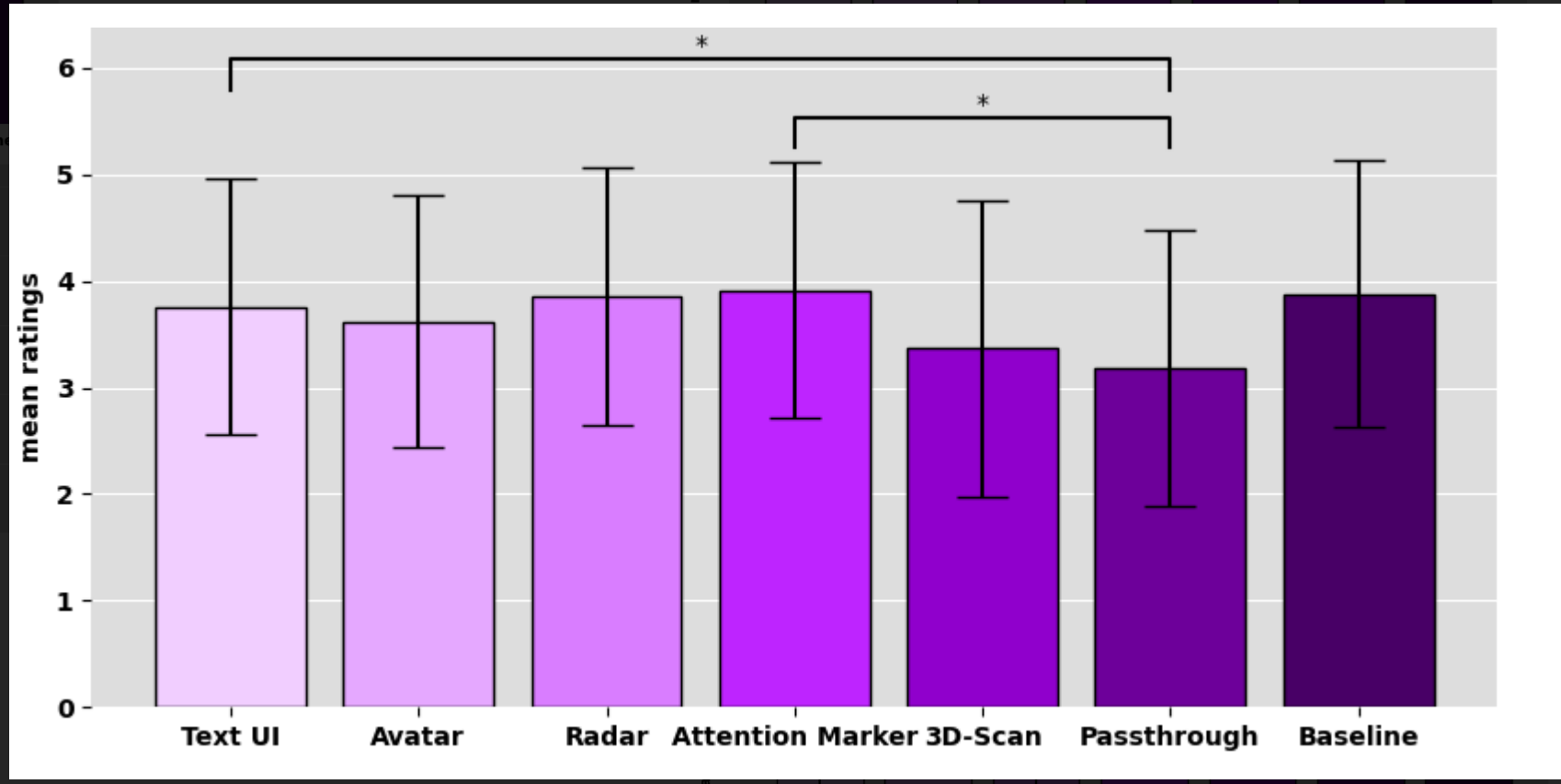
- Highest: **Attention Marker**
- Lowest: **Passthrough**
- No significant differences
- Users' sense of spatial presence wasn't affected



