8

Human factors in virtual reality

Immersion, presence, embodiment and comfort

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COURSE NOTES

The same technical system can lead to different experiences and outcomes. Immersion describes system capabilities; presence and embodiment describe aspects of experience; comfort and symptoms concern other consequences of use. Keeping these dimensions distinct helps explain and evaluate what happens to the participant.

Course outline

Immersion and presence

8.1

Body and embodiment

8.2

Cybersickness, comfort and evaluation

8.3

COURSE NOTES

The same technical system can lead to different experiences and outcomes. Immersion describes system capabilities; presence and embodiment describe aspects of experience; comfort and symptoms concern other consequences of use. Keeping these dimensions distinct helps explain and evaluate what happens to the participant.

The sequence connects the following topics: Immersion and presence ; Body and embodiment ; Cybersickness, comfort and evaluation.

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Part 1 of 3

8.1

Immersion and presence

COURSE NOTES

Keep system characteristics, subjective experience and task outcomes separate. They can influence one another without being equivalent. High presence is not proof of learning, a detailed avatar is not proof of ownership, and a technically stable application can still be uncomfortable to use. The course therefore evaluates several dimensions together.

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8.1 Immersion and presence

System, experience and outcome

Level	What is being described?
System	Immersion, tracking and feedback
Experience	Presence, embodiment and discomfort
Outcome	Task performance, learning and behaviour

COURSE NOTES

Keep system characteristics, subjective experience and task outcomes separate. They can influence one another without being equivalent. High presence is not proof of learning, a detailed avatar is not proof of ownership, and a technically stable application can still be uncomfortable to use. The course therefore evaluates several dimensions together.

Characterising immersion

Sensory extent

Which modalities are stimulated?

Sensory fidelity

What information can each convey?

Coverage

How much physical input remains?

Interactivity

How stimulation responds to action

COURSE NOTES

Immersion describes the sensory and interactive capabilities of a system. Extent concerns which channels are stimulated; coverage concerns how much of the surrounding stimulation is provided by the system; quality concerns the information reproduced. Interactivity concerns how stimulation changes with the user's actions. These characteristics describe the apparatus, while presence describes an experience that can vary between people using it.

Presence

A subjective location

Experiencing the depicted place as where one is

An ongoing experience

It can change during a session



A virtual place experienced through an immersive system

COURSE NOTES

Witmer and Singer and Slater describe presence in terms of being in the depicted environment despite physical location elsewhere. This experience does not require the participant to believe intellectually that the simulation is real. It can fluctuate, break and recover during an activity.

Place illusion and plausibility

Place illusion

The sense of being in the depicted place

Plausibility

The sense that events are really occurring

COURSE NOTES

Slater’s framework separates place illusion from plausibility. Sensorimotor relations help explain the former, while coherent events and responses involving the participant help explain the latter. The participant can retain knowledge of the simulation. These are explanatory constructs rather than two interchangeable names for visual realism.

Social presence

Other people

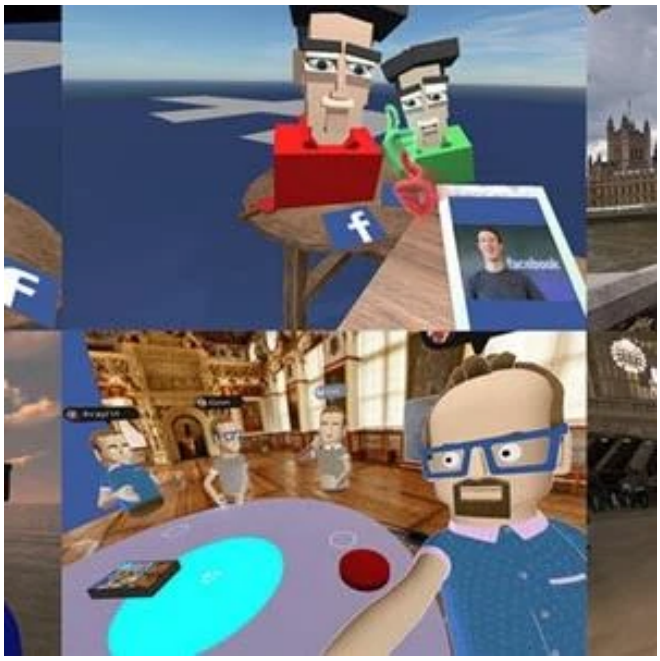
A sense of being together

Embodied cues

Position, gaze, gesture and action

Shared activity

Coordination around common events



Communication in a shared virtual setting

COURSE NOTES

Social presence concerns the experience of another person or agent as socially available. Co-presence concerns being together in a shared situation. Communication channels make exchange possible, but the experienced relationship also depends on responsiveness, avatar behaviour and the activity. Sharing geometry alone does not establish that participants understand or attend to one another.

Attention and spatial presence

Spatial information

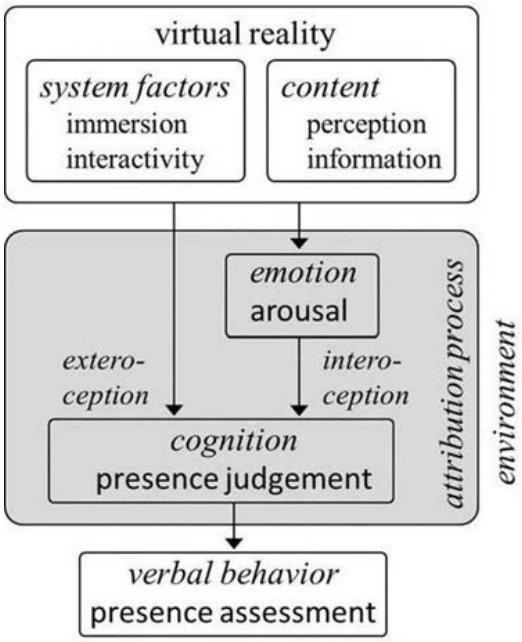
A representation of the depicted environment

Attention

Resources allocated to the virtual situation

Self-location

The environment becomes the primary spatial reference



A structural model connecting VR, emotion and judgement

COURSE NOTES

Spatial presence can be understood as the construction of a spatial interpretation in which the mediated environment becomes the experienced place of action. The MEC model relates spatial information, attention and the user’s interpretation of where they are. Task relevance, expectations and emotional involvement can affect that process. The diagram represents an explanatory framework, not a direct measurement of presence.

