



SINTEF

# Trustworthy Metaverse



Shukun Tokas  
SINTEF Digital

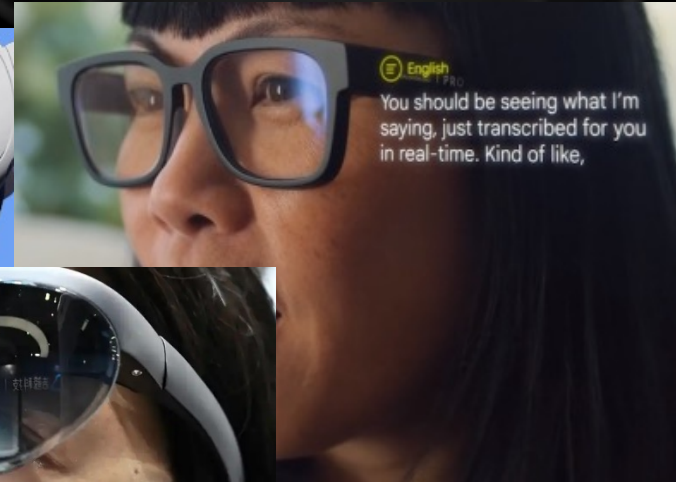
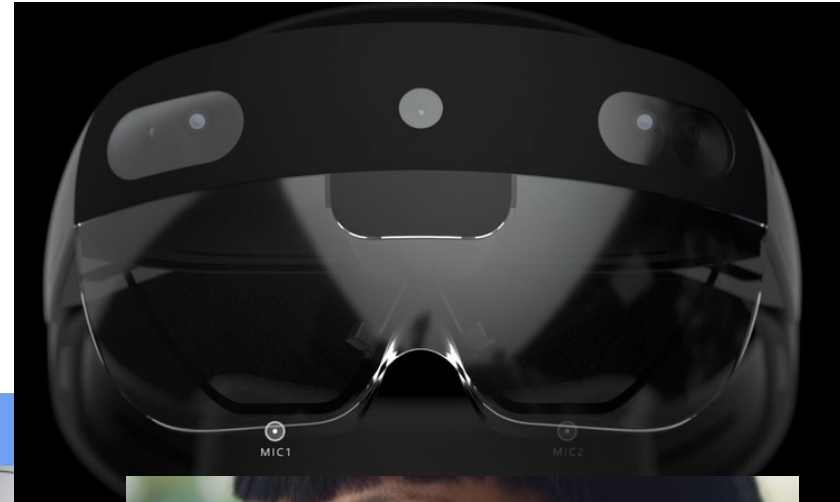


Technology for a better society



SINTEF

# AR/VR headsets





SINTEF

# Tech specification of Hololens

**Head tracking:** 4 visible light cameras

**Eye tracking:** 2 IR cameras

**Depth:** 1-MP Time-of-Flight (ToF) depth sensor

**IMU:** Accelerometer, gyroscope, magnetometer

**Camera:** 8-MP stills, 1080p30 video

**Microphone array:** 5 channels

**Speakers:** Built-in spatial sound





SINTEF

# Innovative (surveillance) technologies strapped to face to enhance our lives



- Immersive learning
  - More visual, interactive way to learn
- Immersive entertainment
- Immersive work environment
- Virtual vacations ...
- TRACKING: Face – Head – Eye – Body
  - mimic facial, micro-expressions, eye contact.
- 6DoF tracking
- Spatial mapping



# Pre-metaverse world

- Revenue for publishers and audiences for advertisers
  - Website publisher auction space on webpage, advertiser buys it to reach potential consumer
  - Billions of online ads are placed on webpages/apps every day (**RTB**: real time bidding)
- Advertisements fund much of what we enjoy online
- Information included in a bid request
  - User location, time zone, device type, sites visited, page interactions (scrolling, clicking, highlighting), search queries, demographic data
  - Directly received / inferences: mental health, health conditions, sexual health, reproductive health, ethnic groups, substance abuse,