***Error bars denote standard deviation**

IPQ – Involvement

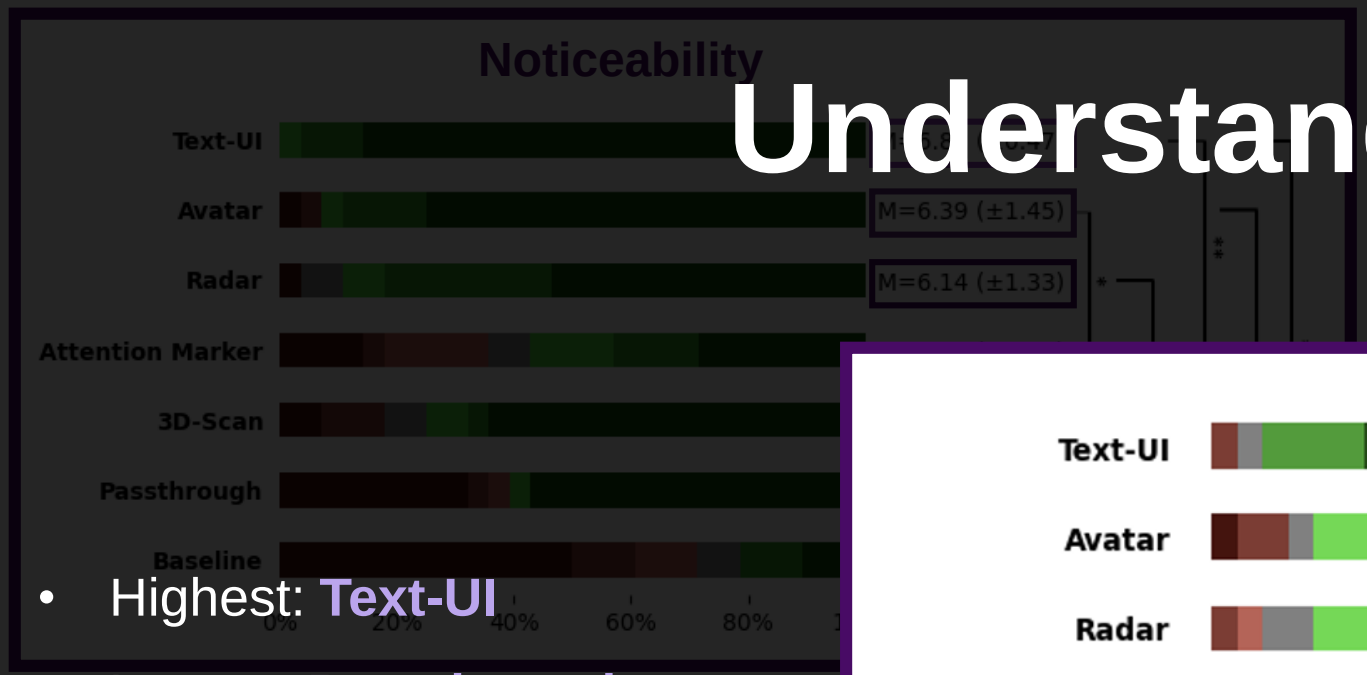
- Highest: **Attention Marker**
- Lowest: **Passthrough**
- Significant differences detected
- Users' sense of involvement was affected

