UNIVERSITY OF CANTERBURY
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HITLabNZ
Human Interface Technology Laboratory New Zealand
www.hitlabnz.org

Multi-sensory XR Experiences

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HIT Lab NZ Role in ARIVE

- Multi-sensory XR
- Applied Games
- Long-term Immersion
  - Reduce cybersickness
  - Reduce fatigue
  - Integrate with Real World (e.g., office environment)
- All tied together with XR

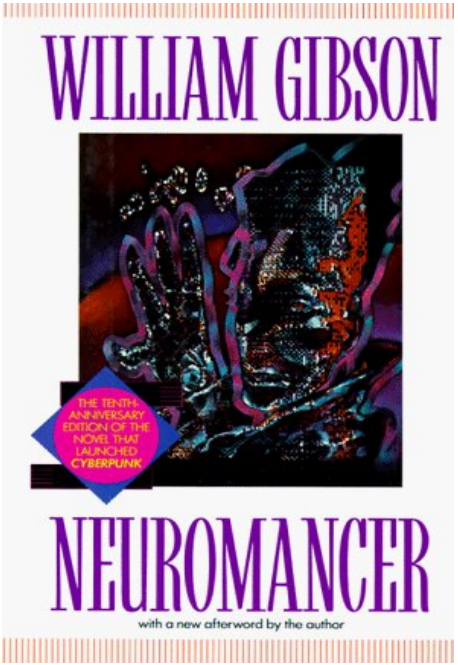
Multi-sensory vs. Multi-modal

- The term ***multi-modal*** is overused in the literature for both input and output, which is confusing
- We propose using multi-modal for input to the system, and ***multi-sensory*** for output to the user

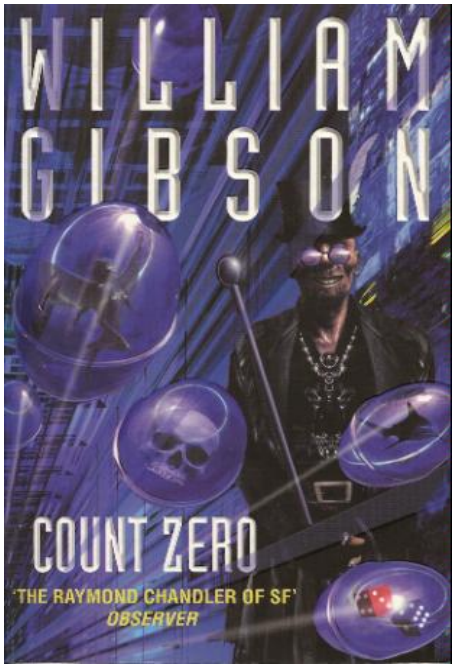
Overview

- Current systems do graphics and sound pretty well
  - Well understood visual and auditory systems
  - Mature hardware
  - Non-intrusive senses
- What is necessary to get us to the next level?

