4

Perception and theoretical foundations

The mechanisms behind immersive experience

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COURSE NOTES

A VR experience depends on how sensory information is produced and interpreted in relation to action. Definitions and models frame the activity; spatial and multisensory mechanisms explain how an environment can be perceived. Sensorimotor coupling and perceptual illusions reveal both the capabilities and the limits of that construction.

Course outline

Definitions and models

4.1

Spatial perception

4.2

Multisensory perception

4.3

Sensorimotor coupling

4.4

Perceptual illusions

4.5

COURSE NOTES

A VR experience depends on how sensory information is produced and interpreted in relation to action. Definitions and models frame the activity; spatial and multisensory mechanisms explain how an environment can be perceived. Sensorimotor coupling and perceptual illusions reveal both the capabilities and the limits of that construction.

The sequence connects the following topics: Definitions and models ; Spatial perception ; Multisensory perception ; Sensorimotor coupling ; Perceptual illusions.

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Part 1 of 5

4.1
Definitions and models

COURSE NOTES

The term cannot be understood only by opposing real and unreal. In ordinary English, virtual can describe something that is almost so or functions as such without having exactly that status. The computing sense also refers to a software-based simulation.

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4.1 Definitions and models

“Virtual reality”: what do the words mean?

An English expression, several readings in French

Virtual · English

In effect · almost · functioning as such

Virtuel · philosophy

Potential rather than actual — also a French meaning

An apparent oxymoron

If virtuel is read as unreal, the French expression réalité virtuelle sounds contradictory

> For VR: a simulated environment that functions as a reality for perception and action.

COURSE NOTES

The term cannot be understood only by opposing real and unreal. In ordinary English, virtual can describe something that is almost so or functions as such without having exactly that status. The computing sense also refers to a software-based simulation.

The historical root evokes force or power. However, potentiality is not uniquely English: French virtuel also has a philosophical meaning opposed to actual. It would be misleading to say that English virtual simply means potential while French virtuel only means unreal.

The French expression can sound like an oxymoron when virtuel is read as unreal. The paradox depends on the chosen meaning, rather than being a necessary contradiction in the technology. The final formulation connects to our approach: simulating perception and action in relation to an environment.

4.1 Definitions and models

A name that was not self-evident

Several terms coexisted, each emphasising a different aspect.

Réalité artificielle

Artificial reality: a constructed environment

Réalité vicariante

A proposed French alternative: a substitute that functions as reality

Réalité de synthèse

Computer synthesis: the French official term published in 2007

> Réalité virtuelle became the established French usage, despite terminological reservations.

COURSE NOTES

The vocabulary was not settled in a single step. These competing proposals and usages show that the name was not universally accepted. The three cards compare conceptual emphases rather than presenting a strict chronological sequence.

Philippe Fuchs discusses the proposed expression réalité vicariante. French vicariant means something that replaces or substitutes for something else. It highlights functional substitution, rather than mere potential existence or the need for a visually identical copy of the physical world.

FranceTerme records réalité de synthèse as an official French term published on 20 April 2007. This recommendation does not mean that it displaced réalité virtuelle in ordinary usage. The December 2022 ÉduNum publication notes that réalité virtuelle became the established expression despite alternative proposals.

4.1 Definitions and models

Several definitions, several viewpoints

Purpose

The human activity to support

Function

Changing place, time or possible action

Technique

Simulation and behavioural interfaces

Interface

How the person relates to the world

Relationship with reality

What simulation makes us notice

Perception

How the user interprets the experience

COURSE NOTES

These definitions foreground different objects of study: activity, function, technical system, interface, philosophical interpretation and perception. Their relevance depends on the context and the question being studied.

Fuchs and colleagues distinguish the purpose of VR from its functional possibilities and technical implementation. This prevents defining the field by a particular device. An application can recreate a real situation, amplify a phenomenon or support an imaginary activity. Design begins with the activity, then selects mechanisms and interfaces.

4.1 Definitions and models

Defining virtual reality by its purpose

> The purpose of virtual reality is to enable a person (or several people) to carry out sensorimotor and cognitive activity in an artificial, digitally created world, which may be imaginary, symbolic, or a simulation of certain aspects of the real world.

> Burkhardt and Fuchs · 2006

Viewpoint **Human activity**

COURSE NOTES

The purpose-based definition starts with the human activity, not the headset. Sensorimotor activity means perceiving and physically acting; cognition concerns the interpretation and organisation of that activity. The environment can reproduce aspects of a real situation, give form to an abstract relation or create an imaginary world. What matters is which activity the artificial world enables.

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4.1 Definitions and models

A functional definition

> Virtual reality will allow the user to extract himself from the physical reality in order to virtually change the time, place and/or type of interaction: interaction with an environment simulating reality or interaction with an imaginary or symbolic world.
>
> Fuchs, Moreau and Guitton · 2011

Viewpoint **Changing the frame of possible activity**

COURSE NOTES

A functional definition describes what the experience makes possible: acting in a different place, time or situation. The simulated environment can reproduce a real activity or provide conditions that would be inaccessible physically. This perspective helps state requirements before choosing devices: observing an otherwise invisible phenomenon and practising an everyday gesture need different forms of mediation.

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4.1 Definitions and models

A technical definition

> Virtual Reality is a technical and scientific area making use of computer science and behavioral interfaces in order to simulate 3D entities

> behavior in a virtual world that interact in real time among themselves and with the user in pseudonatural immersion through sensory-motor channels.
>
> Fuchs, Moreau and Guitton · 2011

Viewpoint **Simulation, interfaces and real time**

COURSE NOTES

The technical definition connects real-time simulation with interfaces that capture behaviour and provide sensory feedback. A movement must be measured, interpreted and followed by an appropriate change in the environment. The experience therefore depends on the complete loop, including timing and coordinate transformations. A detailed computer-generated scene alone does not provide this relationship.

Defining the interface relationship

> The substitution of the interface between a person and the physical environment with an interface to a simulated environment.
>
> Jaron Lanier

Viewpoint **Mediating the person–world relationship**

COURSE NOTES

This definition places the interface at the centre of the person–world relationship. Sensory output replaces or mediates information normally received from the physical environment, while tracking and input devices mediate action. The virtual environment can differ radically from the physical room while preserving a coherent relationship between what the person does and what they perceive.