Attention in an experiment

Task

Explore a virtual city

Probe

Task-irrelevant sounds

Observation

Attention-related brain responses



Virtual-city environments in an attention study

COURSE NOTES

Kober and Neuper (2012) measured event-related responses to sounds during virtual exploration. The reported findings support an association between presence and allocation of attention to the virtual environment. A physiological correlate is not a uniquely identifying readout of presence; alternative influences need consideration.

Why presence matters

Behaviour

Responses to virtual events

Experimental interpretation

Relevance to the target situation

Application goal

A convincing activity or encounter



A height-related virtual scene

COURSE NOTES

Presence helps explain why people respond to a simulated situation while knowing it is artificial. This matters in experimental scenarios and some applied experiences. It remains only one part of the evidence: a high score does not validate every aspect of a simulation or establish a clinical benefit.

System factors and presence

Control

Available and predictable action

Sensory information

Useful cues and their coherence

Viewing conditions

Display properties and calibration

COURSE NOTES

Interaction, control, sensory modalities and viewing properties can influence presence. Their effects depend on the task and measurement. Clemente and colleagues are cited for a distinction between neural responses and questionnaire results. This is a reason to avoid assuming that every measure changes together.

Emotion and visual fidelity

Scene content

Neutral or affective situations

Display properties

A possible interaction with content

Response

Presence and emotion may covary



Different affective contexts in a virtual environment

COURSE NOTES

Baños and colleagues compare affective and neutral environments. It illustrates that the effect of display quality can depend on scene content. The cited anxiety literature reports associations under particular conditions; it does not justify a universal rule that a certain personality always produces higher presence.

Individual differences

Visual and spatial factors

What information a user can access

Attention and emotion

How the situation engages the person

Experience and expectations

What the person brings to the session



Neutral and public-speaking study conditions

COURSE NOTES

Ling and colleagues' study involved 85 participants and compared neutral and public-speaking conditions. It considered visual acuity, empathy, immersive tendencies, prior experience and other variables. Some reported effects differ from previous work. Present the findings as study-specific and avoid treating all measured characteristics as confirmed predictors.

Avatar style and repeated exposure

Representation

Abstract or more human-like avatars

Familiarity

Experience with the environment

Interpretation

Effects depend on the task and design



Avatar representations in the source study

COURSE NOTES

Avatar style and repeated exposure are two different influences on an experience. Work by Gerhard and colleagues examines representation, while Gamito and colleagues examine familiarity across exposures. Neither factor supports a universal rule that greater visual realism always improves social experience. Behavioural coherence and the quality of communication also shape how a represented person is encountered.

8.1 Immersion and presence

Lighting and the virtual pit

Manipulation

Lighting and reflection conditions

Experience

Questionnaire responses about the scene

Response

Physiological reactions to a threat-related setting



Rendering conditions in the virtual-pit experiment

COURSE NOTES

The example describes Slater, Khanna, Mortensen and Yu’s comparison of rendering conditions. It reports differences in physiological responses alongside presence questions. Preserve the distinction between the manipulation, measures and interpretation. Electrodermal activity and heart rate can reflect arousal as well as other processes, so neither is specific to presence.

Do additional modalities always help?

Information

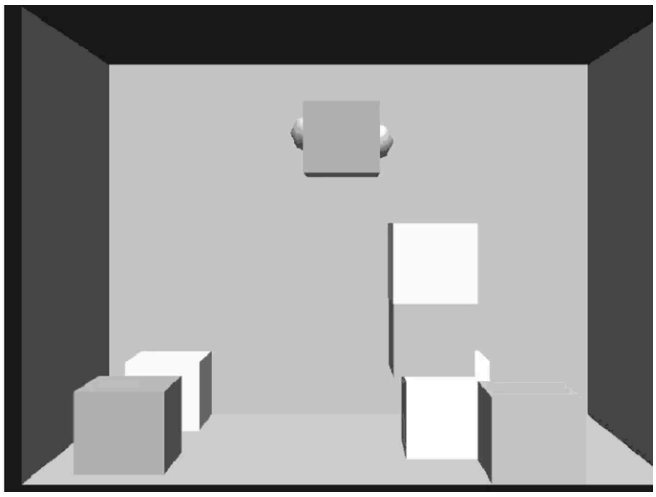
What does the extra cue contribute?

Redundancy

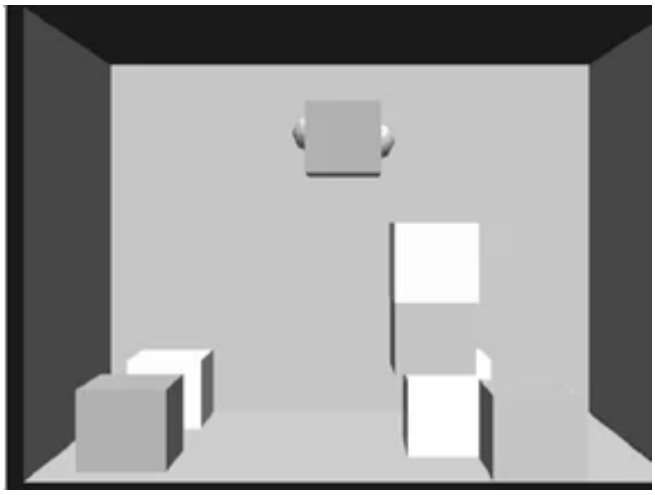
Is another channel already sufficient?

Task

Does the cue support the activity?



An audio-visual-haptic collaboration task



A comparison of communication and haptic conditions

COURSE NOTES

Sallnäs' examples compare visual, auditory and haptic channels in collaboration. An added haptic cue can contribute differently when verbal communication is present or absent. The lesson is conditional benefit, not that every extra channel increases presence. Examine the task, baseline information and dependent measures.

Immersion and presence are distinct

System properties

Can be specified and measured

Personal experience

Varies across users and sessions

Relationship

Influenced by content, action and attention

COURSE NOTES

A distinction is needed between objective immersion descriptions from subjective presence. The relationship is not a simple one-to-one conversion. This does not mean that hardware never matters. It means that changes in system capability must be interpreted together with task, content, expectations and individual experience.

Visible reactions, an experience to investigate

Behaviour

Stepping back, movement, hesitation

Reported experience

Presence, emotion, discomfort

Measurement

Ask and compare

COURSE NOTES

The next video shows a first headset experience. It helps distinguish observable behaviour from subjective experience: stepping back or moving is not a measure of presence, and a strong reaction does not establish discomfort.

After viewing, ask what the person reports feeling and distinguish presence, emotion and symptoms. The next section introduces presence measurement; comfort and symptoms are covered in the third part. One individual reaction cannot be generalised to all users.