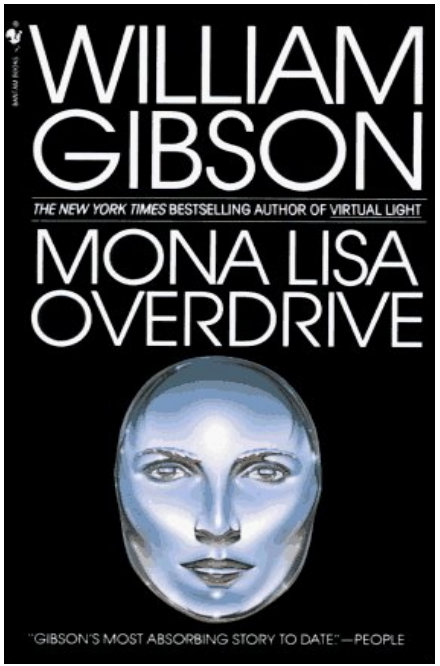
1980s / Early 1990s



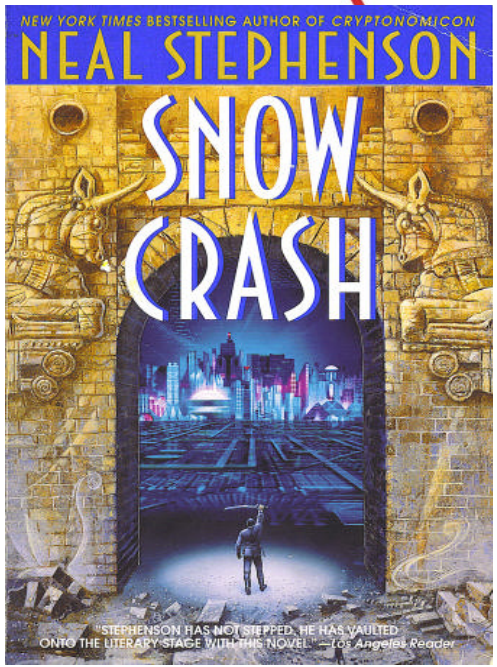
1984



1986

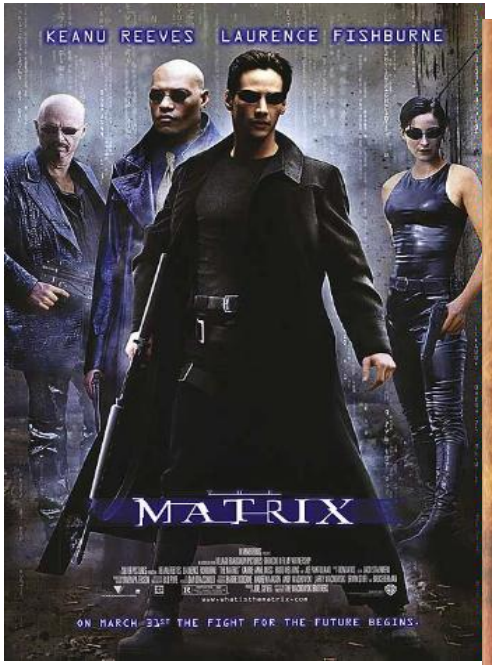


1988

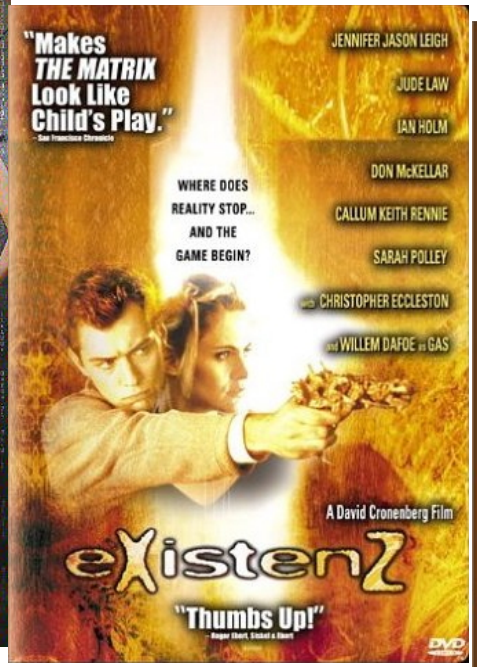


1992

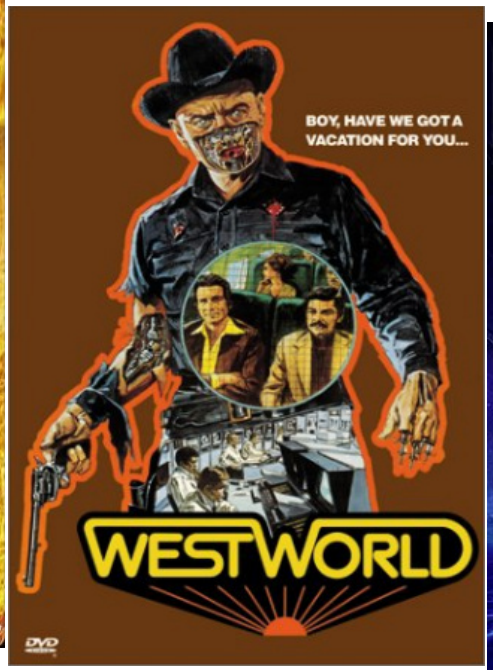
Late 1990s~



1999



1999



1972

2018

What are we talking about?

- VR defined:
  - Fooling the senses into believing they are experiencing something they are not actually experiencing (Lindeman, 1999)
- Maybe this needs to be updated?
- VR redefined:
  - Fooling the *brain* into believing it is experiencing something it is not actually experiencing

VR Components

- Virtual reality systems consist of:
  - User(s) ← Really important!
  - Content
  - Graphical/audio/haptic/... rendering
  - Tracking of people and objects
  - Physics, collision detection, etc.
  - Interaction techniques
  - Networking (optional)
  - Autonomous agents (optional)

What is *Real* Reality?

- *Your focus determines your reality.*
  - *Qui-Gon Jinn*

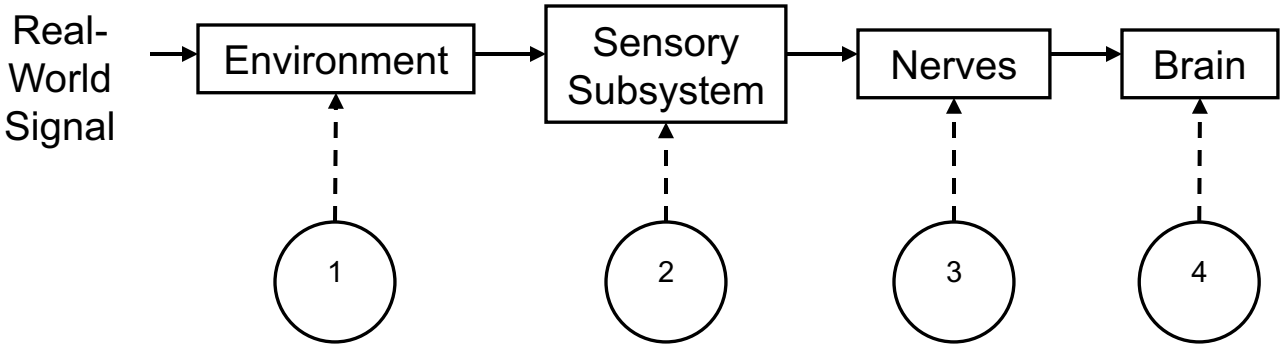
- Translation:
  - "Reality is just an illusion, so fake it!"

Nothing New?
SENSORAMA by Morton Heilig (1960)

Where Can We Mix Reality?