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4.1 Definitions and models

Defining a relationship with reality

> A coarser, simulated reality fosters appreciation of the depth of physical reality in comparison. As VR progresses in the future, human perception will be nurtured by it and will learn to find ever more depth in physical reality.
>
> Jaron Lanier

Viewpoint **Reflecting on the experience of reality**

COURSE NOTES

A simulated environment provides a point of comparison with ordinary perception. Simplifying or changing familiar relationships can make us notice information that normally goes unquestioned. The interest of VR is therefore not limited to escaping the physical world: it can reveal how we perceive it and how our body participates in that experience.

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4.1 Definitions and models

Defining the role of perception

> Technology that rallies the brain to fill in the blanks and cover over the mistakes of a simulator, in order to make a simulated reality seem better than it ought to.
>
> Jaron Lanier

Viewpoint **The user contributes to the experience**

COURSE NOTES

The perceived experience is not a pixel-for-pixel copy of the system’s output. Perception interprets incomplete signals, uses expectations and integrates information from movement and several senses. Coherent relationships can make a simplified simulation convincing, while an inconsistency can become noticeable despite detailed graphics. The user’s perceptual activity is part of the functioning of the system.

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4.1 Definitions and models

Virtual reality and LSD: a shared world

> … VR users can share a world objectively, even if it is fantastical, while LSD users cannot.
>
> Jaron Lanier · Dawn of the New Everything (2017)

Viewpoint **Experiencing a common world**

COURSE NOTES

In this passage, Lanier responds to the comparison between virtual reality and LSD by emphasising a shared world. This expresses his view of VR as a communication medium, rather than adding another technical definition.

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4.1 Definitions and models

The I²: immersion and interaction

I² denotes the immersion–interaction pair

Immersion: perceiving the virtual world

The device engages the senses and lets the user appropriate a new perceptual space. Example: turning the head to explore the scene.

Interaction: acting in the virtual world

The user acts and perceives the consequences of their actions in real time. Example: grasping a part and seeing it follow the hand's movement.

> In 3I², this pair applies at three levels: sensorimotor, cognitive and functional.

COURSE NOTES

The two I's stand for immersion and interaction. The notation I² associates these two closely related concepts. The number 3 denotes the sensorimotor, cognitive and functional levels, detailed on the next slide.

In Auvray and Fuchs's approach, perception is an activity: users discover regularities between their actions and sensory feedback. Immersion therefore also depends on how they appropriate the device to perceive and act. It involves more than wearing a headset or

receiving realistic images.

Turning the head to explore a scene already involves an action and its perceptual feedback. Grasping a part illustrates the same coupling: the hand's movement controls the object's movement, which the user can see. The examples distinguish the concepts for teaching purposes while showing their interdependence.

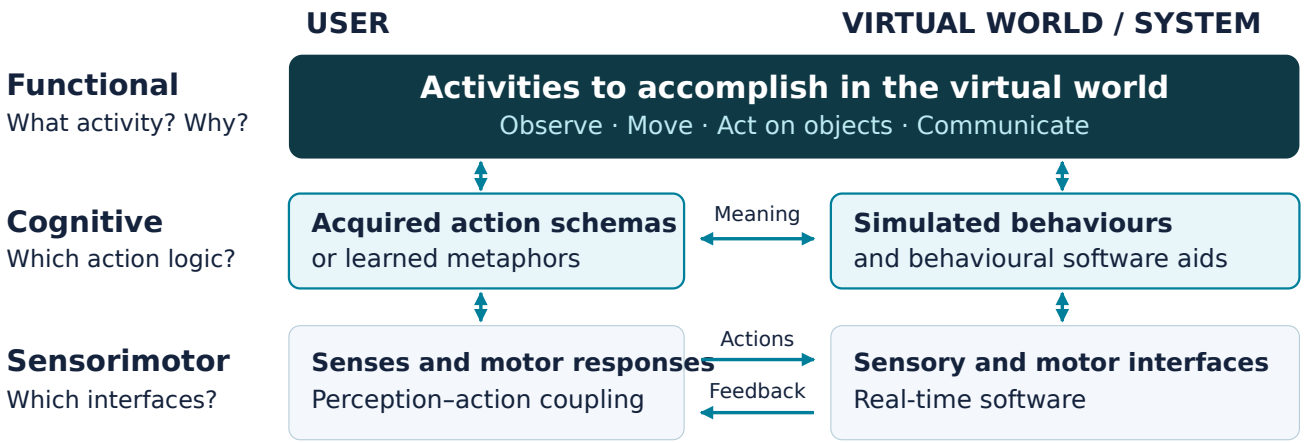
Reference: M. Auvray and P. Fuchs (2007), Perception, immersion et interactions sensorimotrices en environnement virtuel, Intellectica 45, pp. 23–35, sections 1 and 2. https://intellectica.org/SiteArchives/archives/n45/45-1-Auvray.pdf

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4.1 Definitions and models

The 3I² reference model

3 levels × (Immersion + Interaction)



> Design from the activity; check that all three levels work together.

COURSE NOTES

3I² means three levels of immersion AND interaction: sensorimotor, cognitive and functional. It is a reference framework for designing and evaluating virtual-reality applications, rather than a score of immersion. The two columns relate the user's activity to the technical construction of the virtual world.

At the sensorimotor level, senses and motor responses are coupled to the simulated world through sensory and motor interfaces, their drivers and real-time computation. Relevant questions include tracking, latency, sensory resolution and consistency between action and feedback.