A first headset experience



A first headset experience

Watch the video ↗

COURSE NOTES

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After viewing, ask what the person reports feeling and distinguish presence, emotion and symptoms. The next section introduces presence measurement; comfort and symptoms are covered in the third part. One individual reaction cannot be generalised to all users.

Measuring presence

Questionnaires

IPQ, PQ and Slater–Usoh–Steed

Behaviour

Responses and breaks in the experience

Physiology

Complementary, non-specific observations

COURSE NOTES

Choose an instrument for the construct and context, retaining its wording and scoring procedure. In presence research, SUS may refer to Slater–Usoh–Steed; the System Usability Scale uses the same acronym for a different construct. Physiological observations need independent interpretation and do not replace a clear operational definition.

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Part 2 of 3

8.2

Body and embodiment

COURSE NOTES

Riva’s framework brings together information about and from the body. Bodily self-perception depends on integration rather than a single visual image. This provides a bridge from sensory mechanisms to the question of why a virtual body can sometimes be experienced as one’s own.

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8.2 Body and embodiment

Perception of one’s body

External signals

Seeing and touching the body

Internal signals

Interoception and bodily state

Movement and posture

Proprioceptive and vestibular information

COURSE NOTES

Riva’s framework brings together information about and from the body. Bodily self-perception depends on integration rather than a single visual image. This provides a bridge from sensory mechanisms to the question of why a virtual body can sometimes be experienced as one’s own.

Body schema and body image

Body schema

Representations supporting action and posture

Body image

Perceptual, conceptual and affective representations

Plasticity

Representations can adapt

COURSE NOTES

Body schema concerns bodily representations involved in controlling action, while body image concerns perceptual and other representations of one’s body. The boundary between them varies across theoretical accounts. Neither is reducible to a picture of the body. Changes in visual, proprioceptive or tactile information can reveal how these representations contribute differently to movement and bodily self-perception.

The rubber-hand illusion

A hidden real hand

Receives tactile stimulation

A visible artificial hand

Receives matching visual stimulation

A possible shift

The artificial hand feels body-related



Left hand



Artificial hand

COURSE NOTES

In Botvinick and Cohen’s rubber-hand experiment, the real hand is hidden while an artificial hand remains visible. Corresponding visual and tactile events can produce a feeling that the visible hand belongs to oneself. Comparing synchronous and asynchronous stimulation isolates an important temporal relationship. Spatial arrangement and anatomical compatibility also constrain the effect, so appearance alone does not establish ownership.

A multisensory ownership interpretation

1. **See**
   Contact on the artificial body
2. **Feel**
   Contact on the physical body
3. **Integrate**
   Evidence for a common event
4. **Attribute**
   The seen body may feel like one’s own

COURSE NOTES

A multisensory account of ownership considers whether visual, tactile and bodily signals can be attributed to the same body. Matching timing and spatial organisation support that interpretation. Delays, incompatible locations or anatomical inconsistencies can weaken it. This integration does not require an explicit decision to believe that the artificial hand is real; the experienced ownership and the person’s intellectual knowledge can differ.

The sense of embodiment

Ownership

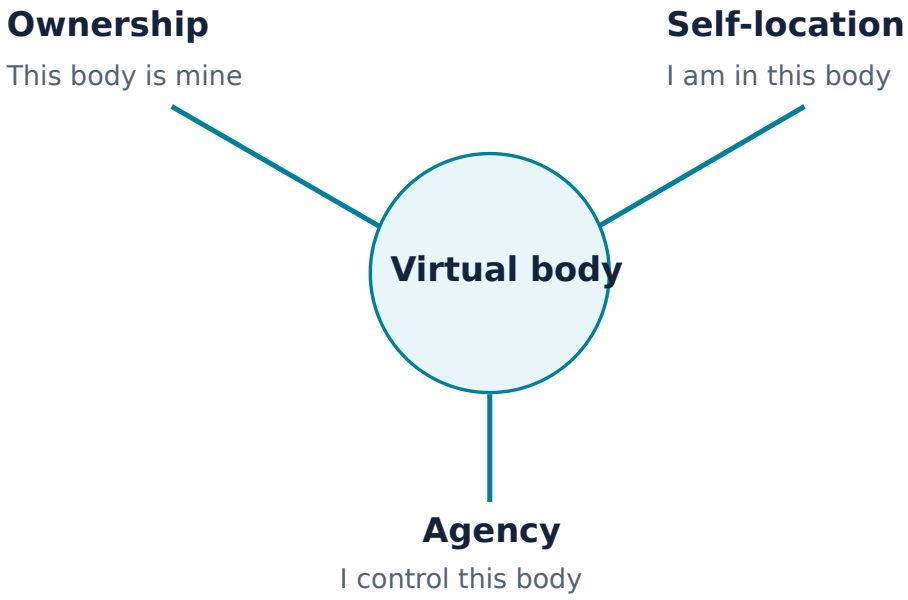
This body is mine

Self-location

I am located in this body

Agency

I control this body



COURSE NOTES

Kilteni, Groten and Slater distinguish ownership, self-location and agency within the sense of embodiment. Ownership concerns whose body it feels like; self-location concerns where one feels situated; agency concerns being the origin of an action. These components can vary separately. Controlling a tool does not necessarily make it part of the body, and experiencing a bodily location does not require complete voluntary control of every movement.