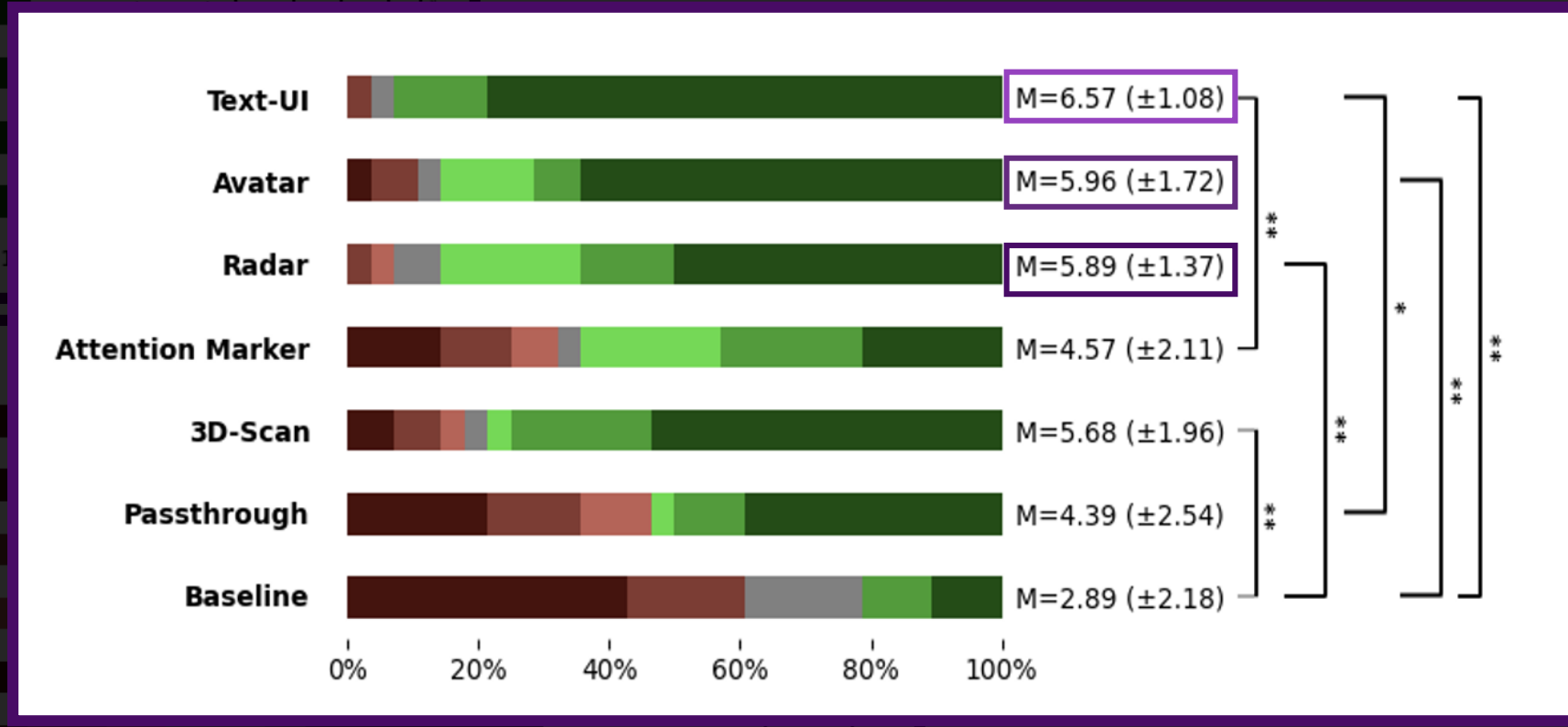


*Error bars denote standard deviation

Understandability

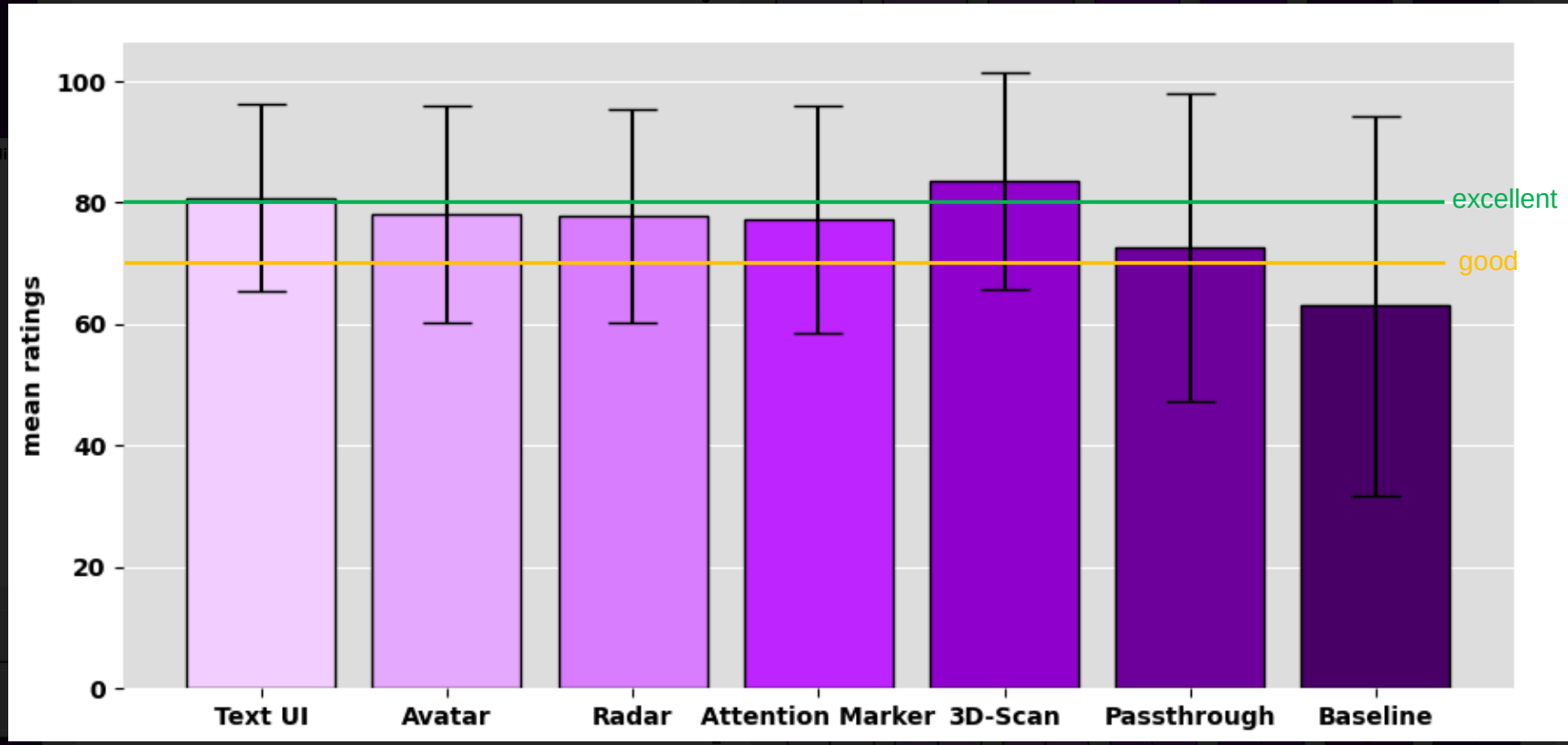
- Highest: **Text-UI**
- Lowest: **Passthrough**
- Significant differences detected





System Usability Scale

- Highest: **3D Scan**
- Lowest: **Baseline**
- No significant differences
- Usability of the notification systems is between good and excellent