At the cognitive level, the user appropriates a way of perceiving and acting. An acquired action schema can be transferred from everyday life, or an interaction metaphor can be learned. On the system side, behavioural models and software aids support these actions. A

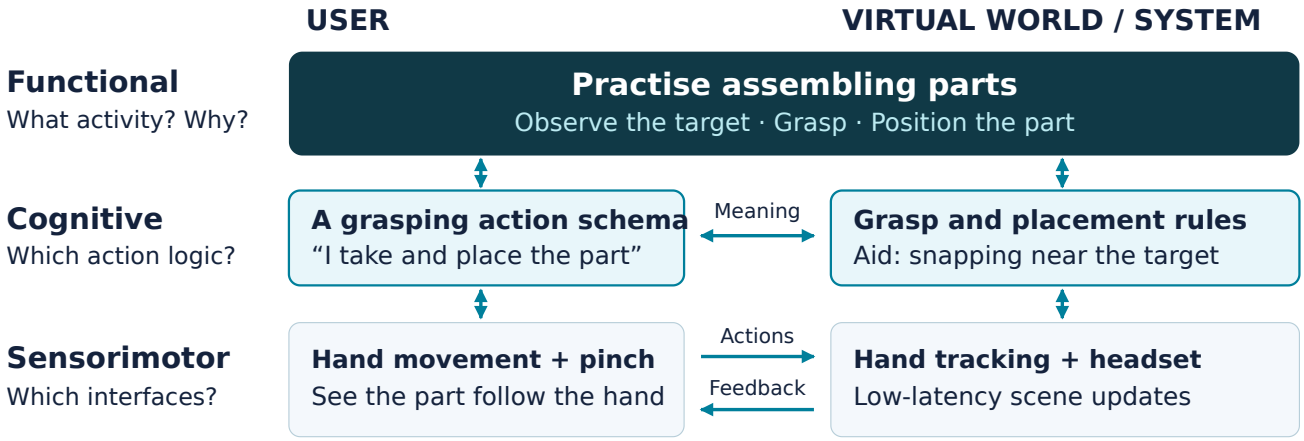
familiar gesture alone does not guarantee that the interaction will be understood or usable.

At the functional level, the question is which activity the application must enable and for what purpose. Activities can be decomposed into observing, moving, acting on the virtual world and communicating. Start from the required activity before choosing interfaces. The bidirectional links indicate dependencies between levels, not three successive stages or three independent qualities.

4.1 Definitions and models

3I² in practice: grasping a part

One assembly task, three linked design questions



> Too much latency → difficult grasping → the assembly task is compromised.

COURSE NOTES

This teaching example applies the model to a virtual assembly exercise. At the functional level, the learner must grasp a part and place it at a target. The purpose and success criterion come before the choice of device: which placements, constraints and tolerances matter for the learning objective?

At the cognitive level, the interaction uses a familiar grasp-and-place schema, adapted to a tracked pinch. The application must implement understandable rules for attachment, movement and release. Snapping near the target is an example of a behavioural software aid; whether it is appropriate depends on what the learner is meant to practise.

At the sensorimotor level, hand tracking captures movement and pinch while the headset provides visual feedback. Low latency and stable tracking help the user experience the object as moving with the hand. Delayed feedback can make grasping unreliable, disrupt the action schema and prevent completion of the assembly task. Conversely, responsive hardware does not establish that the learning objective has been achieved.

Fidelity depends on the task

Physical fidelity

How stimulation matches the target situation

Functional fidelity

Whether the relevant actions are possible

Psychological fidelity

Whether the relevant responses occur

COURSE NOTES

Fidelity is meaningful in relation to a target. A needle simulator may require precise contact mechanics. A spatial planning task may require correct scale and occlusion. An emotional experiment may prioritise a credible situation over detailed textures. These dimensions can diverge, so avoid a single undifferentiated realism score.

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Part 2 of 5

4.2
Spatial perception

COURSE NOTES

This overview follows the order of the section. We first examine cues available in a single image, then binocular disparity, then the relative image motion produced by moving the viewpoint. The head-tracking demonstration illustrates this third family.

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4.2 Spatial perception

Spatial perception: the route through this section

Which information helps us perceive depth, distance and scale?

1. Monocular image cues

Occlusion · perspective · texture · size and height · shadows

2. Binocular disparity

Differences between the two eyes’ views

3. Motion parallax

Relative image motion as the viewpoint moves

4. Vergence and accommodation

Eye alignment and optical focus

5. Perceived distance and scale

Putting the cues in context: viewpoint height, familiar size and field of view

COURSE NOTES

This overview follows the order of the section. We first examine cues available in a single image, then binocular disparity, then the relative image motion produced by moving the viewpoint. The head-tracking demonstration illustrates this third family.

We then distinguish vergence from accommodation, using the focus video as an analogy for optical focus. These are different mechanisms, even though they are usually linked in natural viewing.

The final slide returns to the outcome: perceived distance and scale. Viewpoint height, familiar size and the available field of view provide context; this final step is not an additional, independent family of depth cues. The families overlap: motion parallax can be perceived with one eye, and familiar size already appears among monocular cues.

Monocular depth cues

Occlusion

Which surface hides another?

Perspective and texture

How patterns change with depth

Size and height

Objects relative to familiar references

Shadows

Evidence about contact and position



Perspective



Texture gradient



A pictorial depth example



A pictorial depth example

COURSE NOTES

Depth perception combines multiple cues. Pictorial information can support depth on a conventional display. Relevant cues include horizon relations, texture gradients and shadows. These cues can conflict with each other or with stereo information, changing perceived scale or distance. A surrounding display is not the only source of spatial information.