8.2 Body and embodiment

Body ownership

Self-attribution

The body feels like mine

Sensory source

Events seem to happen to this body

Manipulation

Timing, appearance and correspondence

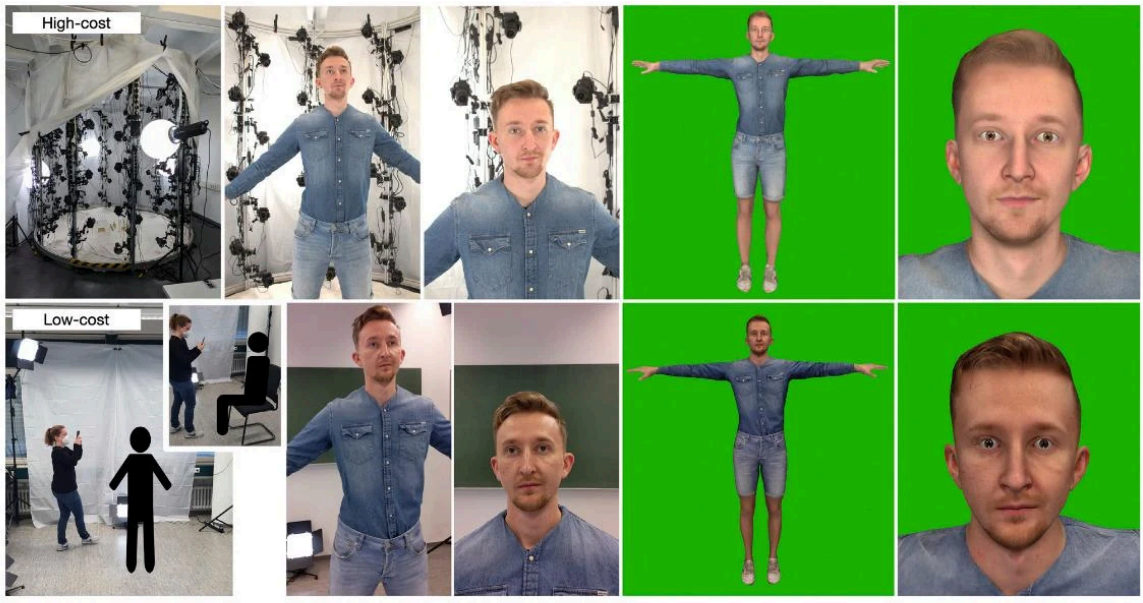


FIGURE 1 | The high-cost (top) and the low-cost (bottom) scan process.

Virtual-human representations in an ownership-related study

COURSE NOTES

Ownership involves attributing a body or body part to oneself. Relevant factors include structural and morphological constraints and personalised avatars. Individualisation can contribute to self-recognition, but similarity alone does not guarantee ownership. Behaviour, viewpoint and multisensory coherence need consideration.

8.2 Body and embodiment

Self-location

Bodily location

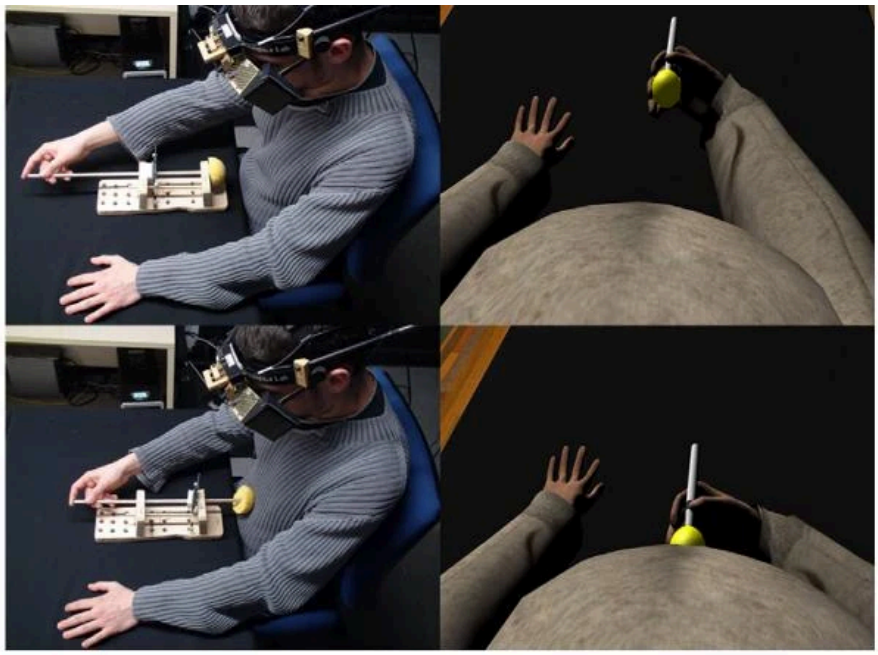
Where I experience myself

First-person perspective

A viewpoint associated with the body

External perspective

A different relation to the seen body



A body viewed from different spatial perspectives

COURSE NOTES

Self-location concerns the relation between the self and a body. Viewpoint and somatosensory information contribute. First-person and external perspectives manipulate more than screen composition: they alter the spatial relation among the observer, visible body and world. A particular viewpoint does not uniquely determine the experience.

8.2 Body and embodiment

Self-location and presence

Construct	Spatial relation
Self-location	Self in relation to a body
Presence	Self in relation to an environment

COURSE NOTES

Self-location concerns where the person experiences the self in relation to a body, whereas spatial presence concerns being in an environment. These relations can interact without being identical. A person can feel present in a virtual place without seeing a virtual body. A bodily illusion can also change experienced self-location without presenting a fully surrounding virtual world.

8.2 Body and embodiment

Sense of agency

Motor intention

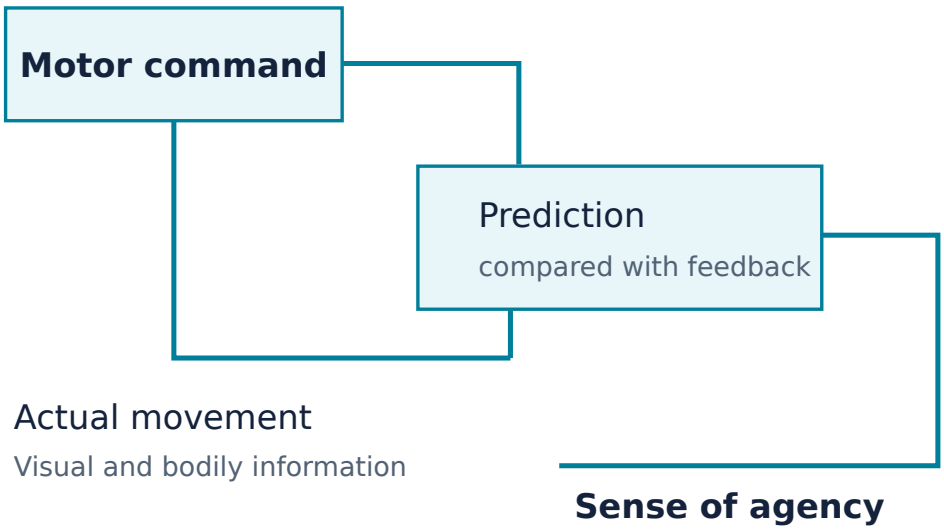
An intended action

Prediction

Expected consequences

Feedback

Observed movement and outcome



COURSE NOTES

Agency is the sense of being the origin of an action and its consequences. A comparator account relates predicted consequences of a motor command to observed feedback. Delay or an altered movement can change that correspondence, although agency cannot be reduced to one universal timing threshold. The model helps separate successful control from the experience of causing what happens.

Factors in embodiment

Body form

Structure, morphology and self-recognition

Viewpoint

Relation between observer and body

Motion correspondence

Spatial and temporal alignment

COURSE NOTES

The three factors connect to the three components without forming a one-to-one checklist. A manipulation of viewpoint can influence ownership as well as location. Delayed motion can influence both agency and ownership. Evaluate the components separately and check whether the manipulation also changes presence or discomfort.