SINTEF

# Facts: ICCL note on scale of Real-Time Bidding data broadcasts

- US, people have their location exposed 747 times a day
- EU, location exposed 376 times a day
- “RTB tracks and broadcasts what a person in Germany is doing online roughly once per minute that they are online”
- Biggest RTB companies include Google, Microsoft ([Xandr](#))



SINTEF

# % share of RTB broadcasts per company per European country

	Google	Index Exchange	PubMatic	Magnite	Microsoft (Xandr)	BidSwitch	OpenX	Smar
Austria	23%	13%	16%	10%	8%	8%	7%	5
Belgium	22%	11%	14%	10%	10%	9%	7%	5
Bulgaria	35%	19%	6%	14%	4%	6%	9%	3
Croatia	25%	18%	9%	15%	5%	2%	18%	3
Cyprus	35%	13%	6%	10%	5%	6%	8%	2
Czech Republic	30%	9%	19%	14%	14%	2%	2%	2
Denmark	26%	10%	14%	13%	13%	4%	4%	1
Estonia	30%	14%	10%	16%	5%	7%	5%	2
France	22%	13%	13%	10%	9%	8%	4%	8
Germany	21%	19%	15%	9%	6%	7%	7%	5
Greece	32%	24%	7%	8%	4%	3%	14%	1
Hungary	38%	7%	7%	20%	6%	5%	5%	3
Ireland	17%	14%	17%	10%	7%	8%	9%	2
Italy	22%	10%	13%	11%	6%	10%	6%	8
Latvia	31%	17%	6%	14%	5%	6%	9%	4
Liechtenstein	8%	14%	14%	13%	11%	2%	9%	4
Luxembourg	23%	16%	8%	10%	8%	6%	7%	5
Malta	17%	14%	9%	10%	8%	4%	11%	3
Netherlands	20%	9%	16%	22%	9%	5%	5%	3
Norway	21%	4%	5%	17%	37%	2%	2%	1
Poland	20%	19%	12%	9%	4%	9%	15%	5



SINTEF







SINTEF

# Experiment Setup



Meta Quest 2

Sensors: 3

Camera: 4

Tracking: Hand



Meta Quest Pro

Sensors: 6

Camera: 5 external, 5 internal

-eyes (2), upper face (1), lower face (2)

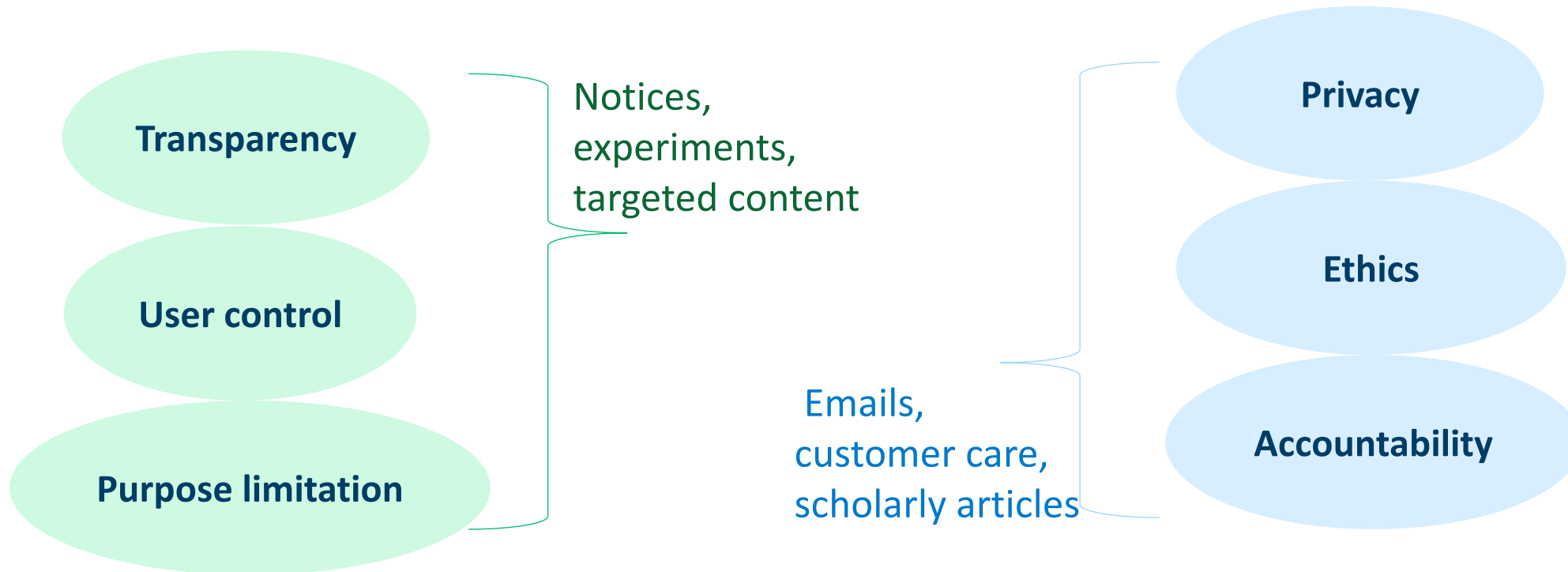
-front facing (3), side facing (2)

