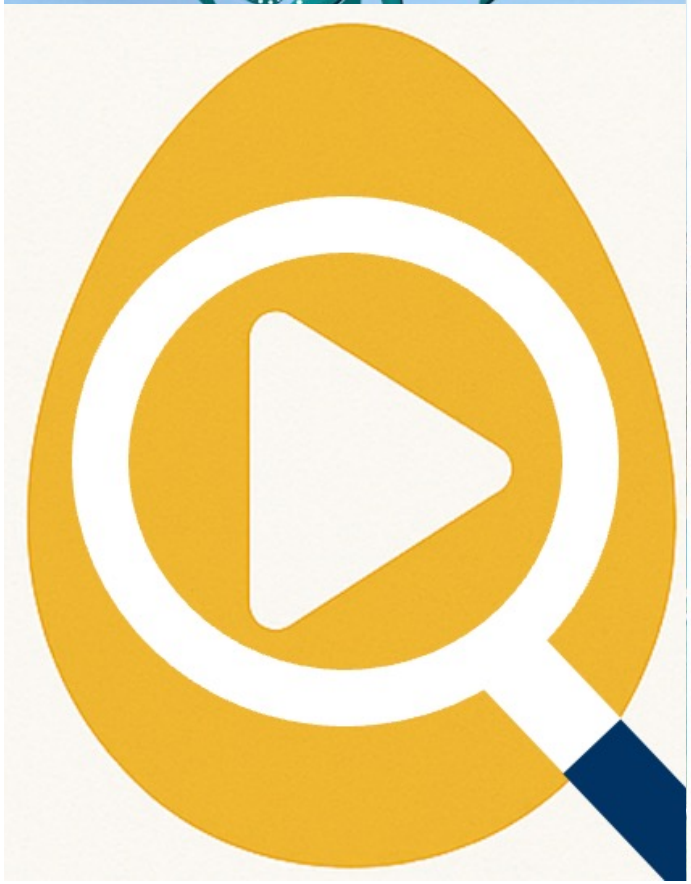

Interactions between vibroacoustic discomfort and visual stimuli: Comparison of real, 3D and 360 environments

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VQEG spring meeting 2025 - IMG session

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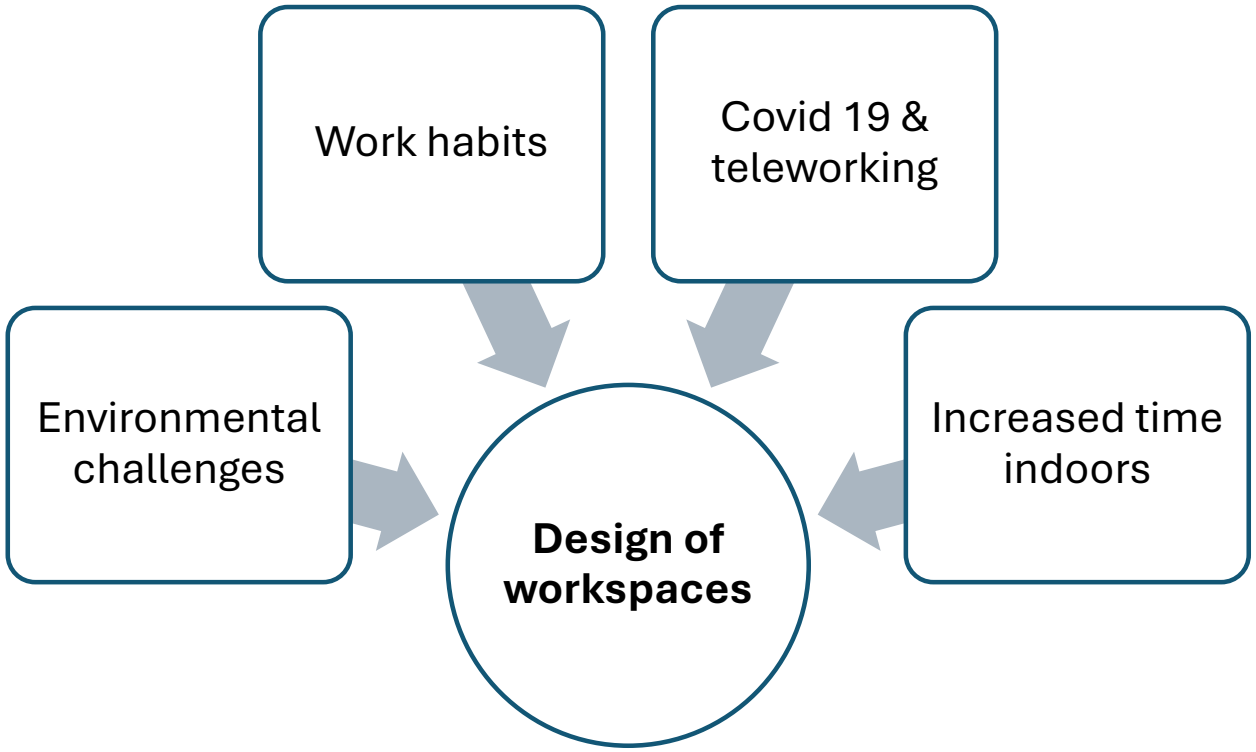
Introduction – Context: Use of VR for building studies