Visuotactile and visuomotor induction

Visuotactile

Seen and felt contact correspond

Visuomotor

Seen movement follows action

Control condition

Change the relevant correspondence



Visuomotor correspondence



A visuotactile induction setup

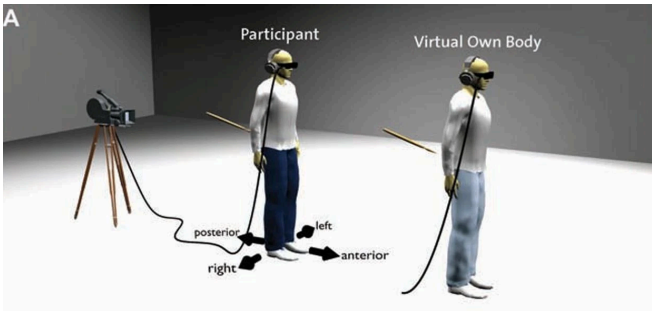
COURSE NOTES

Visuotactile induction relates seen contact to felt touch. Visuomotor induction relates the movement of a visible virtual body to the person’s own movement. Both provide correspondences that can contribute to ownership. Comparing conditions requires specifying which relationship changes, since delay, difficulty and attention may also change. An ownership measure concerns the bodily experience rather than general enjoyment.

Hands, faces and full bodies



Enfacement: a face-related illusion



A full-body experimental arrangement

COURSE NOTES

Ownership-related experiments extend from hands to faces and full bodies. Enfacement studies examine how matched sensory events affect the relation to a seen face; full-body studies examine the experienced relation to an entire represented body. These arrangements differ in viewpoint, stimulation and outcome measures. Similar terminology does not imply identical procedures or effects.

Bodies with different properties

Extended arm

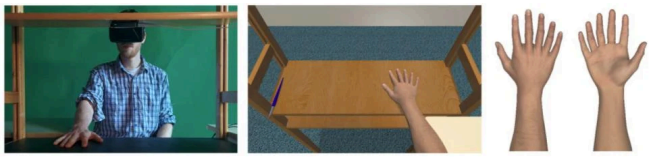
A changed limb geometry

Extra finger

An additional controlled element

Altered size

A changed relation to the environment



Experiments with altered body properties



Body-size perception research

COURSE NOTES

Changing the apparent size, proportions or available body parts explores the flexibility of bodily representation. Adaptation involves both learning to control a new mapping and possibly experiencing the representation as one’s body. These are different outcomes. A result depends on the geometry, training, sensory correspondences and measure used, so successful control alone does not demonstrate ownership.

A walking avatar and point of view

Perspective

First-person or external view

Body motion

Observed movement of the avatar

Experience

Agency, ownership and apparent walking



Walking-avatar and viewpoint conditions

COURSE NOTES

Kokkinara, Kilteni, Blom and Slater’s example examines the relation between viewpoint, embodiment and apparent locomotion. It connects this unit with navigation. The participant’s physical movement, the displayed body movement and the questionnaire constructs must be specified independently.

Experiencing a child-sized body

Viewpoint

A body-relative perspective

Congruence

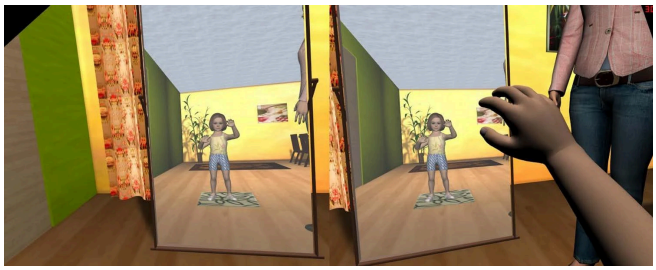
Corresponding sensory information

Outcome

Body-related perception and responses



A child-body embodiment study



A view during the child-body experiment

COURSE NOTES

A child-sized virtual body changes the relation between apparent body scale and the surrounding environment. The experiment distinguishes inducing an embodied experience from measuring its effects on perception or behaviour. Viewpoint and control must be specified because they can also change the interpretation. The demonstration shows the arrangement, while the participant's reports and task responses provide evidence about the experience.

Banakou, Groten and Slater: child-body experiment

Banakou, Groten and Slater: child-body experiment

Watch the video ↗

COURSE NOTES

A child-sized virtual body changes the relation between apparent body scale and the surrounding environment. The experiment distinguishes inducing an embodied experience from measuring its effects on perception or behaviour. Viewpoint and control must be specified because they can also change the interpretation. The demonstration shows the arrangement, while the participant's reports and task responses provide evidence about the experience.

Body-size distortion research

Question

How is bodily size estimated?

Manipulation

A full-body illusion

Measure

Estimates before and after exposure



Fig 2. Experimental set up. Experimenter touching participants' actual abdomen with a movement sensor, stroking movements are displayed in VR (inlay).

The study setup for body-size estimates

COURSE NOTES

The example describes anorexia-related body-size research and cites Keizer and colleagues. It reports reduced overestimation of shoulders, abdomen and hips following the experimental induction, with follow-up observations. This is a study result about a perceptual measure, not proof of a general treatment effect or evidence that all clinical symptoms changed.

8.2 Body and embodiment

Phantom limbs and visual feedback

Phantom sensation

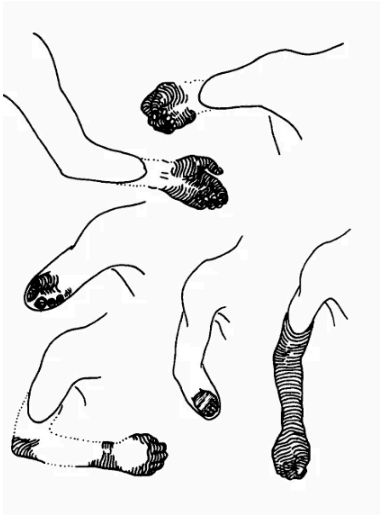
A perceived missing limb

Mirror feedback

A visual relation to movement

Virtual feedback

A controllable limb representation



A mirror-box arrangement

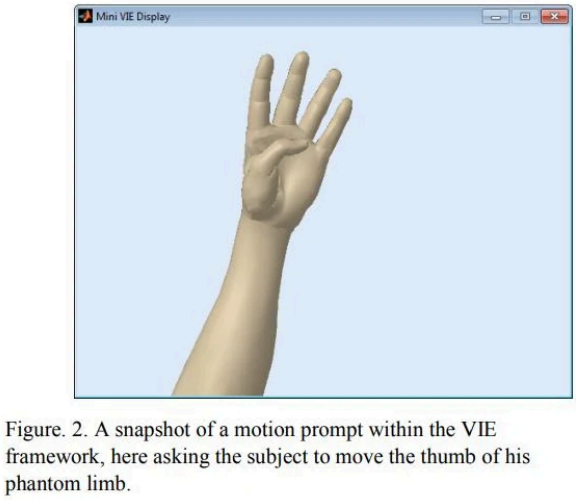


Figure. 2. A snapshot of a motion prompt within the VIE framework, here asking the subject to move the thumb of his phantom limb.