Binocular disparity

Two viewpoints

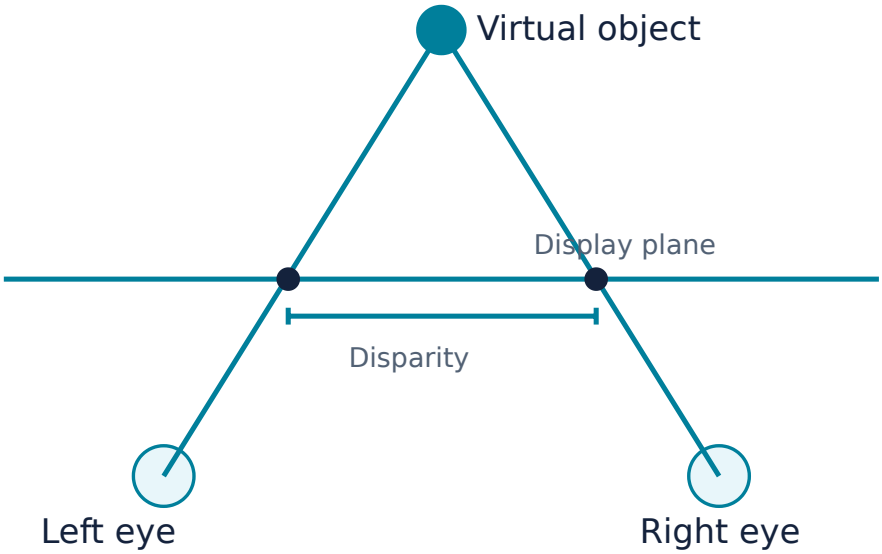
The eyes occupy different positions

Two projections

A feature falls at different retinal positions

Depth interpretation

Disparity contributes to perceived distance



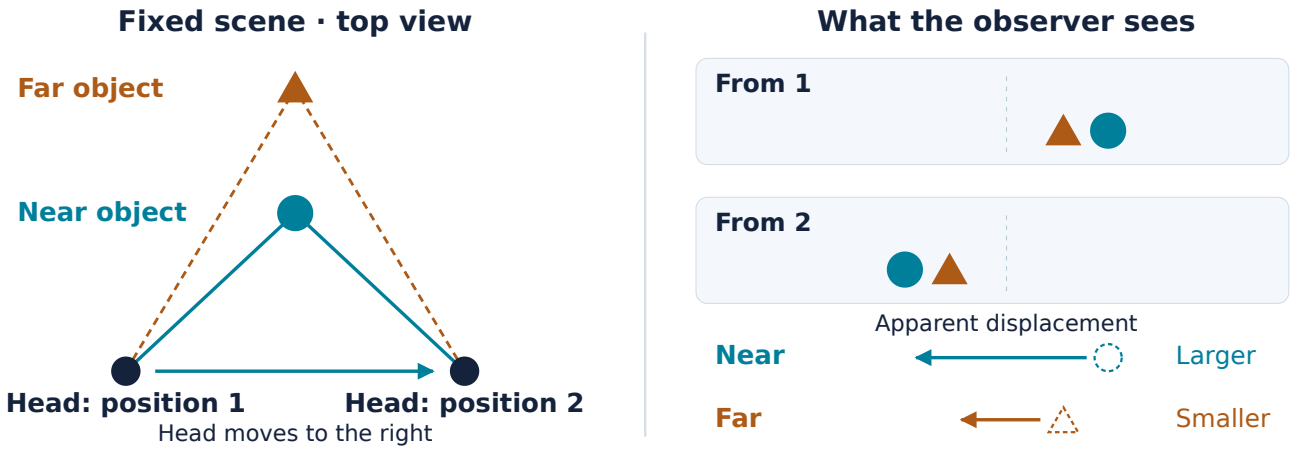
COURSE NOTES

Stereoscopy depends on the difference between images reaching the two eyes. The system must use an appropriate interocular separation and correct projection geometry. Binocular disparity is one depth cue among several. Distinguish it from accommodation and vergence, which concern focusing and eye alignment.

4.2 Spatial perception

Motion parallax

Two fixed objects · head translation without rotation



> In VR, rendering must follow head position to reproduce this depth cue.

COURSE NOTES

Motion parallax provides a depth cue when the observer translates. The diagram considers two fixed objects and a rightward head translation without rotation: for the same head displacement, the near object has a larger apparent shift than the far object. The objects do not move in the world; their directions relative to the observer change.

On the left, lines connect each head position to the two objects in a top view. On the right, both frames use the same viewing orientation and projection scale. The blue circle is near and the brown triangle is far. From the first viewpoint to the second, both shift left, but the nearer object shifts farther. The two lower arrows compare the displacements.

This depth cue is available to one eye. The illustration assumes constant viewing orientation; visually tracking an object can alter the directions of relative retinal motion while preserving the difference between depths.

To reproduce this effect in VR, the system must track head position and recompute the viewpoint. Rotation tracking alone is insufficient. With a fixed display, this involves adapting projection to eye position, as illustrated in the following video.

The viewpoint follows head movements

Johnny Lee · 21 December 2007



The viewpoint follows head movements

Watch the video ↗

COURSE NOTES

Johnny Lee’s demonstration adapts projection to tracked head position in front of a fixed display. As the observer moves, the scene is seen from different viewpoints, like a window onto a space with depth. Observe changes in relative position and occlusion; head rotation alone does not reproduce the same geometry.