Tracking: Hand, face, eye



# Trustworthiness of Meta's Metaverse

- Key elements contributing to trustworthy metaverse:





SINTEF

# Meeting in Metaverse: Horizon World



Oda



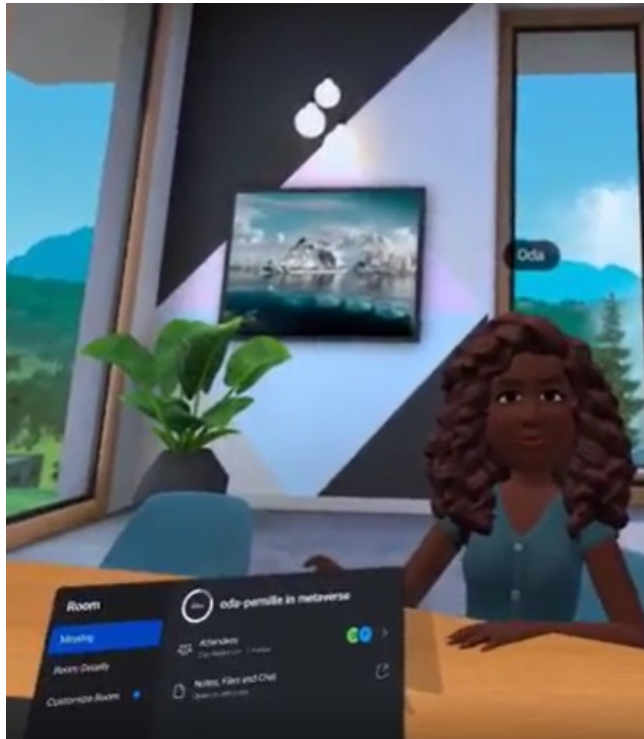
Pernille



SINTEF

# Horizon World Meeting

Oda



Pernille



## Study

- Investigate if facial expressions affect targeted content
- Pernille's expressions: lack of emotional reactivity, lowered eyebrows, frowns, looking 'down' or 'away', less intense-shorter smiles.
- Screen recordings of facebook feed were taken before and after experiment

- Home
- Pernille Nord
- Friends
- See all
- See all groups
- See all shortcuts

**Moonsoulchild** 11h · 🌐


From my book "I Was Never Broken: Vol. 2"  
Get a copy on Amazon ✨




I Was Never Broken Vol. 2

APRIL 16, 2021  
5:39 PM

**Sponsored**


 m51.no

 Linderud Senter  
linderudsenter.no

**Group conversations**

+ Create new group




 Home

 Pernille Nord

 Friends

 See all

 See all groups

 See all shortcuts

## Suggested groups



### Braids and Hairstyles

5.3M members • 10+ posts a day

 Private group

Join group

### Private group

20M members • 10+ posts a day

 Public group

[See more groups](#)