*Error bars denote standard deviation

Tasks

1. **Windows Login**
   Login to windows using username and password followed by pin verification

2. **Change Email Password**
   The user enters his old password (from task 1) and then types a new one 2 times followed by pin verification

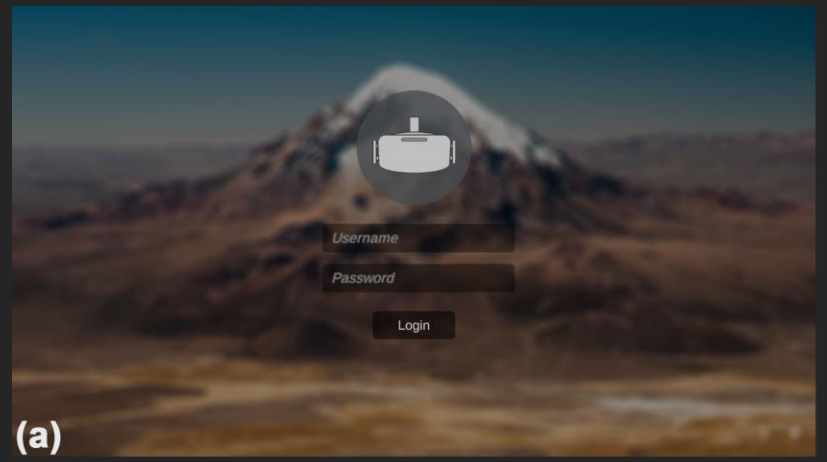
3. **Send a Confidential Email**
   The user sends a confidential email to their co-worker containing a pin code