Vergence and accommodation

Vergence

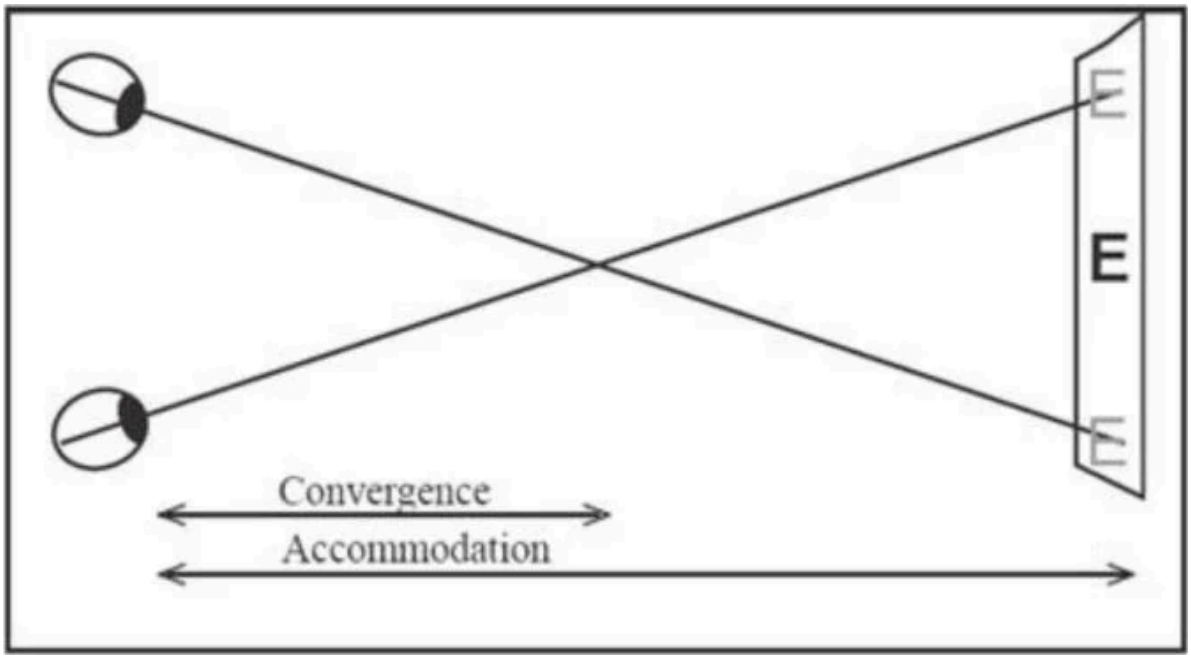
Aligning both eyes on a target

Accommodation

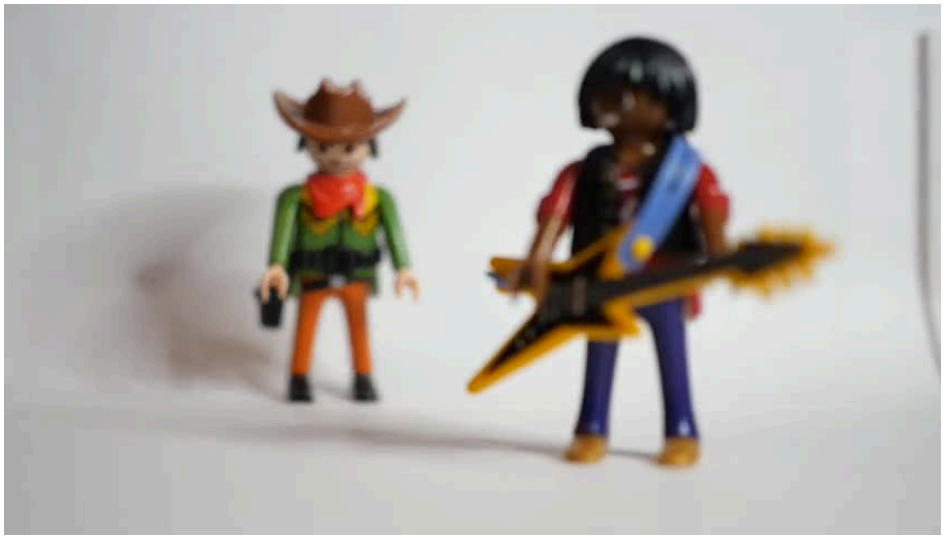
Focusing the eye’s optics

Conventional stereo displays

These demands can differ



Vergence and accommodation geometry



Accommodation: changing the plane of focus

Watch the video ↗

COURSE NOTES

In natural viewing, the object's distance usually links vergence and accommodation. In many stereo displays, focus remains at an optical display distance while disparity asks the eyes to converge elsewhere. This mismatch can contribute to visual fatigue. Alternative optical architectures address aspects of the problem; their effectiveness depends on the display and viewing task.

Watch how the sharp image alternates between two figures at different distances. This camera focus sequence illustrates selective focus and blur. It does not show left/right stereo views or directly measure the viewer's ocular accommodation. Relate the image to the distinction on this slide between vergence and optical focus.

Perceived distance and scale

Viewpoint height

A reference for the scene

Familiar size

A cue to object dimensions

Available field of view

Changes the visible spatial context

COURSE NOTES

Distance and scale are inferred from viewing geometry, familiar dimensions, viewpoint height and the available visual context. Changing these relationships can change how large an object or room appears. Distances may be underestimated in some virtual viewing conditions, but the effect is not a constant correction factor. Consistent units and a clearly defined viewpoint are necessary to interpret a spatial judgement.

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Part 3 of 5

4.3
Multisensory perception

COURSE NOTES

Exteroception provides information about the surroundings, proprioception about bodily position and movement, and interoception about internal bodily states. Vestibular information contributes to head-motion and orientation estimates. These signals are integrated rather than treated as interchangeable readings. Their relationships help explain how a person locates the body, controls action and experiences congruence or conflict in VR.

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4.3 Multisensory perception

Sensory channels and information

Exteroception

Signals about the surrounding world

Proprioception

Position and movement of the body

Interoception

Signals from inside the body

Vestibular information

Head motion and orientation to gravity

COURSE NOTES

Exteroception provides information about the surroundings, proprioception about bodily position and movement, and interoception about internal bodily states. Vestibular information contributes to head-motion and orientation estimates. These signals are integrated rather than treated as interchangeable readings. Their relationships help explain how a person locates the body, controls action and experiences congruence or conflict in VR.

4.3 Multisensory perception

Spatial hearing

Localisation

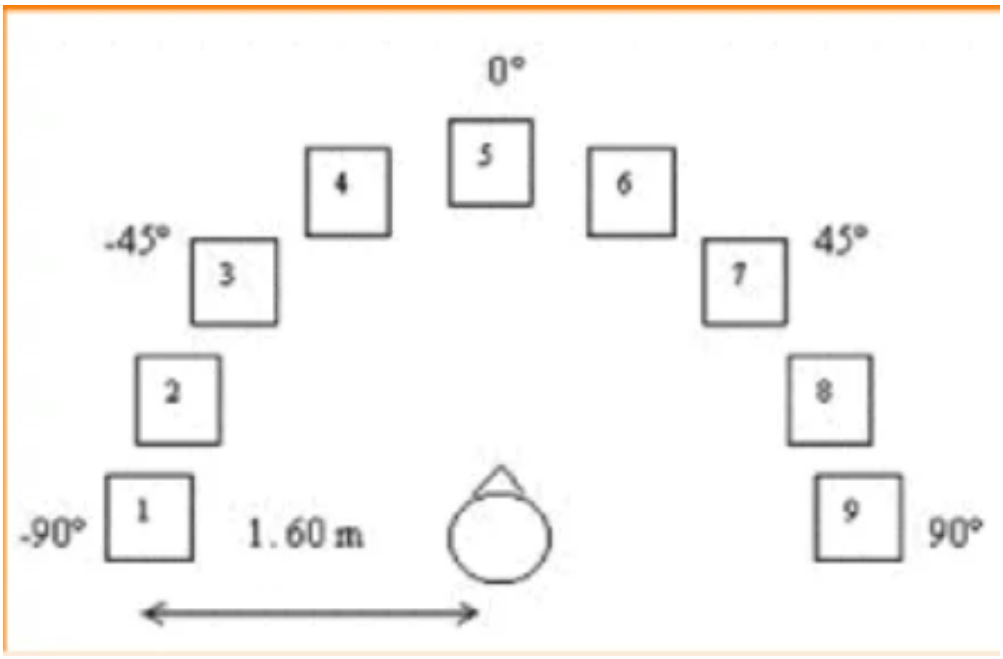
Direction and distance cues

Material and event

What happened, and to what?