→ Impact of visual, acoustic, thermal and olfactory signals on well-being, comfort, health and **productivity** (C.Spence, 2020)

→ Relevance of immersive technologies for **building evaluation** (M.E Portman et al, 2015)

Introduction – Research questions: validity of VR

- Increasing use of VR in sensory science (EC Crofton et al, 2019)
- Importance of validating VR settings to ensure reliability and repeatability (K Chamilothori et al, 2019)

Which VR format (360 « panorama » vs 3D) provides greater validity for studying human perception?

How is discomfort to sensory stimuli perceived in VR vs real environment?

Can physiological, subjective and cognitive data collected in VR reliably reflect responses expected in real world scenarios?

Introduction - Methodology

Sensory information: visual + vibroacoustic stimuli (train recordings)

Comparison of visual environments: real vs VR 360 vs VR 3D

Discomfort evaluation: subjective, physiological and cognitive measures

Methodology – Material: vibroacoustic stimuli

Acoustic system Vibration system

Sequences	Vibrations	Solid-borne noise	Air-borne noise
Original Noise			
Max Noise			+10 dB
Min Noise			-10 dB
Original Coexposure			
Max Coexposure	Filtering 20Hz/+25 dB	Filtering 20Hz/+25 dB	+10 dB
Min Coexposure	-10 dB	-10 dB	-10 dB
Original Vibration			
Max Vibration	+10 dB	+10 dB	
Min Vibration	-10 dB	+ 10 dB	