A virtual limb used in rehabilitation research

COURSE NOTES

Phantom-limb sensations and phantom pain are distinct phenomena. Mirror and virtual approaches provide visual feedback related to action. In Perry and colleagues' example, EMG-related input controls a virtual representation. The findings concern that study and protocol. The common conceptual link is the relationship among intended action, sensory feedback and body representation.

8.2 Body and embodiment

Evaluating embodiment

Questionnaires

Separate ownership, location and agency

Behaviour

A task-related response or estimate

Control conditions

Test the proposed source of the effect

COURSE NOTES

Use component-specific measures and a justified comparison condition. A threat response can provide complementary evidence but has multiple interpretations. A changed size estimate measures a perceptual outcome rather than directly measuring every component of embodiment. Report the induction procedure, participant characteristics and timing of assessment.

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Part 3 of 3

8.3

Cybersickness, comfort and evaluation

COURSE NOTES

Comfort includes more than the absence of cybersickness. Headset pressure, heat, visual effort and sustained arm elevation can make an otherwise stable scene difficult to use. These outcomes can have different causes and need separate observations. A design change can improve one aspect while making another worse, so evaluation concerns the whole activity as well as individual symptoms.

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8.3 Cybersickness, comfort and evaluation

Comfort as a design outcome

Cybersickness

Nausea, dizziness and disorientation

Visual comfort

Eye strain and viewing demands

Physical comfort

Fit, heat, posture and effort

Cognitive demands

Attention, complexity and control

COURSE NOTES

Comfort includes more than the absence of cybersickness. Headset pressure, heat, visual effort and sustained arm elevation can make an otherwise stable scene difficult to use. These outcomes can have different causes and need separate observations. A design change can improve one aspect while making another worse, so evaluation concerns the whole activity as well as individual symptoms.

Cybersickness and physical motion sickness

Context	Typical situation
Physical motion sickness	Physical motion in a setting such as a vehicle
Cybersickness	Symptoms associated with a virtual exposure, often with visual motion

COURSE NOTES

Visually induced motion can produce symptoms even when the body remains stationary. Physical motion sickness involves actual bodily movement, but the two situations can overlap, for example on a motion platform with visual simulation. Exposure does not produce the same response in everyone. The motion presented, bodily cues, duration and individual susceptibility matter more than the device label alone.

Symptom dimensions

Nausea

Queasiness and related bodily symptoms

Oculomotor symptoms

Eye strain, blurred vision or headache

Disorientation

Dizziness and disturbed spatial orientation

COURSE NOTES

Nausea, oculomotor symptoms and disorientation describe different dimensions of simulator-related symptoms. They can overlap, and a visible reaction does not identify a score or diagnosis. Assessment uses a specified instrument at defined times relative to exposure. General discomfort, sweating and fatigue may also matter, depending on the question being studied.

Sensory conflict

Visual information

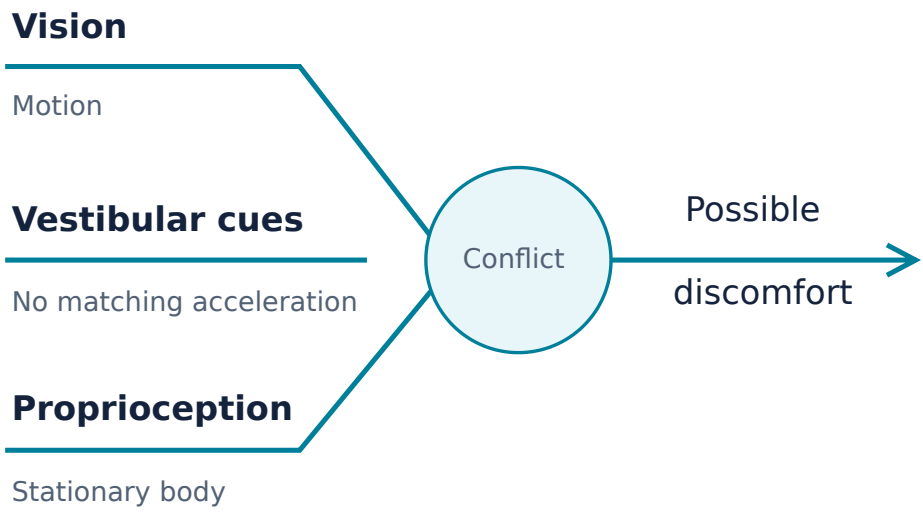
The world suggests self-motion

Vestibular information

No corresponding physical acceleration

Bodily information

A stationary posture or different movement



COURSE NOTES

Sensory-conflict accounts explain discomfort through discrepancies among signals about movement or between those signals and expected relationships. A common case presents visual travel while vestibular and bodily information indicate a stationary body. This explains an important design concern, but does not account for every uncomfortable experience. Physical ergonomics, individual susceptibility and the task also contribute.

Complementary explanations

Postural instability

Difficulty maintaining a stable bodily relation

Sensorimotor inconsistency

Unexpected action–perception relations

Device discomfort

Pressure, mass and heat

COURSE NOTES

The examples include postural instability and sensorimotor inconsistency alongside physical device discomfort. These are complementary considerations with different predictions and evidence. Device pressure should not be presented as a sensory-conflict symptom mechanism. A design evaluation can measure several pathways without assuming a single cause.