Direct

Lindeman & Noma (VRST 2007)



Captured/Mediated

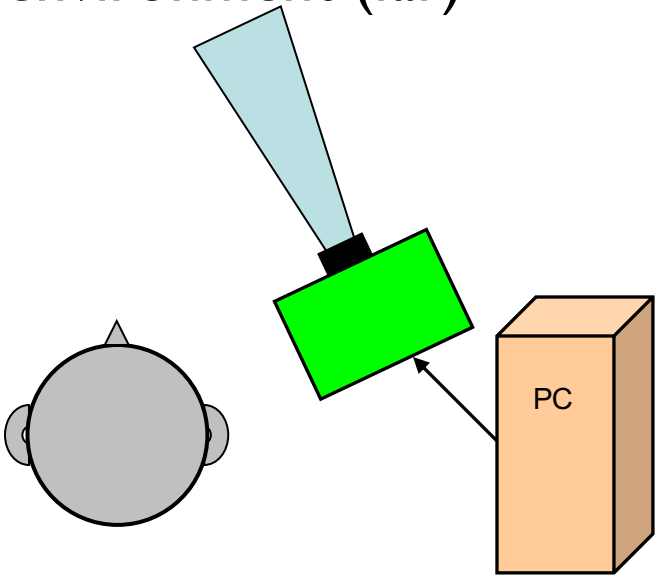
The Senses

- See (Visual Sense):
  - Visuals are excellent!
- Hear (Aural Sense):
  - Spatialized audio is very good!
- Smell (Olfactory Sense):
  - Very hard! Too many types of receptors.
- Touch (Haptic Sense):
  - Application specific and cumbersome
- Taste (Gustatory Sense):
  - We know the base tastes, but that is it!

See: Visual Sense

Lindeman & Noma (VRST 2007)

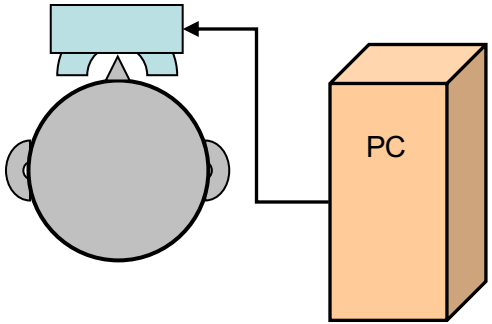
- Projection
  - Mixing in the environment (far)



See: Visual Sense (cont.)

- Optical-see-through AR
  - Mixing in the environment (near)

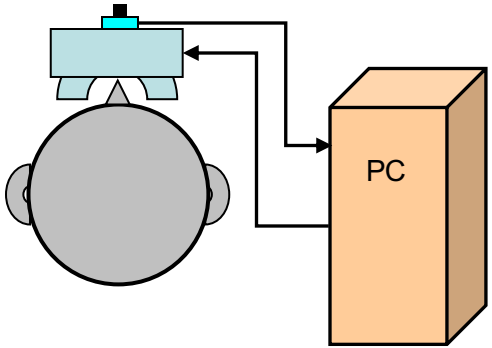
Lindeman & Noma (VRST 2007)



See: Visual Sense (cont.)

Lindeman & Noma (VRST 2007)

- Video-see-through AR
  - Mixing in the Computer



See: Microsoft's Mixed Reality Platform HMDs

- Produced by HP, Acer, Dell, Lenovo, Samsung, Asus…

Idea is to provide a more affordable and more compatible solution

- Resolution: 1440x1440 (1600) per eye
- FoV: 95(up to 110) degrees
- Tracking: 6DoF ("inside out")
- Weight: 400g (up to 800g)
- Price: US$300 – US$500

www.wikipedia.org/wiki/Comparison_of_virtual_reality_headsets

See: Head-Mounted Displays

VictorMaxx CyberMaxx
Released: **1994**
Res: 263x225 / eye
FOV: 56(H)x42(V)
Tracking: Orientation
Weight: 390 grams
Price: US$700
(US$1200 in 2018$)

Virtual IO i-glasses
Released: **1995**
Res: 640x480 / eye
FOV: 30(H)x25(V)
Tracking: Orientation
Weight: ~220 grams
Price: US$800

Forte VFX-1
Released: **1995**
Res: 263x230 / eye
FOV: 36(H)x26(V)
Tracking: Orientation
Weight: ?? grams
Price: US$700

Sony Glasstron
Released: **1998**
Res: 832x624 / eye
FOV: 30(H)x22.5(V)
Tracking: None
Weight: ~120 grams
Price: US$2,730
(US$4200 in 2018$)

eMagin z800
Released: **2005**
Res: 800x600 / eye
FOV: 32(H)x24(V)
Tracking: Orientation
Weight: ~220 grams
Price: US$900

See: Head-Mounted Displays

Razer OSVR
Released: **2015**
Res: 960x1080 / eye
FOV: 90(H)x90(V)
Tracking: 6-DOF
Weight: ?? grams
Price: US$300

Oculus Rift
Released: **Mar. 2016**
Res: 1080x1200 / eye
FOV: 110
Tracking: 6-DOF
Weight: 470 grams
Price: US$600

HTC Vive (pro)
Released: **Apr. 2016**
(Apr. 2018)
Res: 1080x1200 / eye
(1440x1600 / eye)
FOV: 110
Tracking: 6-DOF
Weight: 555 grams
Price: US$800