Methodology – Simulated environment: 360 and 3D

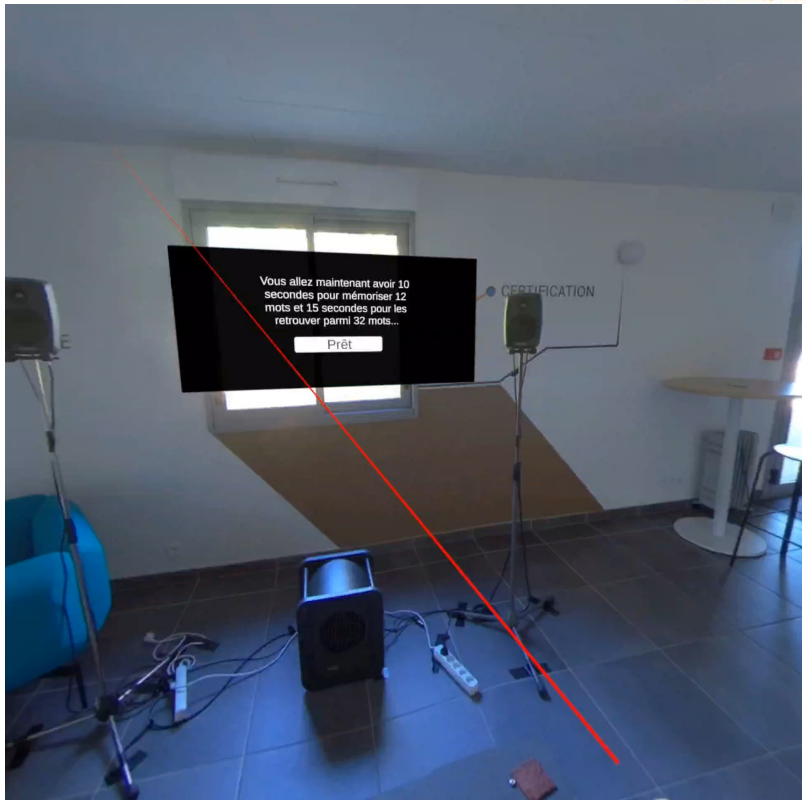
HMD: Pico 4

Methodology – Cognitive test

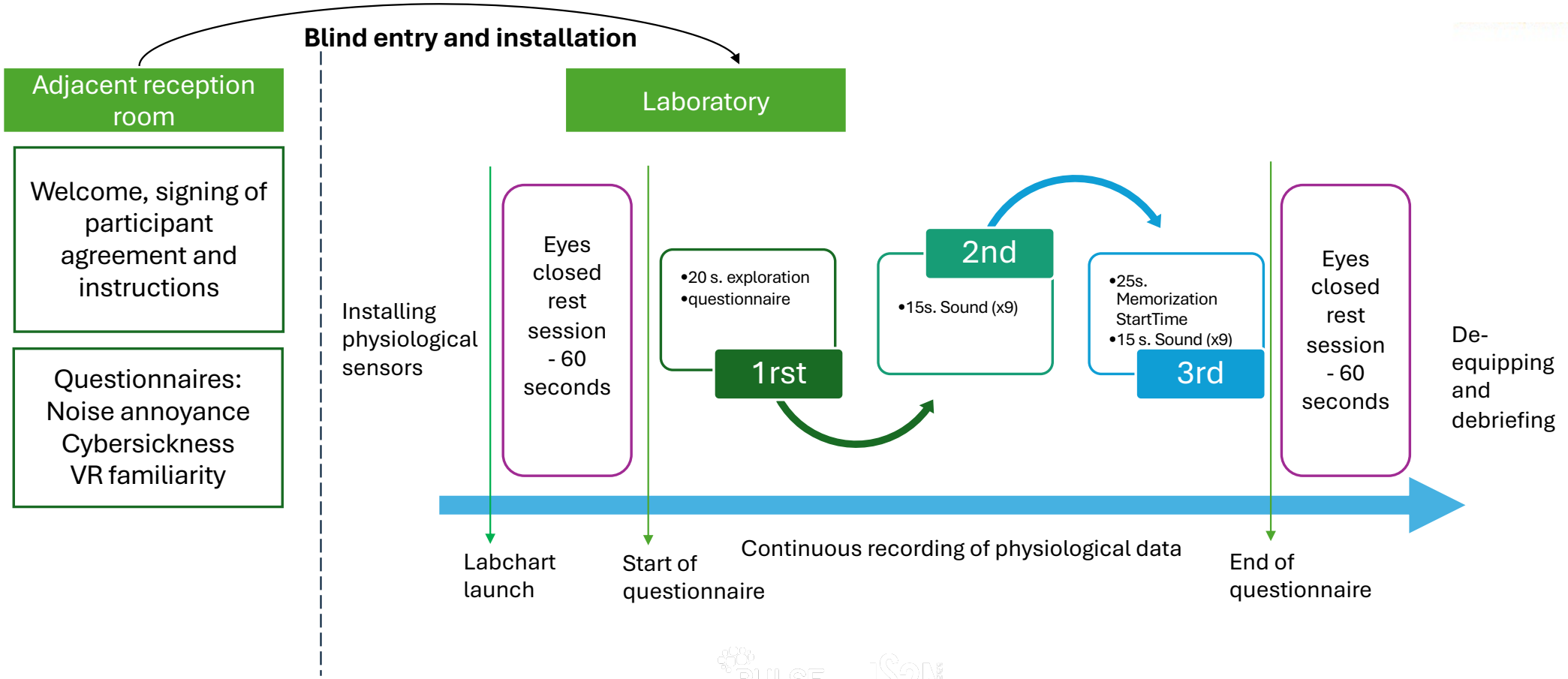
- ***Cognitive test***

Word Memory Test

- 15 seconds to memorize 12 words
- 15 seconds to find the words among 30 distractors