Technical contributors

Latency

A delayed sensory consequence

Jitter and drift

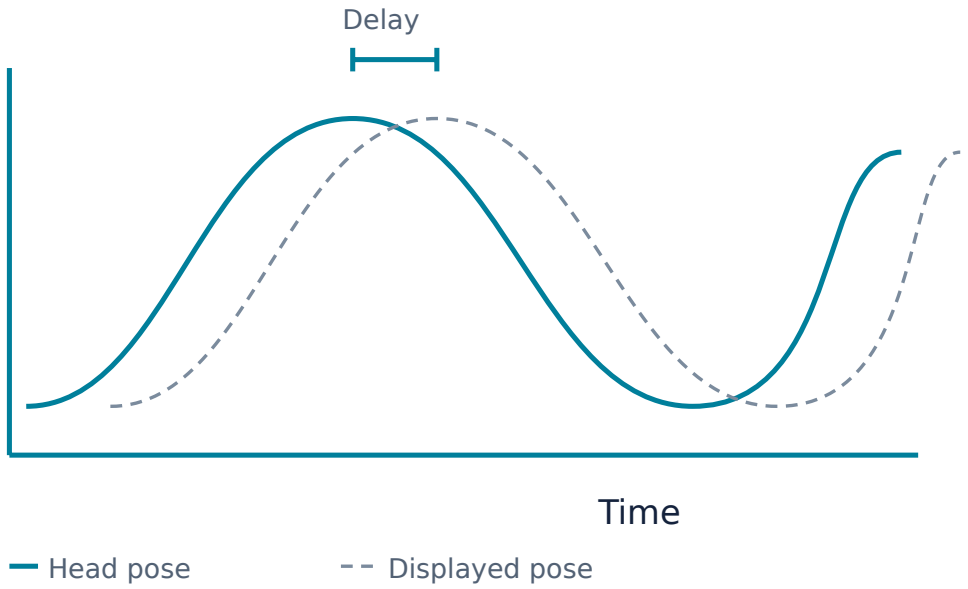
An unstable spatial relation

Frame stalls

Interrupted image updates

Camera updates

Unexpected changes in viewpoint



COURSE NOTES

Latency, irregular frame delivery, tracking instability and incorrect camera updates can break the expected relation between movement and feedback. Average frame rate alone hides brief stalls and variations. Timing and spatial accuracy must therefore be considered together. Technical stability supports comfort, while the activity, locomotion and physical ergonomics can still produce discomfort through other pathways.

Locomotion and turning

Option	Perceptual consequence	Design consideration
Continuous movement	Sustained visual travel	Motion mismatch and exposure matter
Teleportation	A discrete viewpoint change	Arrival and orientation still matter
Continuous turning	Continuous optic flow	Speed and control matter
Snap turning	Discrete angular steps	Step size and preference matter

COURSE NOTES

Locomotion and turning can be implemented in several ways. These are tendencies and design options rather than a universal ranking. Smoothing acceleration alone does not guarantee a comfortable path: duration, motion profile, control and visual context also matter. Offer configurable options and evaluate the target task and participants.

Optic flow

Direction

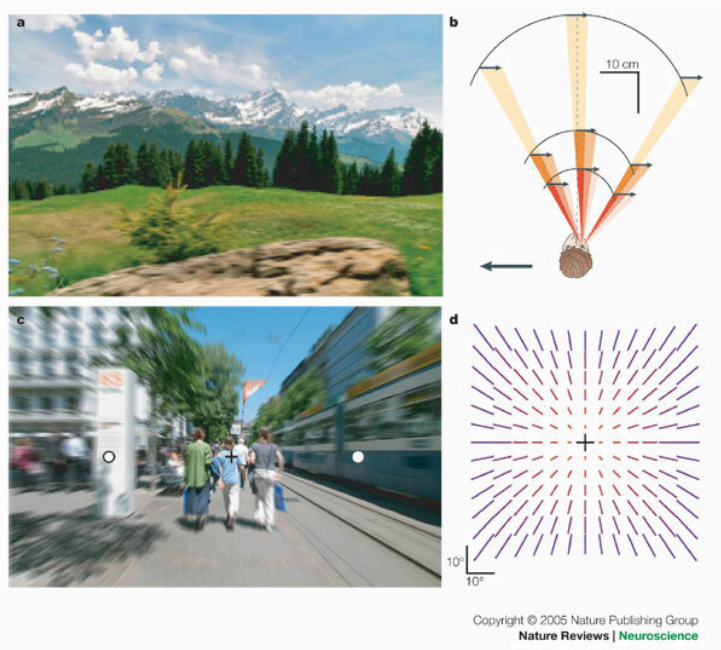
How the image changes during movement

Speed

How quickly features cross the view

Periphery

Large visual regions can carry strong motion cues



Optic flow — original comfort course

COURSE NOTES

Optic flow describes structured changes in the visual field associated with relative movement. It contributes to self-motion perception. High peripheral visual motion can be relevant to discomfort, but removing it also changes information available for orientation. The illustration depicts the visual pattern rather than a quantitative prediction.

Dynamic field-of-view reduction

During motion

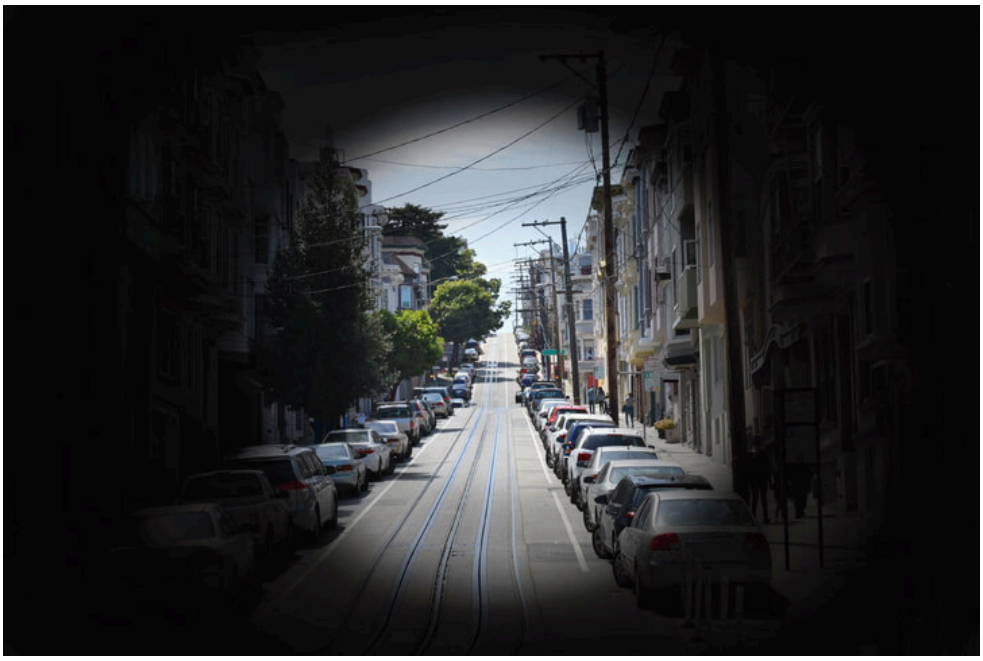
Mask part of the peripheral view

At rest

Restore the wider view

Tradeoff

Less motion information and less spatial context



Dynamic visual masking — original comfort course

COURSE NOTES

A vignette or tunnelling effect masks part of the displayed image during movement. It changes exposure to visual motion rather than changing the headset’s physical optics. Reducing peripheral stimulation can also hide targets and orientation cues. Its usefulness therefore depends on mask parameters, the task and the balance between comfort and the information needed to act.