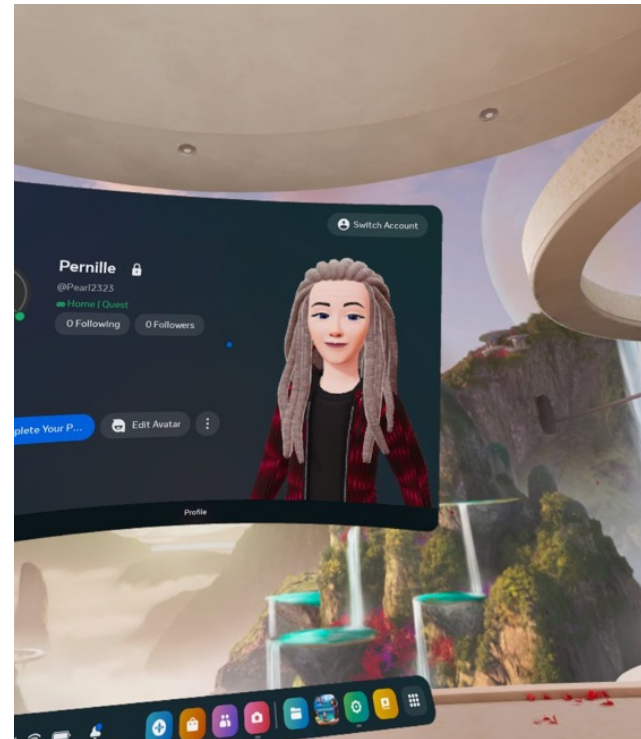
SINTEF

# Horizon World Meeting

Oda (Quest 2)



Pernille (Quest Pro)



## Study

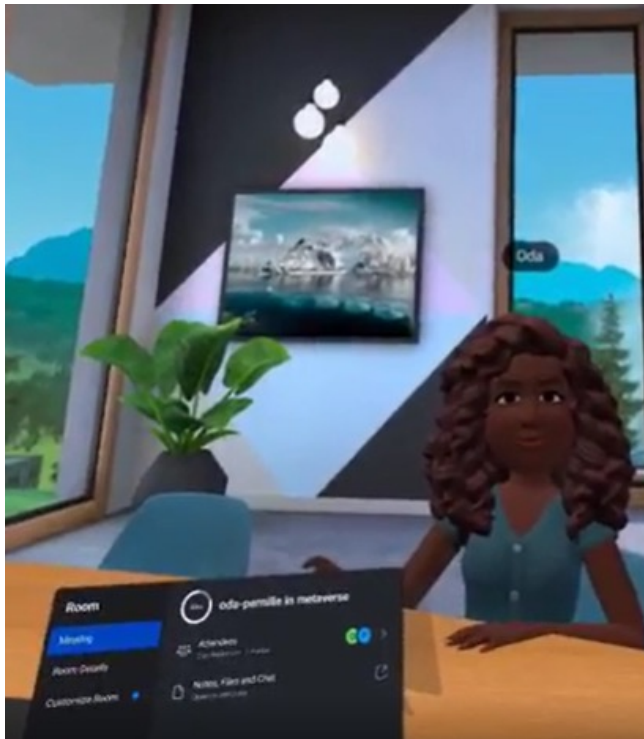
- Result: **TARGETED** content for person behind avatar
  1. Motivational content, first two facebook feed. Results captured after 20 mins of experiment.
  2. Advertisement targeted to IP address on headset
    - IP of laptop used for facebook feed has SINTEF **Trondheim** location
    - IP of VR headset has **Oslo** location
    - **Content targeted for Oslo**
    - Uses voice, face, eye data for personalization