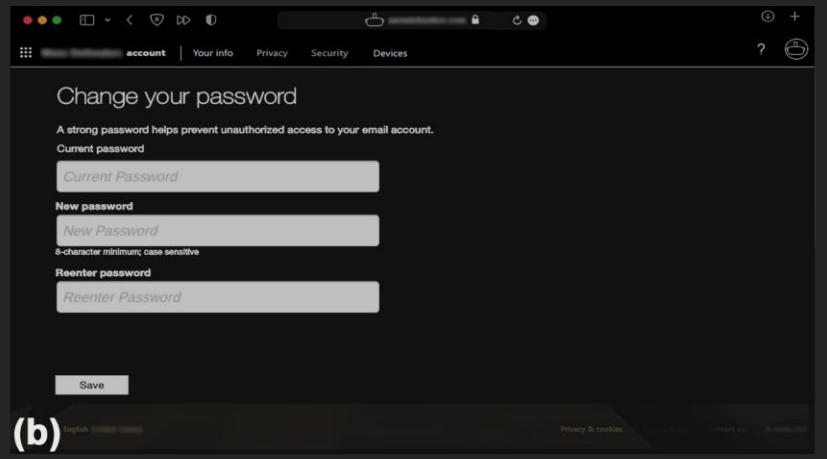
4. **Login to Paypal**
   The users logs in to Paypal using email and password followed by a security question

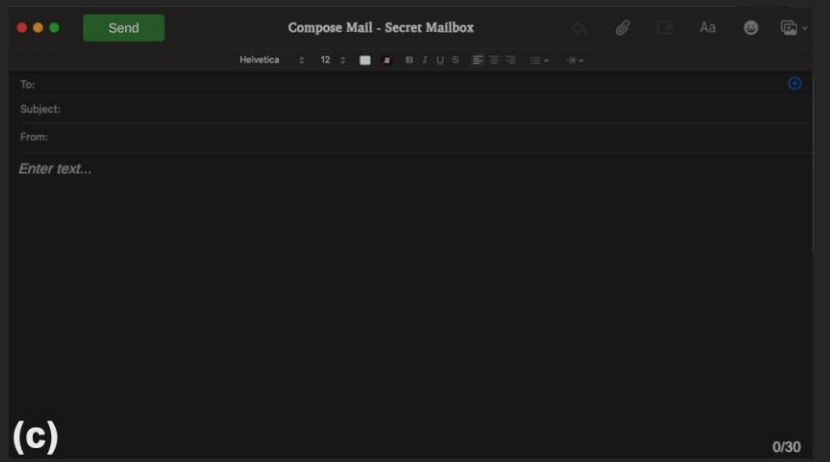
5. **Add Address to Amazon**
   The user fills in 5 fields containing personal information

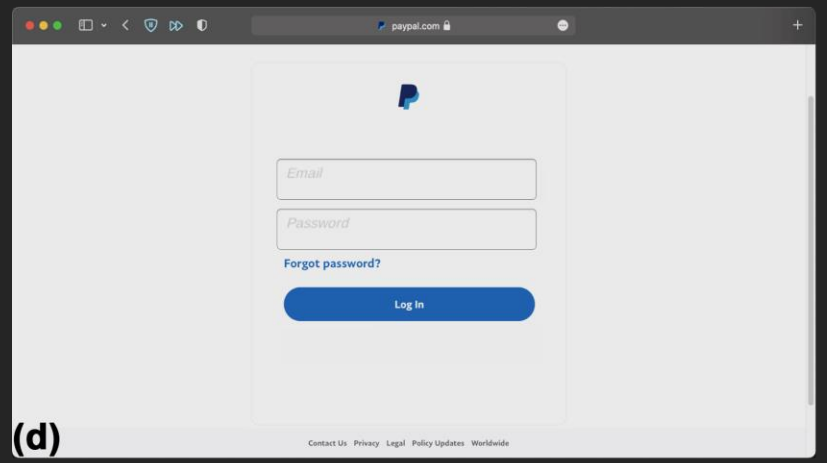
6. **Login to University Portal**
   The users logs in to the university portal using email, password and matriculation number