Spatial consistency

World scale

Objects and body share meaningful dimensions

Viewpoint height

Fits the participant and task

Horizon

Remains coherent with gravity

Head motion

Keeps its expected effect on the view

COURSE NOTES

Scale, camera height and horizon orientation establish the spatial frame in which the user acts. Camera lag, artificial head bobbing or added sway change that frame independently of the person’s actual movement. These manipulations affect different cues and can create inconsistencies. Keeping head-related viewing coherent provides a stable basis for judging objects, moving and maintaining orientation.

Visual comfort and near work

Display alignment

Fit and appropriate eye positioning

Depth demands

Vergence and accommodation

Legibility

Readable content without sustained strain

COURSE NOTES

Visual comfort extends beyond locomotion. Optical alignment and the depth placement of sustained visual tasks matter. Frequent changes in vergence demand can be tiring with conventional fixed-focus stereo optics. Avoid presenting one fixed viewing distance as suitable for every headset, optical design and user.

Physical ergonomics

Headset

Mass, pressure and heat

Posture

Neck angle and sustained position

Reach

Arm elevation, repetition and support

Access

Seated options and alternative controls

COURSE NOTES

A precise pointing technique may still be fatiguing if it requires sustained arm elevation. Menus can move closer to neutral posture or use a supported interaction. Headset fit and thermal load can also influence an otherwise stable experience. Evaluate users with relevant differences in reach, vision and mobility.

Measuring symptoms

Before exposure

A baseline symptom state

During exposure

Brief checks when appropriate

After exposure

Symptoms, timing and recovery

COURSE NOTES

Measure the baseline because participants can arrive with symptoms. Preserve the procedure of the chosen instrument, and record when observations are taken. Provide a way to pause or stop, and do not require a participant to persist through increasing symptoms. Attrition and early stopping are meaningful outcomes, not merely missing data.

The Simulator Sickness Questionnaire

Instrument

A structured symptom questionnaire

Dimensions

Nausea, oculomotor and disorientation

Procedure

Keep wording and scoring consistent

General discomfort	None	Slight	Moderate	Severe
Fatigue	None	Slight	Moderate	Severe
Headache	None	Slight	Moderate	Severe
Eye strain	None	Slight	Moderate	Severe
Difficulty focusing	None	Slight	Moderate	Severe
Increased salivation	None	Slight	Moderate	Severe
Sweating	None	Slight	Moderate	Severe
Nausea	None	Slight	Moderate	Severe
Difficulty concentrating	None	Slight	Moderate	Severe
“Fullness of the head”	None	Slight	Moderate	Severe
Blurred vision	None	Slight	Moderate	Severe
Dizzy (eyes open)	None	Slight	Moderate	Severe
Dizzy (eyes closed)	None	Slight	Moderate	Severe
Vertigo (Giddiness)	None	Slight	Moderate	Severe
Stomach awareness	None	Slight	Moderate	Severe
Burping	None	Slight	Moderate	Severe

SSQ — Kennedy et al. (1993), via the original comfort course

COURSE NOTES

Kennedy and colleagues’ SSQ is widely used, but it originated in simulator research and has limitations when applied to particular VR contexts. Do not label three informal 0–10 symptom ratings as an SSQ score. Select the instrument for the study and use its validated procedure rather than invent a conversion.

Informal ratings and validated instruments

Measure	Interpretation
Classroom symptom ratings	A clearly labelled local measure
SSQ or another selected scale	The instrument’s own items and scoring
Behaviour and stopping	Additional observations with a defined procedure

COURSE NOTES

The companion lab uses nausea, dizziness and eye-strain ratings from zero to ten. These support a classroom comparison but are not automatically a validated composite scale. Report each measure and its limitations clearly. More complex instruments require their own rationale, administration and scoring.

Comparing comfort features

1. **Baseline**
   Define the reference condition
2. **Variation**
   Change a specified feature
3. **Exposure**
   Keep task and timing comparable
4. **Analysis**
   Compare symptoms and performance

Cybersickness and comfort lab ↗

COURSE NOTES

Use independent feature switches so a comparison has a clear interpretation. Counterbalance condition order and account for prior exposure, practice and carryover. Recovery may require more than a fixed short break. Small class samples illustrate methods but do not establish universal design rules. Preserve the ability to stop a session.

Comfort choices and tradeoffs

Technical stability

Track and render consistently

User control

Make movement predictable and optional

Motion options

Offer suitable locomotion and turning choices

Task ergonomics

Reduce unnecessary sustained effort

COURSE NOTES

Comfort features involve tradeoffs that depend on the activity. A stable horizon, appropriate scale and coherent viewpoint can support comfort, while configurable movement helps address differing preferences. A mitigation can reduce visual information or control. Record both the benefit sought and the cost introduced.

Presence, embodiment and discomfort

Related experiences

They can influence one another

Distinct measures

One score does not represent all three

Design outcome

A useful task with acceptable demands

COURSE NOTES

A strong body or place experience does not guarantee comfort, and discomfort can interrupt engagement. Keep the constructs separate in the design and analysis. A participant may complete the task while experiencing substantial symptoms. Conversely, low symptoms do not establish that the system supports the intended activity.

Integrated design assessment

Which activity is supported?

Which cues and mappings are essential?

What could disrupt presence or embodiment?

How will comfort and task success be assessed?

COURSE NOTES

Return to one application from course 3. Justify its display, tracking, interaction and navigation choices using the theoretical foundations. Specify a technical check and a participant measure for each important requirement. Identify a condition under which the design would need to change.

Sources and further reading

Teaching resources

Original lectures and their figure credits

Research references

Study-specific citations in each slide’s notes

Source map

References retained at the point of use

Slater et al. (2022), Place illusion and plausibility ↗

Kilteni, Groten and Slater (2012), Sense of Embodiment ↗

Kennedy et al. (1993), Simulator Sickness Questionnaire ↗ All course materials ↗

COURSE NOTES

Scientific work connects a result to a question, a method and conditions of observation. A demonstration shows a possibility; a study compares conditions and measures their effects. The scope of a conclusion depends on that distinction and on the limits of the evaluation.