Attention

A signal outside the current view



Spatial sound localisation

COURSE NOTES

Sound conveys location, action and material. Differences in timing and intensity between the ears, together with spectral cues, contribute to localisation. The rendered sound should remain coherent with the world when the listener moves. Spatial audio can also support guidance and communication rather than merely add realism.

Touch and active exploration

Cutaneous information

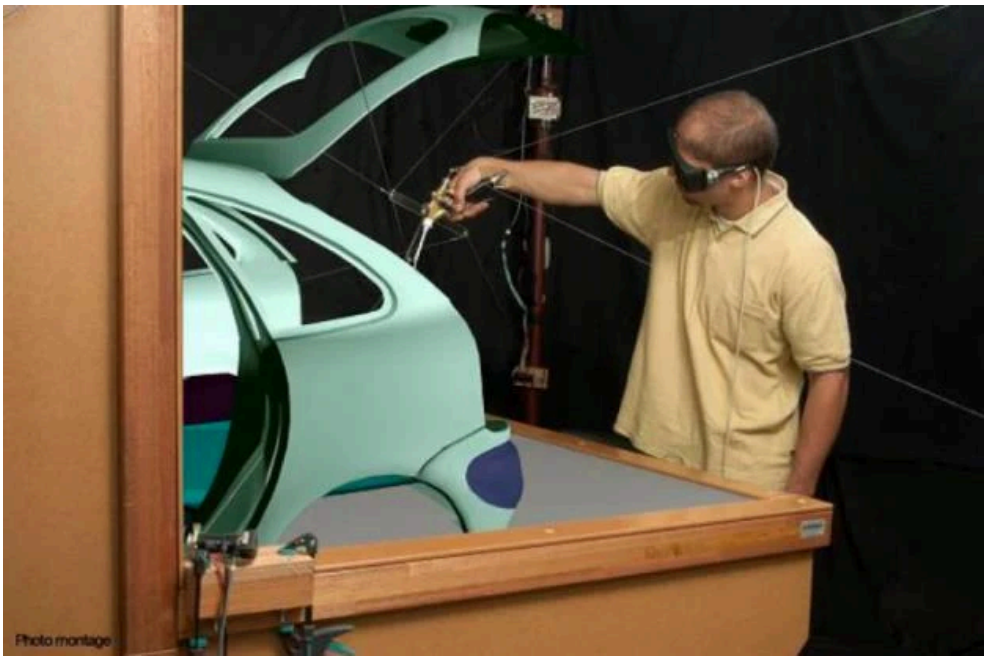
Pressure, vibration and texture

Kinesthetic information

Movement, forces and resistance

Active exploration

Touch combined with movement



Contact with an actively explored virtual surface

COURSE NOTES

It is useful to distinguish passive cutaneous stimulation from active haptic exploration. Exploring an object combines skin information with proprioceptive and motor signals. A vibration is not equivalent to the force that prevents a hand from passing through a surface. That distinction matters when choosing an interface for manipulation or training.

Whole-body feedback: a moving walking surface



Whole-body feedback: a moving walking surface

Watch the video ↗

COURSE NOTES

This demonstration extends haptic feedback to the feet and whole body. Identify the physical support, leg motion and contact forces. Compare these physical cues with the visually simulated movement. The same device is revisited in the technical course as a locomotion interface.

4.3 Multisensory perception

Whole-body feedback: the Virtusphere



Whole-body feedback: the Virtusphere

Watch the video ↗

COURSE NOTES

Observe the combination of active walking, contact with the moving sphere and visual feedback. The body receives physical movement cues even though the virtual trajectory and the room-scale displacement differ. This is a hardware demonstration, not a measurement of perceptual accuracy.

4.3 Multisensory perception

Whole-body feedback: a movable support

surface



Whole-body feedback: a movable support surface

Watch the video ↗

COURSE NOTES

The recording shows an actuated support surface. Identify which physical forces and movements can accompany the virtual display. Discuss which signals come from real contact and which must be interpreted from vision.

The vestibular system

Semicircular canals

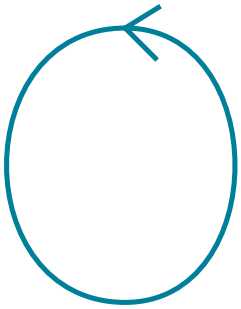
Angular acceleration

Otolith organs

Linear acceleration and gravity

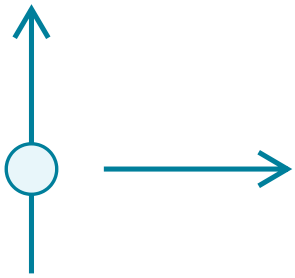
Integrated estimate

Movement and balance



Angular acceleration

Semicircular canals



Linear acceleration

Otolith organs

Also sensitive to gravity

COURSE NOTES

Semicircular canals and otolith organs provide complementary information about head movement and orientation relative to gravity. They do not directly signal the velocity assigned to a virtual camera. Visual travel can therefore disagree with vestibular and other bodily cues. Perceived motion results from the combination of these signals, together with the person’s movement and expectations.