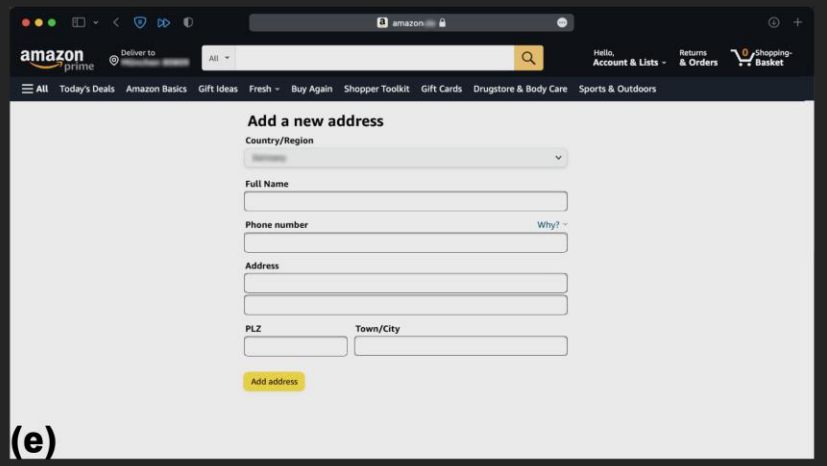
7. **Book a Flight**
   The users enters credit card details to book a flight

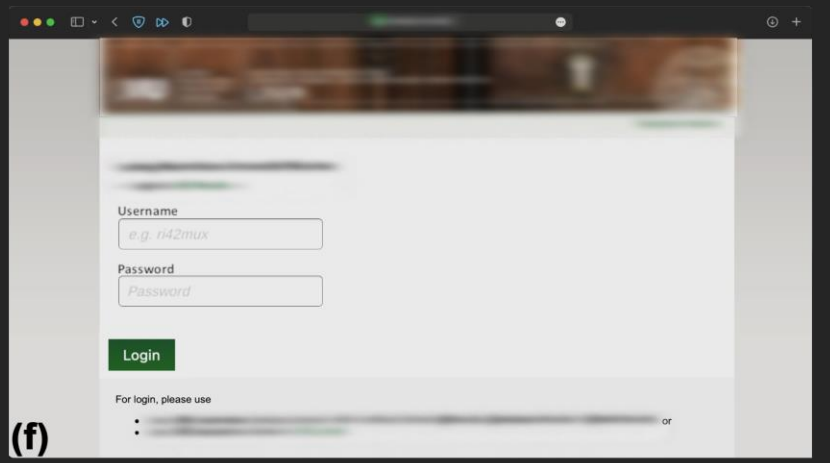

Username
Password
Login
(a)

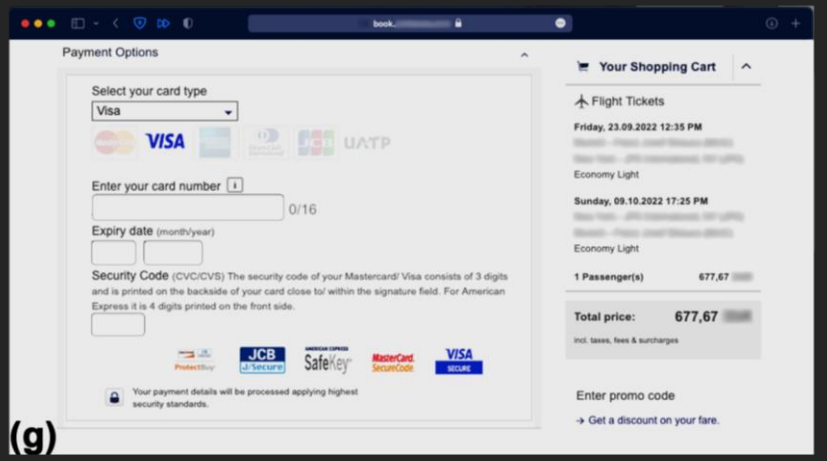

account
Your info
Privacy
Security
Devices
Change your password
A strong password helps prevent unauthorized access to your email account.
Current password
Current Password
New password
New Password
8-character minimum; case sensitive
Reenter password
Reenter Password
Save
(b)


Send
Compose Mail - Secret Mailbox
To:
Subject:
From:
Enter text...
(c)
0/30


paypal.com
Email
Password
Forgot password?
Log In
Contact Us
Privacy
Legal
Policy Updates
Worldwide
(d)


amazon
Add a new address
Country/Region
Full Name
Phone number
Why?
Address
PLZ
Town/City
Add address
(e)


Username
e.g. ri42mux
Password
Login
For login, please use
(f)