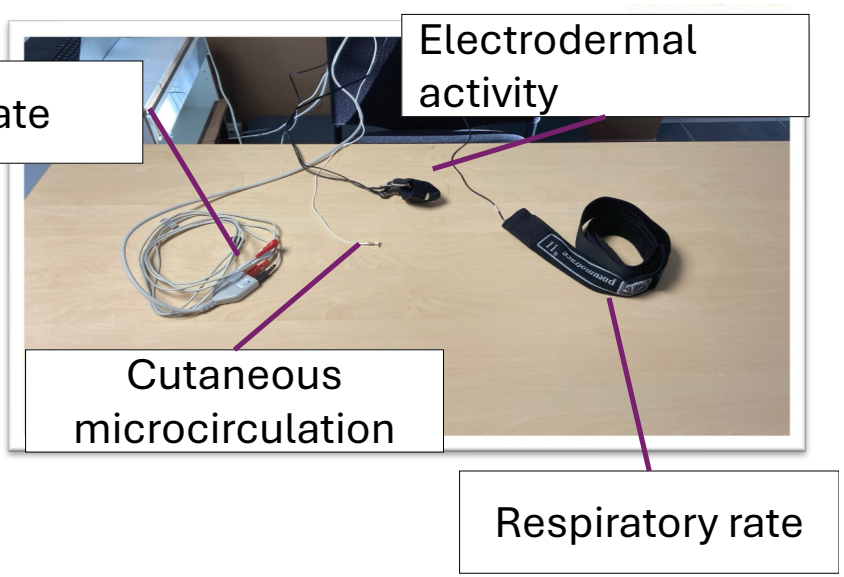


Methodology – Study design: protocol



Methodology – Physiological measurements

Mesure	Indicator
Heart rate	Awakening or Relaxation
Electrodermal activity	Stress
Cutaneous microcirculation	Enjoyment
Respiratory rate	Awakening or Relaxation



Methodology – Questionnaires

- ***Subjective questionnaire (after exploration of the visual environment)***

Emotional state

1. On a scale from negative (0) to positive (8), how would you rate your current emotional state? »
2. On a scale from relaxed (0) to stressed (8), how would you rate your level of excitement?
3. On a scale of not at all (0) to completely (8), how much control do you feel you have?