Sony PSVR
Release: **Oct. 2016**
Res: 960x1080 / eye
FOV: ~100
Tracking: 6-DOF
Weight: 610 grams
Price: US$400

See: Mobile-based VR

Google Cardboard
Released: **2014**
Res: phone
FOV: ~90deg
Tracking: phone
Price: NZ$30

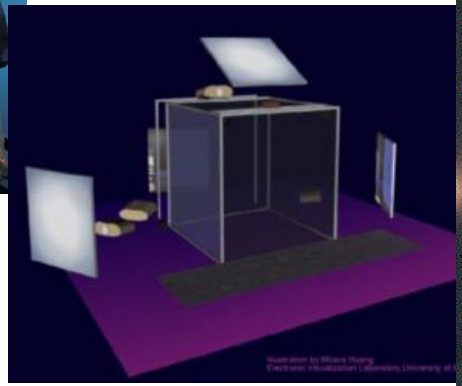
Google Daydream (Gen 2.)
Released: **Nov. 2016**
(Oct 2017)
Res: phone
FOV: ~100deg
Tracking: phone
Price: US$79
(NZ$150)

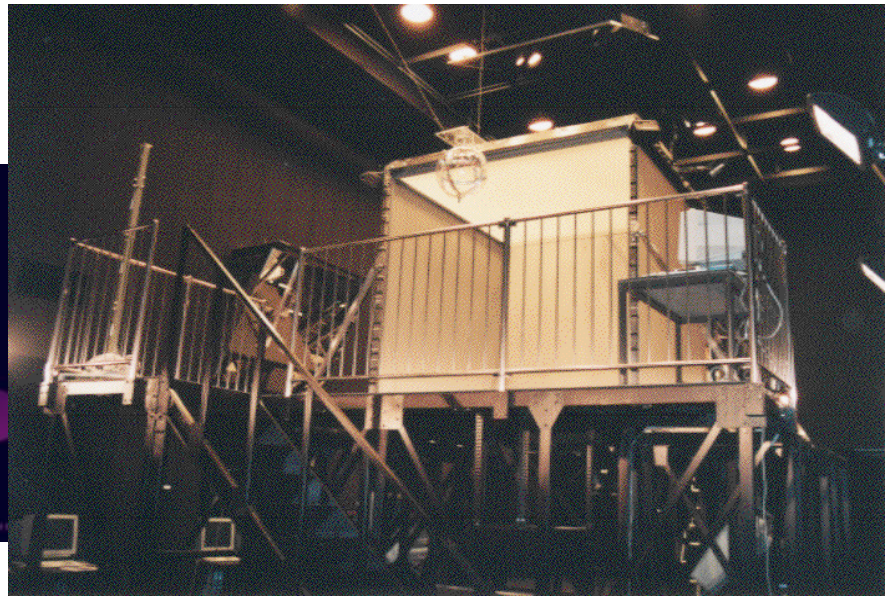
Samsung Gear VR (Gen 2, Gen3)
Released: **Nov. 2015**
(…2017)
Res: phone
FOV: ~101deg
Tracking: phone
Price: US$99
(NZ$200)

Lenovo Mirage (standalone)
Released: **2018**
Res: 2560x1440
FOV: ~110deg
Weight: 645g
Price: US$399
(NZ$575)

Oculus Go (standalone)
Released: **2018**
Res: 2560x1440
Weight: 467g
Price: US$ 200

See: Projection-Based Environments

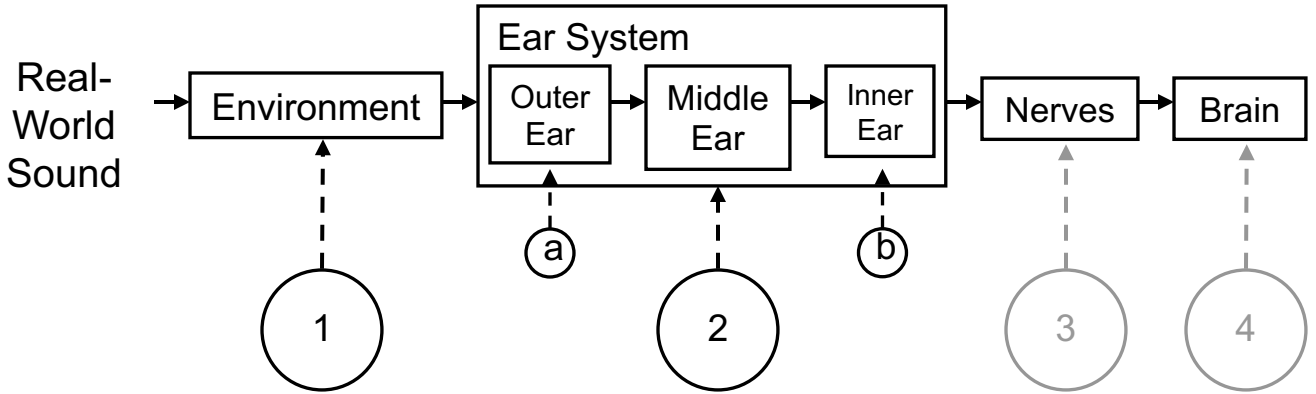




See: Projection-Based Environments (cont.)