Payment Options
Select your card type
Visa
Enter your card number
0/16
Expiry date (month/year)
Security Code (CVC/CVS) The security code of your Mastercard/ Visa consists of 3 digits and is printed on the backside of your card close to/ within the signature field. For American Express it is 4 digits printed on the front side.
Your payment details will be processed applying highest security standards.
Your Shopping Cart
Flight Tickets
Friday, 23.09.2022 12:35 PM
Economy Light
Sunday, 09.10.2022 17:25 PM
Economy Light
1 Passenger(s)
677,67
Total price:
677,67
Enter promo code
Get a discount on your fare.
(g)

User Study

Procedure

Before the simulation:
- **Demographic**

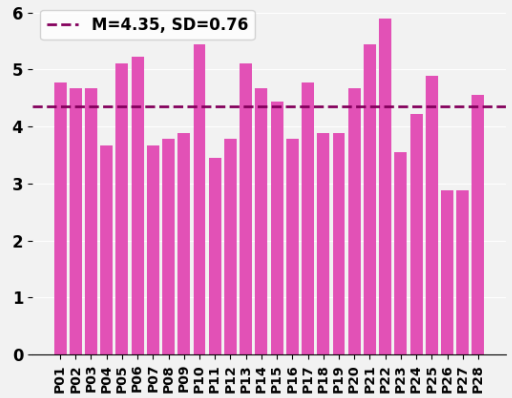
After the simulation:
- **Semi-structured interview:**
  - Order notification methods by preference
  - General feedback

During the simulation:
- **24 Likert scale questions:**
  - How easy or difficult is it to notice the notification?
  - Once you notice the notification, how easy or difficult is it to understand what it stands for?
  - How much of a hindrance was the notification to the overall VR experience?
  - iGroup presence questionnaire (IPQ)
  - System Usability Scale (SUS)

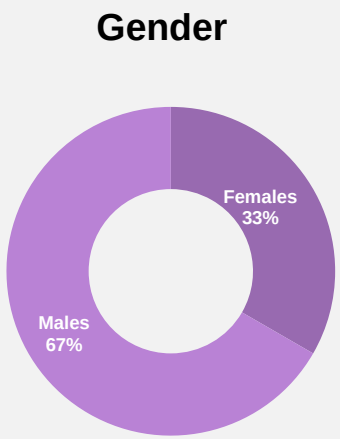
Structure

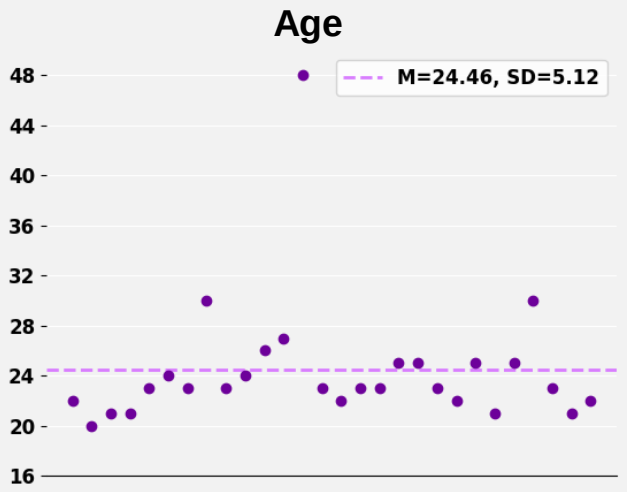
Nested Realities:
- **Simulated Reality:**
  - Moving train with passengers
  - Keyboard and headset visible
  - User wears headset to enter the VR
- **Virtual Reality:**
  - Virtual office
  - 7 Productivity Tasks
  - User goes back to the SR to answer the questionnaire after each task

Demographics

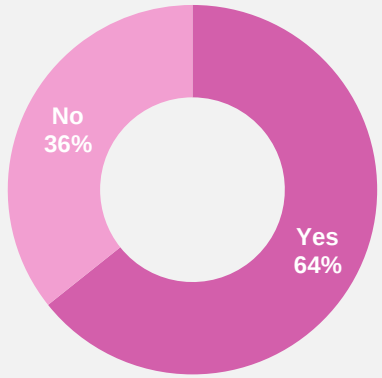


Affinity for Technology Interaction (ATI)





Participants



Previous Experience with VR