Visual perception

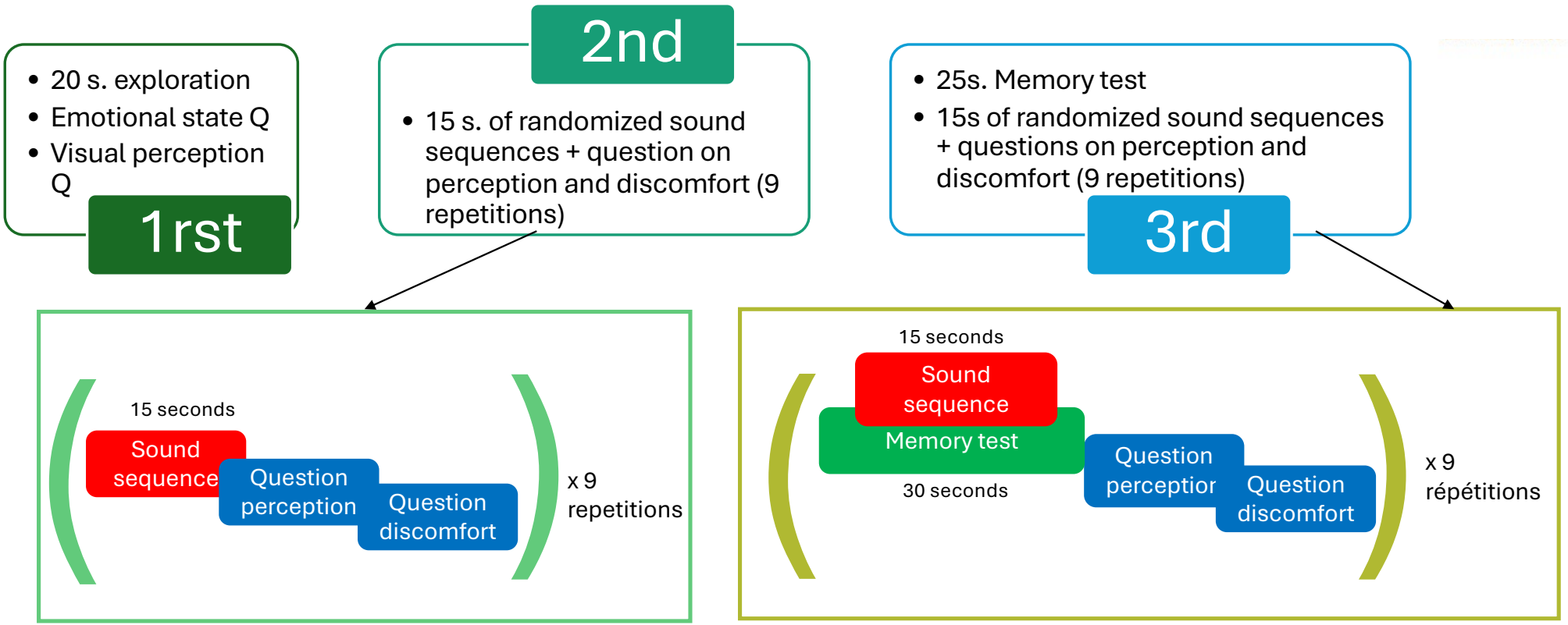
1. On a scale from not at all (0) to completely (8), how visually comfortable do you feel in the space?
2. On a scale from not at all (0) to completely (8), are you satisfied with the current lighting?
3. On a scale from not at all (0) to completely (8), how satisfied are you with the overall ambience of the space?
4. On a scale from not at all (0) to completely (8), do you feel comfortable in the space?

Subjective questionnaire (after vibro-acoustic stimuli)

Noise and vibration perception and annoyance

1. On a scale from 0 to 10, how noticeable was the noise/vibration/both?
2. On a scale from 0 to 10, how annoying was the noise/vibration/both?

Methodology – Study design: protocol



Between subjects design: 10 subjects tested each single condition (real, 360 or 3D)