Hear: Sound Paths & Mixing Points

Lindeman & Noma (VRST 2007)

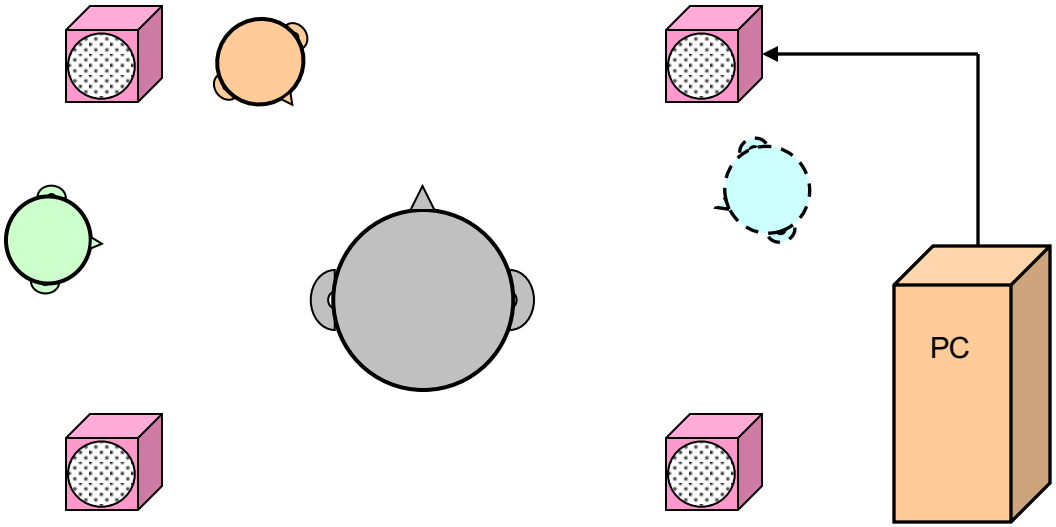


- Typical VR/AR systems use speakers (1) or headphones (2a)
- Could also perform the mixing at the cochlea (2b), using bone conduction

Hear: Auditory Sense

Lindeman & Noma (VRST 2007)

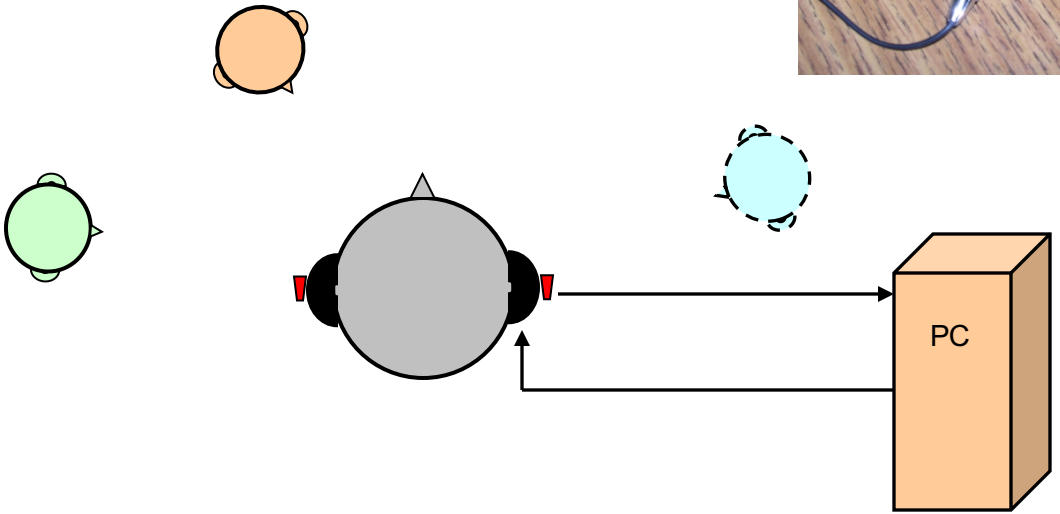
- Acoustic-Hear-Through AR (Speakers)
  - Mixing in the environment (far)



Hear: Auditory Sense (cont.)

Lindeman & Noma (VRST 2007)

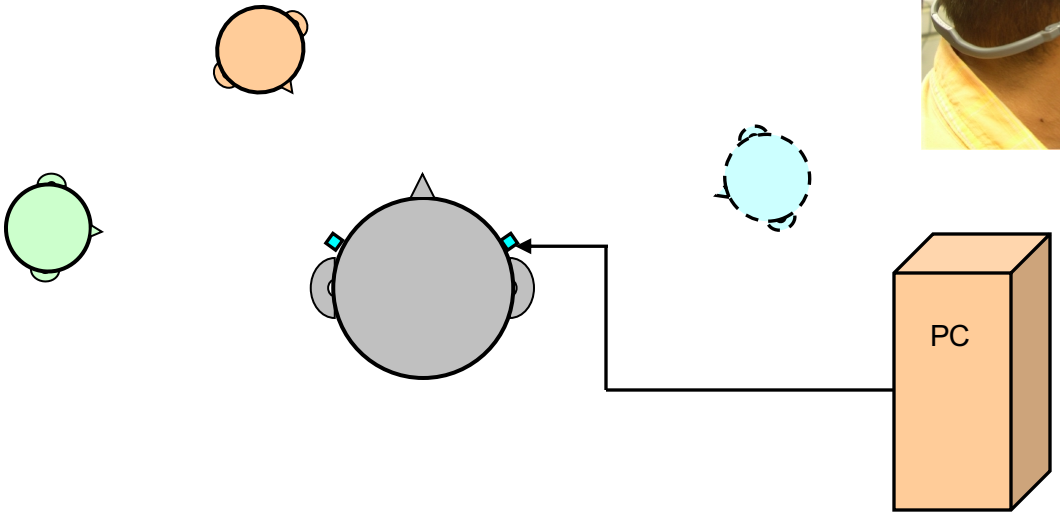
- Mic-Through AR
  - Mixing in the computer



Hear: Auditory Sense (cont.)