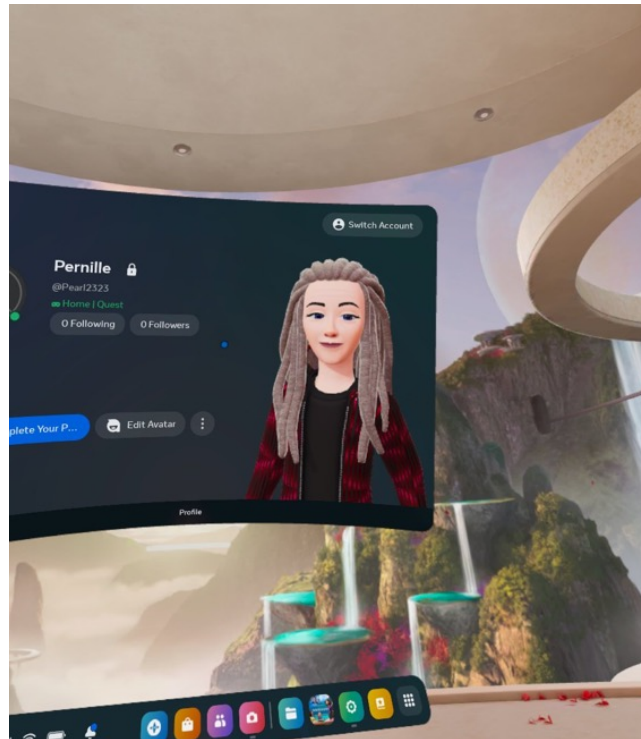
SINTEF

# Horizon World Meeting

Oda (Quest 2)



Pernille (Quest Pro)



## Sensors on VR headset good enough?

- Quest 2, uses voice for avatar facial expression, reasonably good avatar expressions
- Hand tracking works reasonably well, without hand controllers





SINTEF

# Can be in metaverse via avatar or video





Cues when being recorded

When participant in the meeting makes a video recording, others in the meeting should be given some audio/visual/textual cue that they are being recorded, but no cues were shown to other participants in meeting.



# Session recording: Transparency?

- Meeting organizer have control, can **record** whole session, without
  - Participant's consent
  - Visual/audio/textual cue
- Meta's response: "**Before recording a video, the person who is recording**, this will be you, **should always ask** if the other participants agree to being recorded."