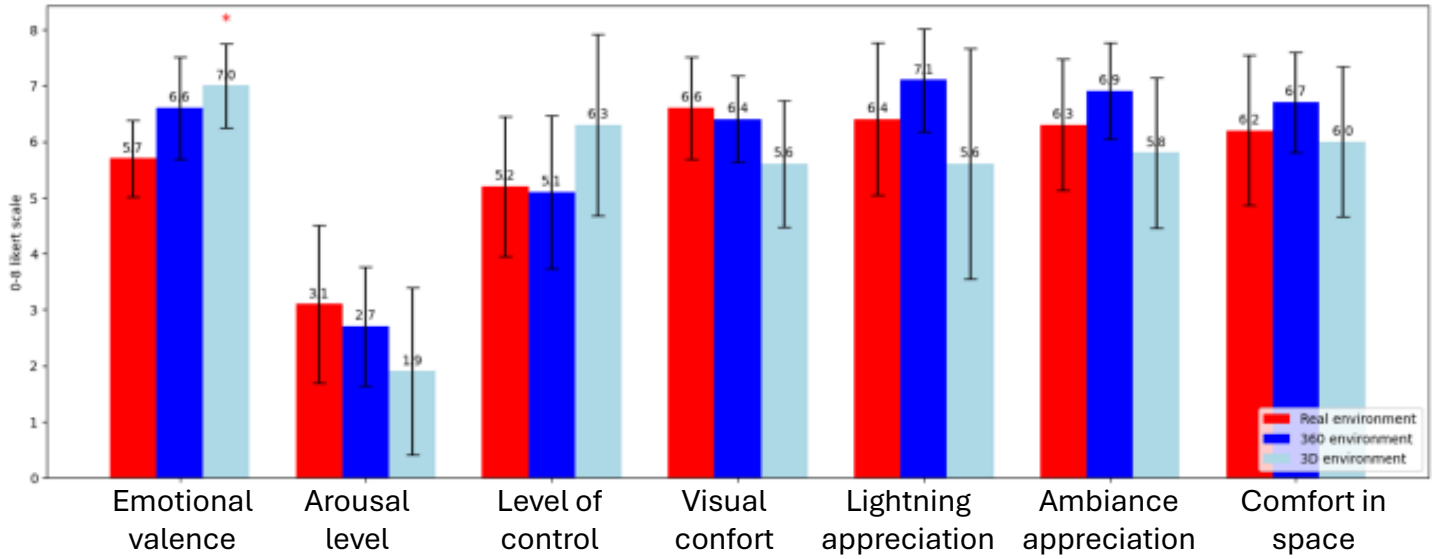
Methodology – Study design: participant

	Real	360	3D
Number	10	10	10
Gender	50% W, 10% nb	40% W	30% W
Age (Mean +/- sd)	25.1 +/- 3.93	26.4 +/- 8.26	25.5 +/- 2.59

Each subject tested a single condition: either real, 360 or 3D

Results – Analysis of subjective response

P-value <0.05



3D elicit more positive emotional state despite less visual comfort appreciation

Results – Subjective discomfort to vibro-acoustic signals

Discriminability of Vibroacoustic Signals: n* of signal pairs that showed significant differences (max = 3)