- Hear-Through AR
  - Bone conduction
  - Mixing at the sensory subsystem

Lindeman & Noma (VRST 2007)



Hear: Bone-Conduction Example

- The sound of your own voice is a combination of:
  - Sound reaching your ears through the air
  - Vibrations reaching your cochlea thou your head
- Example
  - Sound heard through the air
  - Sound heard through the head
  - Combined sound

Mauldin & Scordilis, 2004

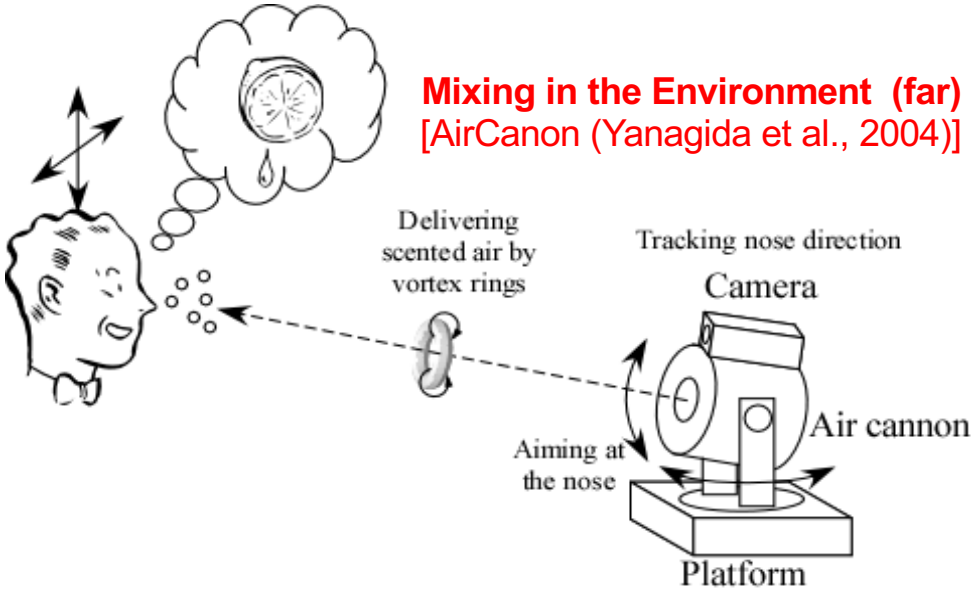
Smell: Olfactory Sense

- Two main problems
  - Scent generation
    - Tens of thousands of receptor types
  - Scent delivery
    - Easier problem

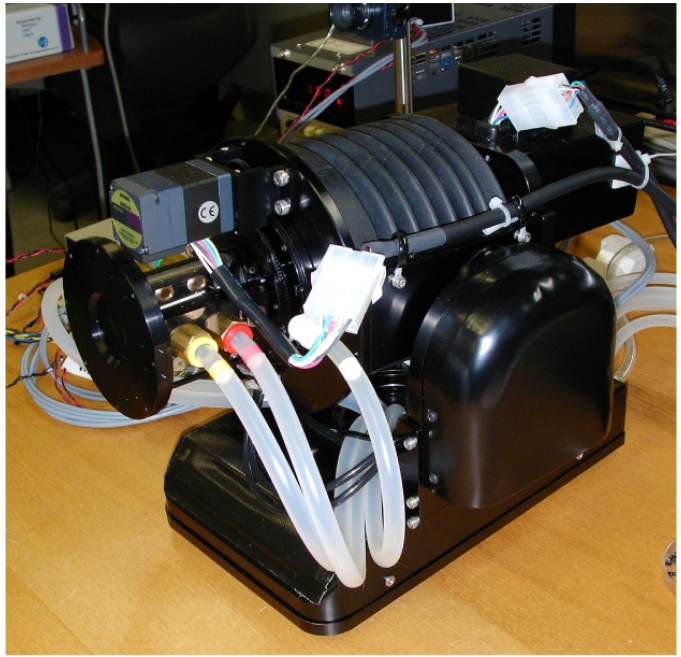
Smell: Olfactory Displays

Mixing in the Computer
(Hirose et al. 1997)