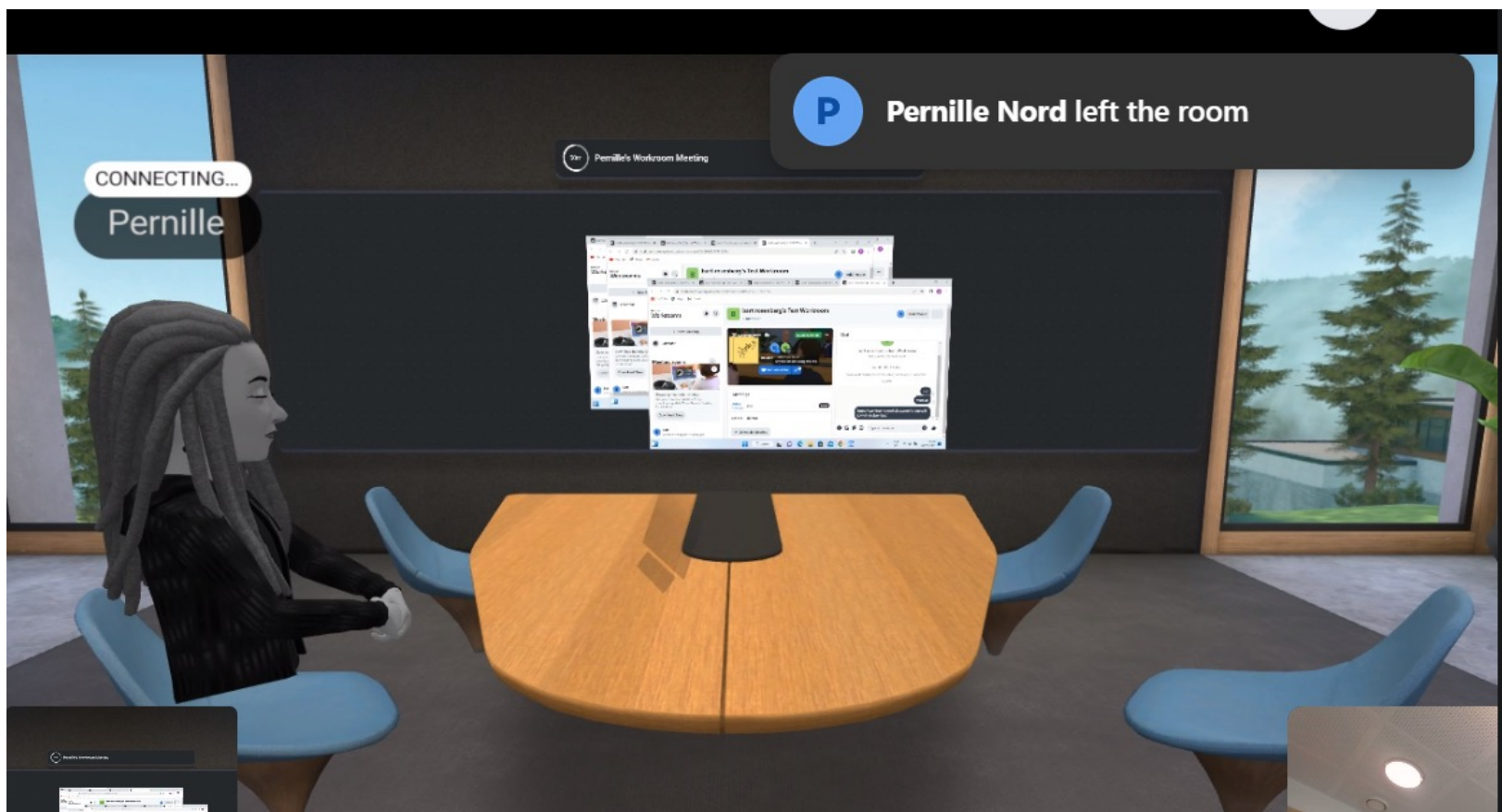


SINTEF





SINTEF



Pernille left the meeting, but her screen was still shared with participants.



# Purpose limitation?

- **Natural facial expressions.** If you choose to enable Natural Facial Expressions in Meta Quest Pro, we process your abstracted facial expressions data to make your avatar's expressions look more natural in VR. Raw image data of your face is stored on your device.

We also collect and retain certain data about your interactions with Natural Facial Expressions (such as how much time it takes to detect expressions) to provide the feature and ensure that it works properly. Learn more in our [Natural Facial Expressions Privacy Notice](#).



SINTEF

# Transparency

## When Natural Facial Expressions is Enabled

When you choose to enable Natural Facial Expressions on the headset or in a specific app, software on the Meta Quest Pro headset analyzes infrared images of your face (“raw image data”) to create an estimate of how your face is moving, producing a set of generic facial expressions, like a broad smile or frown, (“abstracted facial expressions data”) that animate your avatar in VR. This estimation is done on your device in real time as your face moves. The raw image data is deleted from your headset after the abstracted facial expressions data is generated. The abstracted facial expressions data is continuously generated and overwritten in real time as it provides this feature. If you also enable [eye tracking](#), your headset will



# Purpose limitation? Ethics? User Control?

## When Natural Facial Expressions is Enabled

When you choose to enable Natural Facial Expressions on the headset or in the app, we will collect additional data about how you use your headset (including facial movements).