4.3 Multisensory perception

Smell and taste

Smell

Identity, memory and context

Taste

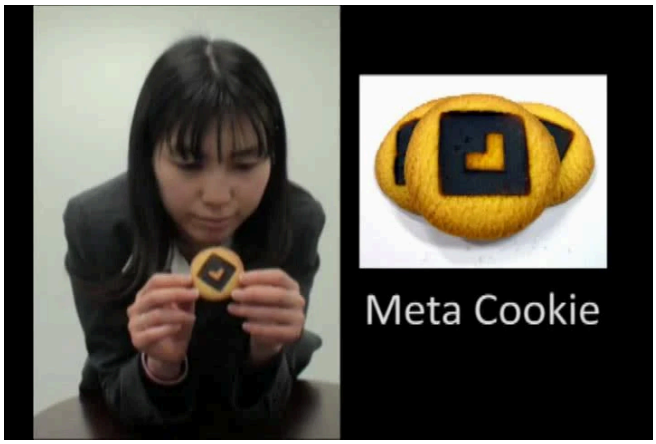
Chemosensory and multisensory experience

Practical constraint

Delivery and persistence



A multisensory taste demonstration



Visual context and food perception

COURSE NOTES

Smell can contribute to identifying a situation and its emotional context. Taste experiences also depend on interactions among sensory signals, including what is seen and smelled. Providing these signals requires specialised interfaces. Scent can persist after release, so stopping and clearing stimulation differs from replacing an image on a display. The sensory channel must fit the scenario and its timing.

Multisensory taste demonstration



Multisensory taste demonstration

Watch the video ↗

COURSE NOTES

Smell can contribute to identifying a situation and its emotional context. Taste experiences also depend on interactions among sensory signals, including what is seen and smelled. Providing these signals requires specialised interfaces. Scent can persist after release, so stopping and clearing stimulation differs from replacing an image on a display. The sensory channel must fit the scenario and its timing.

Multisensory integration

Redundancy

Several cues indicate the same event

Complementarity

Different cues add different information

Congruence

Timing and spatial alignment support a common cause

COURSE NOTES

Multisensory perception combines signals rather than simply accumulating them. Congruent cues can support a stable interpretation, while differences can create ambiguity or an illusion. Whether a cue helps depends on reliability and task relevance. Adding another modality may have little effect when the required information is already available.

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Part 4 of 5

4.4

Sensorimotor coupling

COURSE NOTES

A sensorimotor contingency is a regular relation between action and sensory change. In a tracked scene, the consequences of head movement should be appropriate to that movement. Interaction techniques can intentionally change the mapping, but the change still needs to be understandable and stable enough for the activity.

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4.4 Sensorimotor coupling

Sensorimotor contingencies

An action

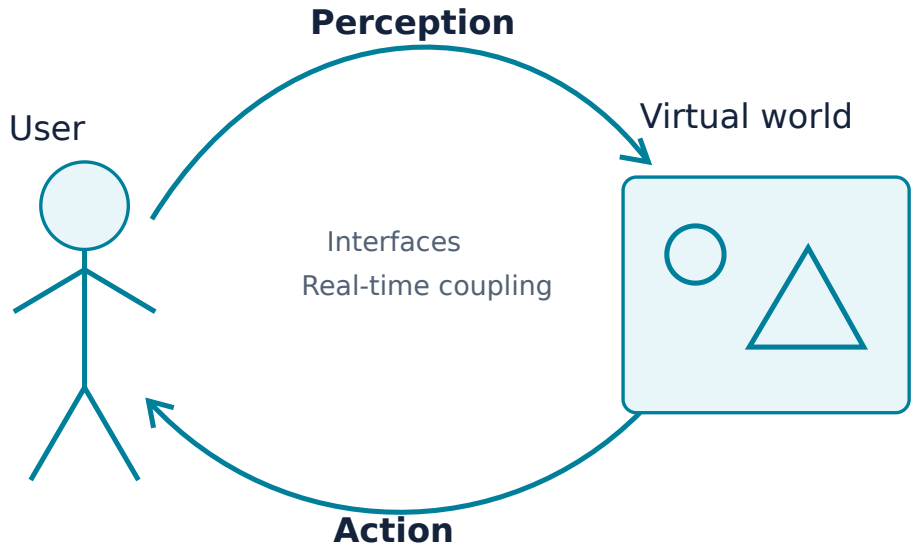
The head turns or a hand reaches

An expected change

The view or hand should update

A perceived result

Feedback confirms or violates the expectation



COURSE NOTES

A sensorimotor contingency is a regular relation between action and sensory change. In a tracked scene, the consequences of head movement should be appropriate to that movement. Interaction techniques can intentionally change the mapping, but the change still needs to be understandable and stable enough for the activity.

Spatial and temporal coherence

Space

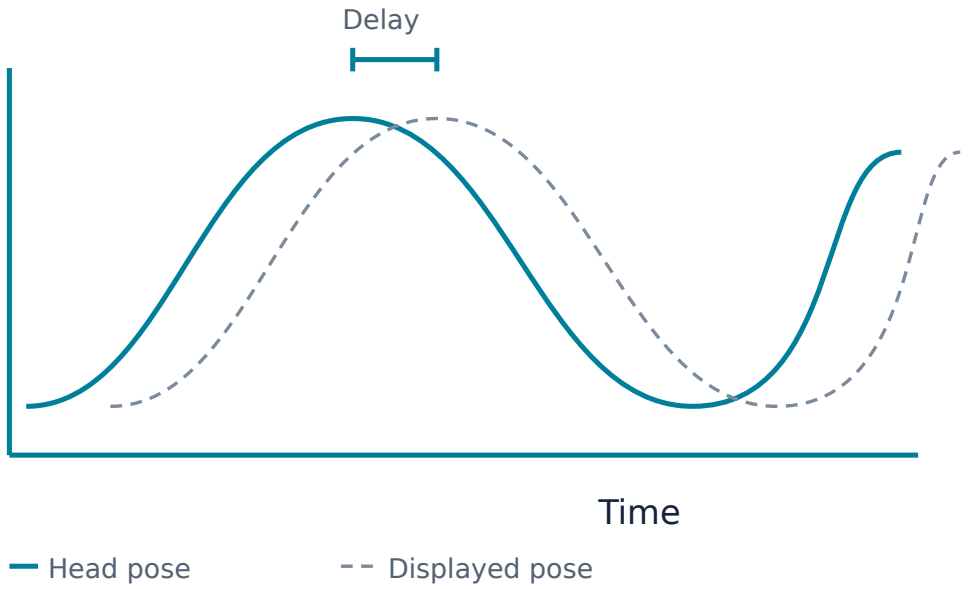
Inputs and outputs share an alignment

Time

Feedback follows the action with limited delay

Modalities

Events agree across sensory channels



COURSE NOTES

A spatial offset can place the visible hand away from the physical hand. A temporal offset can make the hand follow late. Cross-modal offsets can separate the seen and felt contact. Those errors affect action, embodiment and comfort differently. Low average latency alone does not remove jitter or intermittent stalls.