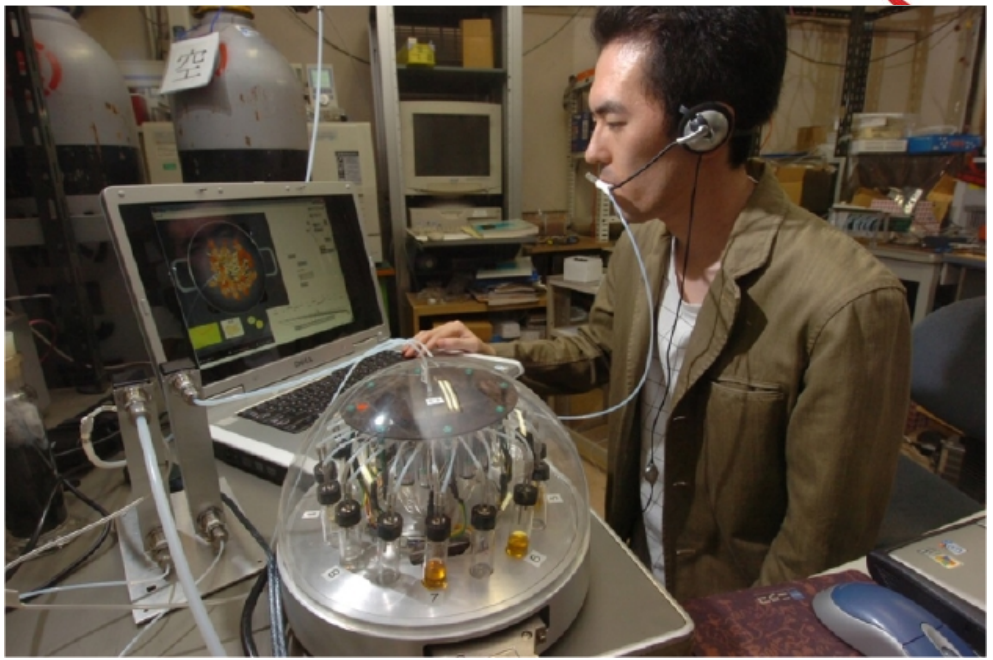
Mixing in the Environment (far)
[AirCanon (Yanagida et al., 2004)]



Smell: Olfactory Displays (cont.)



Mixing in the Environment (mid)
[AirCanon (Yanagida et al., 2004)]



Mixing in the Environment (near)
(Nakamoto & Min, 2007)

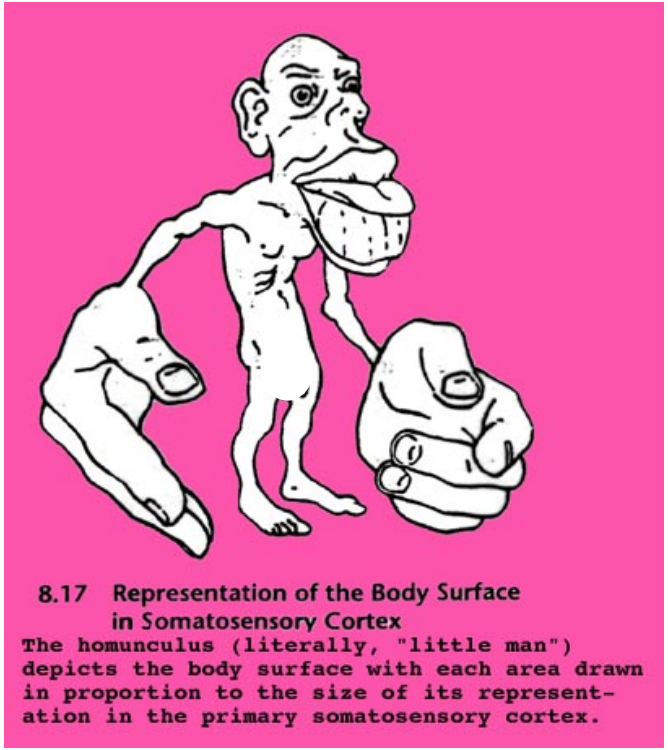

Air cannon is tracking
the user's nose.

Touch: Called “Haptics”

- Actually covers many different senses
  - Force/pressure
  - Slipperiness
  - Vibration
  - Wind
  - Temperature
  - Pain
  - Proprioception: Knowing where your hands are without looking
  - Balance (?)

Touch: Tactile/Kinesthetic Displays

- Tactile: Surface properties
  - Most densely populated area is the fingertip (okay, it's the tongue)
- Kinesthetic: Muscles, Tendons, etc.
  - Also known as proprioception



8.17 Representation of the Body Surface in Somatosensory Cortex
The homunculus (literally, "little man") depicts the body surface with each area drawn in proportion to the size of its representation in the primary somatosensory cortex.

Touch: Sensitivity

- Sensitivity varies greatly
  - Two-point discrimination

http://faculty.washington.edu/chudler/chsense.html

Body Site	Threshold Distance
Finger	2-3mm
Cheek	6mm
Nose	7mm
Palm	10mm
Forehead	15mm
Foot	20mm
Belly	30mm
Forearm	35mm
Upper Arm	39mm
Back	39mm
Shoulder	41mm
Thigh	42mm
Calf	45mm