If you have chosen to share additional data with Meta, we collect additional data about how you use your headset (including Natural Facial Expressions) to help Meta personalize your experiences and improve Meta Quest. [Learn more](#). Data sent to and stored on our servers will be disassociated from your account when we no longer need it to provide the service or improve the Natural Facial Expressions feature. If you







SINTEF

# Caveats in privacy notice

- Abstracted facial tracking information could be stored and processed by servers,
- Abstracted gaze data can be shared with third parties (where the data is subject to 3<sup>rd</sup> party privacy policies)
- Dark patterns are prevalent,
  - “Enable” buttons are more highlighted than the “Not Now” option.



SINTEF

# Caveats in privacy notice

- Abstracted facial tracking information could be stored and processed by servers,
- Abstracted gaze data can be shared with third parties (where the data is subject to 3<sup>rd</sup> party privacy policies)
- Dark patterns are prevalent,
  - “Enable” buttons are more highlighted than the “Not Now” option.

But: **what is abstracted facial expression / abstracted gaze data?**

: what personal/sensitive inferences can be made?



SINTEF

# Risks originating due to the nature of sensitive data processed

- **Sensitive inferences**, intrusive profiling
  - 3D camera that captures photos and videos with remarkable depth, providing more data about us and our environment (detailed map of face/env)
  - Data could be used to make inferences about sensitive aspects of peoples' lives
- Invisible and more intrusive data collection and processing
  - **Transparency** issues exist for the ecosystem (extended from traditional Internet Adtech). Opaque of data supply chain.
- Use of innovative technologies for **immersive personal surveillance**?
  - Imagine every step you take, every item you interact with, every face expression, every eye gaze, being recorded and analyzed.
- **AI-powered influence**: Polarization, weaken democracy, radicalization
- Extended virtual presence may lead to
  - mental health problems: anxiety, disconnection from reality, and depression



SINTEF

# Trustworthy metaverse

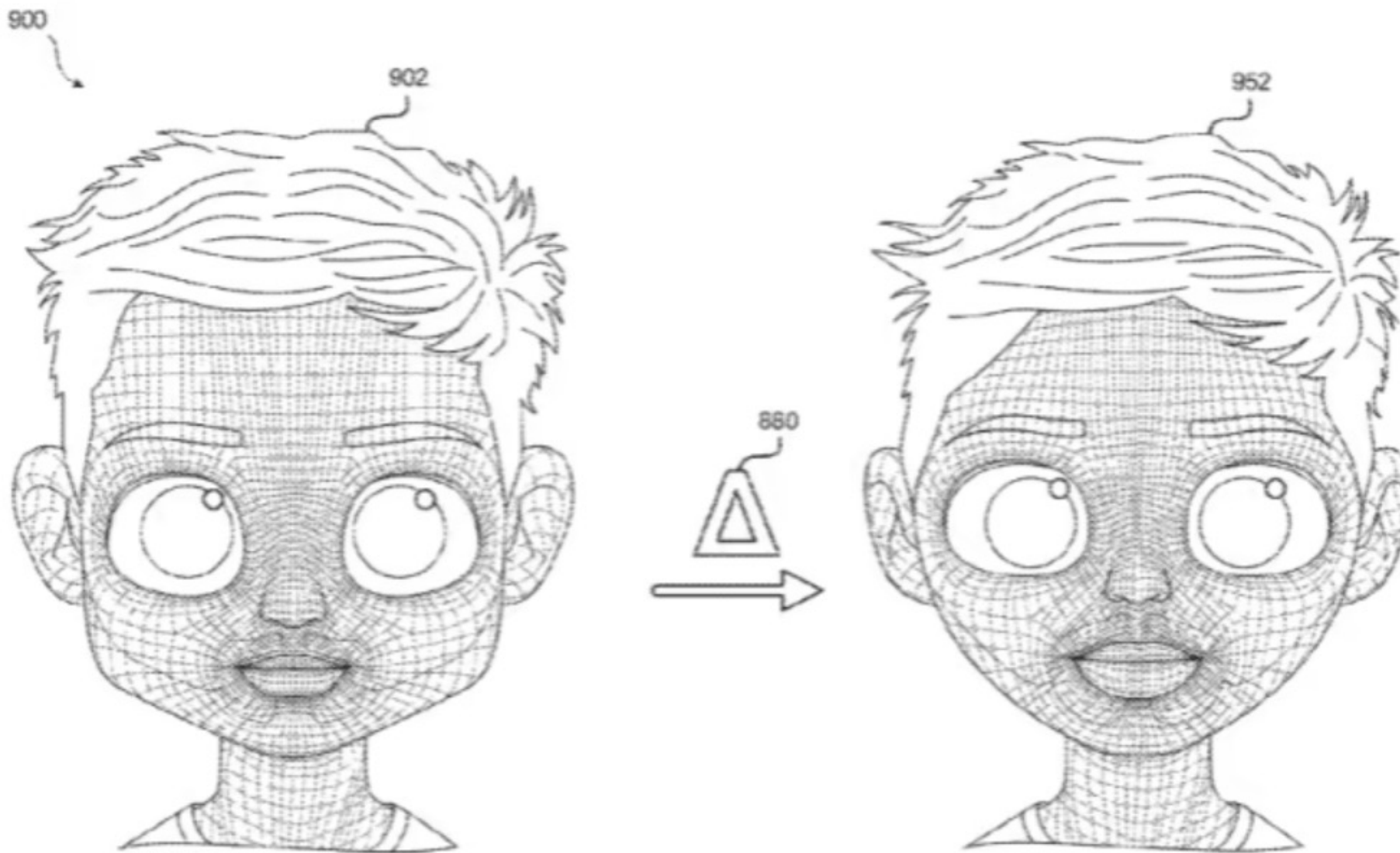
- We need to examine virtual and augmented worlds thoughtfully, evaluating not just their benefits for us but also their potential impact on us.
- These products are shaping our future interactions and experiences. Our role as scientists/designers/technologists/... in this process is crucial, to influence how these technologies impact our lives.
  - Products that respect our privacy, our autonomy, and our human values.