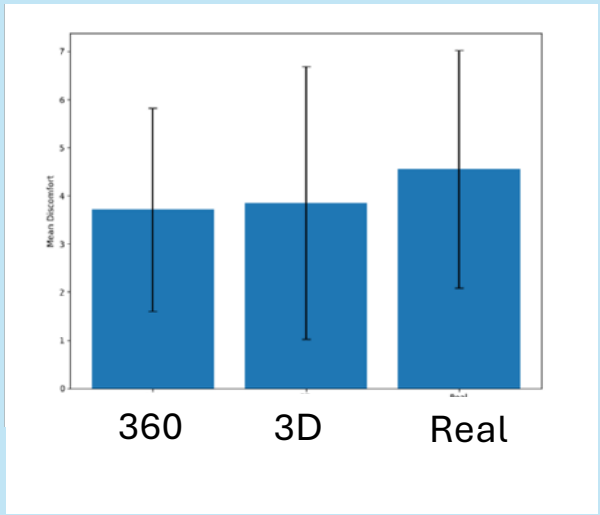
Only noise: p-value=0,403

Environment	Sound	Vibration	Coexposition
Real	2	2	3
360	2	2	2
3D	2	2	2

Noise + memory test: p-value=0.066

Environment	Sound	Vibration	Coexposition
Real	0	0	0
360	0	0	1
3D	2	1	1

Mean Discomfort to Vibroacoustic Stimuli in Interaction with Memory Test

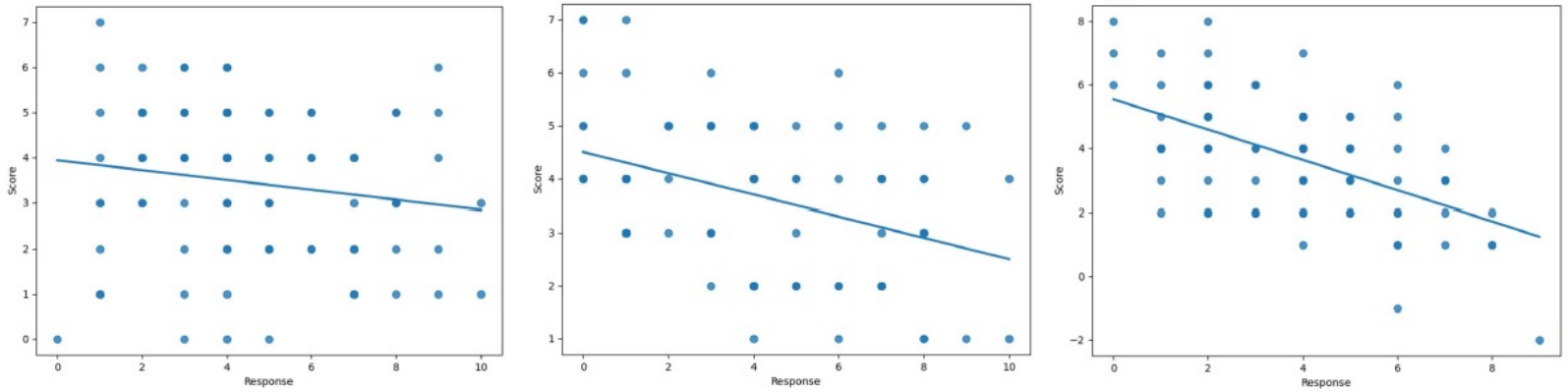


- Comparable performances across conditions without tasks.
- Degraded discriminability observed with cognitive tests in all conditions.
- Better pair discriminability in the 3D condition.

Results – Memory test scores and discomfort ratings

Correlation scores between cognitive (memory) and self reported discomfort scores

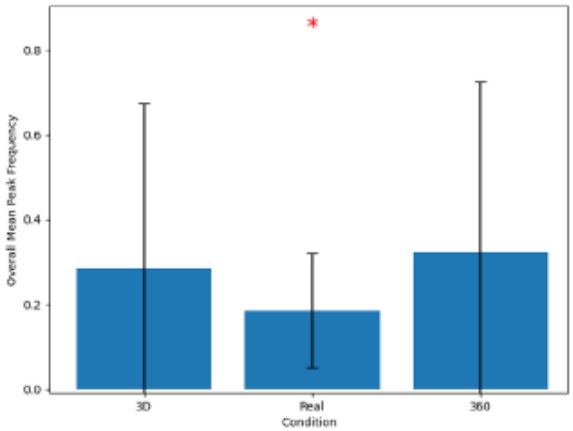
Real:	**3D:**	**360:**
PCC = -0.163	PCC = -0.396*	PCC = -0.542*
SCC = -0.189	SCC = -0.358*	SCC = -0.479*



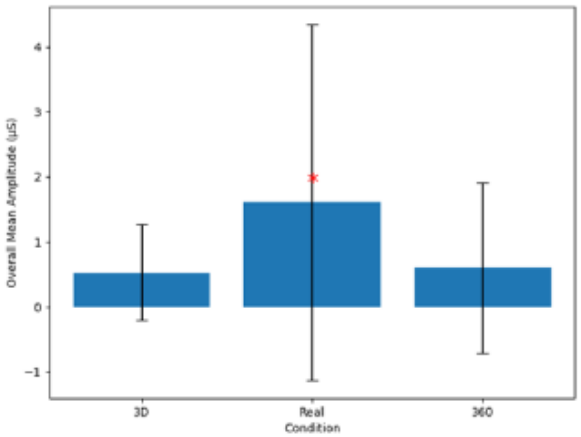
- Negative correlation between memory score and discomfort in virtual conditions (3D and 360°).
- Real environment: Slight trend observed, but non-significant.

Results – EDA peak analysis

Mean peak frequency comparison



Mean peak amplitude comparison



EDA signal is different in simulated environments:

- More peaks
- Lower amplitude

Real condition significantly different from 3D and 360 for frequency & amplitude

Conclusion – Discussion and future work

Ecology and Validity of Simulated Environments

- 3D: more positive emotional response
- 360: higher visual comfort

Discomfort of vibroacoustic signal in VR

- Similar discriminability without tasks
- Better discriminability in VR with tasks

Correlation between score and discomfort in VR

- Cognitive indicators of discomfort only in VR ?

EDA signal

- Impact of VR system on EDA
- No effect of train sequences

1. Indirect Measurement of Discomfort: potential of VR
2. Expand stimuli range: both visual and vibro-acoustic
3. Test higher/different cognitive functions
4. Test on trained participant: controlled physiological data

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