Physical and virtual surroundings

Physical support

Props or equipment serve the task

Neutral background

Some real cues remain irrelevant

Interference

Real cues contradict the virtual situation

COURSE NOTES

Biocca’s discussion distinguishes how physical surroundings contribute to immersion. A real surgical instrument can support a simulated procedure. Unrelated room sounds can distract or contradict the scenario. The fraction of a sensory channel occupied by virtual stimulation is different from the fidelity or relevance of that stimulation.

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Part 5 of 5

4.5
Perceptual illusions

COURSE NOTES

Lécuyer’s examples alter the relation between input and displayed motion or deformation. Slowing a controlled object in a region can suggest friction; varying deformation for the same input can suggest stiffness. This does not generate an equivalent physical force. It exploits perceptual interpretation under particular task and cue conditions.

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Online slide ↗

4.5 Perceptual illusions

Pseudo-haptic feedback

Physical input

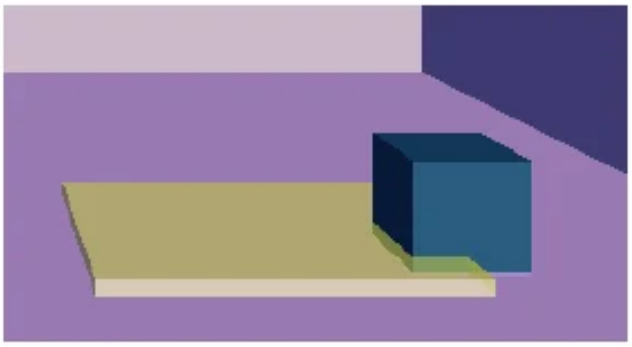
A movement or force

Visual manipulation

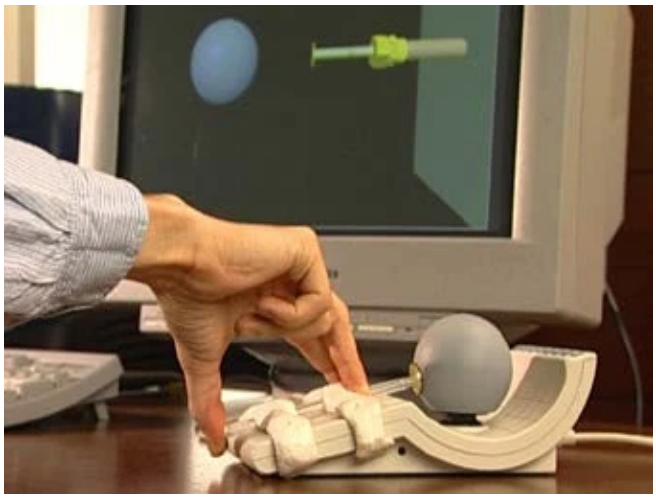
Change displacement or deformation

Haptic interpretation

An apparent resistance or material property



Visual manipulation of apparent friction



A pseudo-haptic stiffness example

Try it: feel resistance through vision ↗

COURSE NOTES

Lécuyer’s examples alter the relation between input and displayed motion or deformation. Slowing a controlled object in a region can suggest friction; varying deformation for the same input can suggest stiffness. This does not generate an equivalent physical force. It exploits perceptual interpretation under particular task and cue conditions.

Palpation: changing visible deformation

Palpation: changing visible deformation

Watch the video ↗

COURSE NOTES

This palpation demonstration shows how visual deformation can contribute to perceived stiffness. Distinguish the physical action, the displayed deformation and the property the user is trying to estimate. Watching the video explains the mechanism; experiencing the illusion requires performing the interaction oneself.

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Online slide ↗

4.5 Perceptual illusions

Control–display gain

Gain = virtual displacement / physical displacement

Physical displacement

The movement made by the person

Virtual displacement

The movement shown by the system

Gain

The relation between the two

COURSE NOTES

A gain of one preserves displacement only if units and coordinate conventions agree. A fixed gain scales movement, whereas a nonlinear mapping can change gain with distance or speed. Manipulation, redirected walking and pseudo-haptics use different forms of mapping. Their effectiveness depends on the task and what competing cues remain available.

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Online slide ↗

4.5 Perceptual illusions

Pseudo-haptics in action

Apparent resistance

WebXR Pseudo-haptics — Kenichi Ito (2021)

Watch the video ↗

Alter displayed motion to suggest resistance or surface relief.

Apparent impact

Hit-Stop in VR — Yuki Ban & Yusuke Ujitoko (2021)

Watch the video ↗

Briefly stop or slow the virtual racket at contact.

COURSE NOTES

On the left, Kenichi Ito’s WebXR demonstrations change the mapping between input and displayed motion to illustrate resistance and surface-relief sensations. Observe the mismatch between the intended movement and the visible response. The video presentation is in

Japanese; the animations can be explained orally.

On the right, Hit-Stop in VR temporarily changes the virtual racket’s motion when it contacts the ball. The study combines this visual effect with vibration, so the entire impact sensation should not be attributed to visual feedback alone. The demonstration allows comparisons of stopping versus slowing, duration, and the presence or absence of vibration.

These videos show visual-feedback manipulations, not the viewer’s subjective sensation. Experiencing pseudo-haptics requires acting oneself and perceiving the mismatch between action and displayed outcome.

Perceptual flexibility

Apparent material

Pseudo-haptic contact

Apparent path

Redirected walking

Apparent body

Ownership illusions

COURSE NOTES

The next units use perceptual flexibility to solve practical problems. A limited physical room can support a larger virtual path; a tool can appear resistant without a matching force device; a virtual body can contribute to self-representation. Each effect has conditions and limits. None means that perception can be changed arbitrarily.

Explaining an illusion

Which signal changes?

Which cues remain consistent?

What does the participant infer?

When might the effect fail?

COURSE NOTES

Apply these questions to pseudo-haptic friction or a body-ownership illusion. The aim is a causal explanation of the manipulation rather than a list of devices. Predict one condition that could weaken the effect.

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

The Virtual Reality Treatise ↗ 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.