# Financial Times review on Meta's patent

- Patent applications are a good indicator of commercial R&D
- Facebook and key competitors have made significant numbers of patent applications for the AR/VR technologies.
  - Overall growth of over 300% in patent filings for AR/VR technology over 5 years.
- FT reviewed applications to the US Patent and Trademark Office. They reveal that **Meta** has patented multiple technologies that use users' biometric data to help power what the user sees and ensure their digital avatars are animated realistically.
- Patents relate to eye and face tracking technology, describing how to enhance a user's virtual or augmented reality experience. For example, a person will be shown brighter graphics where their gaze falls, or ensuring their avatar mirrors what they are doing in real life.

Src: <https://www.ft.com/content/76d40aac-034e-4e0b-95eb-c5d34146f647>



Meta patent application image showing an 'avatar personalisation engine' that can create 3D avatars based on a user's photos using tools such as a so-called skin replicator © Meta patent application



SINTEF

# References

- [1] Nair, V., Guo, W., Mattern, J., Wang, R., O'Brien, J.F., Rosenberg, L. and Song, D., 2023. Unique Identification of 50,000+ Virtual Reality Users from Head & Hand Motion Data. arXiv preprint arXiv:2302.08927.
- [2] Oh Kruzic, C., Kruzic, D., Herrera, F. and Bailenson, J., 2020. Facial expressions contribute more than body movements to conversational outcomes in avatar-mediated virtual environments. Scientific reports, 10(1), pp.1-23.
- [5] Anidjar, L.Y., Packin, N.G. and Panezi, A., 2023. The Matrix Of Privacy: Data Infrastructure In The Ai-Powered Metaverse. Available at SSRN.
- [6] <https://www.meta.com/no/en/legal/privacy-policy-updated/>
- [7] <https://www.apple.com/apple-vision-pro/>
- [10] <https://www.meta.com/no/en/quest/quest-pro/>
- [11] <https://arvr.google.com/>



SINTEF

Technology for a better society