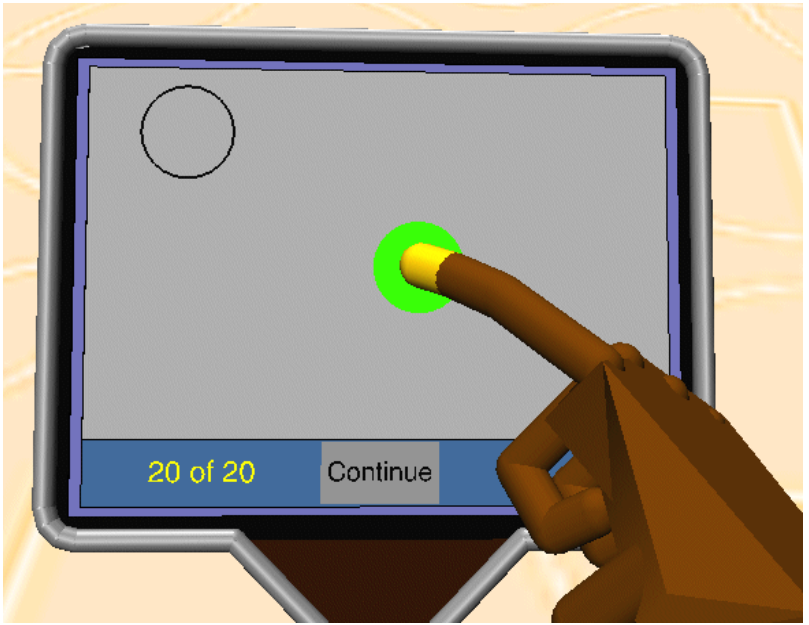
Touch: Haptic Sensory Properties

- The haptic sense is bidirectional
  - Senses the environment
  - Acts on the environment
  - Tight coupling between the two
- Skin is the largest organ

Touch: Tactile/Force Devices

- Pin arrays for the finger(s)
- Force-feedback "arms"
- "Pager" motors
- Particle brakes
- Passive haptics
- Many devices are application specific
  - Like surgical devices

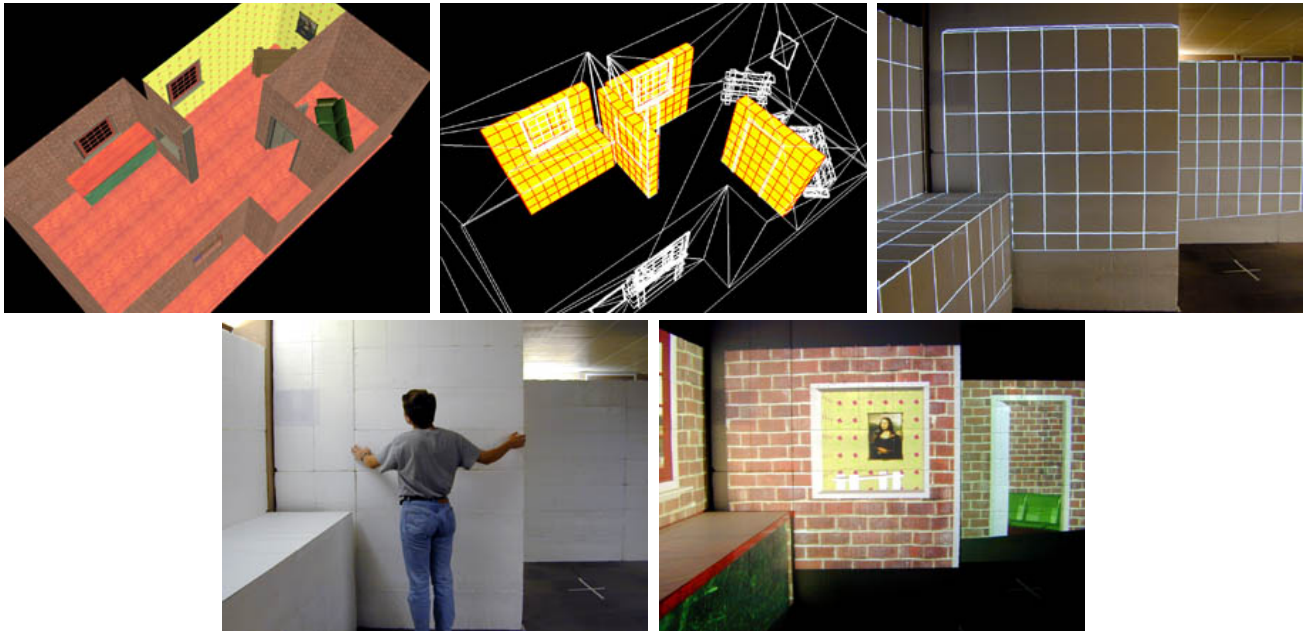
Touch: Passive Haptic Paddle



Lindeman (CHI 1999; IEEE VR 1999)

Touch: Passive Haptic Walls

(UNC Being There Project)

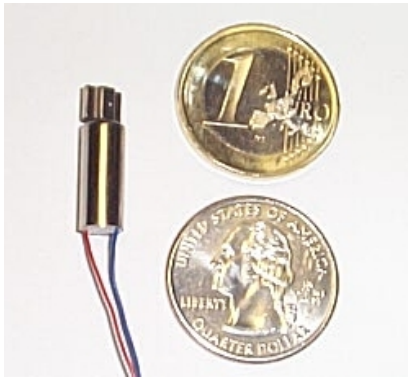


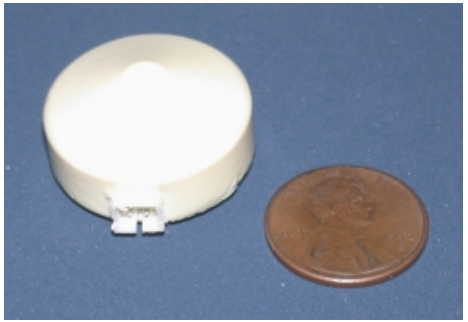
Touch: Virtual Contact

- What should we do when we know that contact has been made with a virtual object?
- The *output* of collision detection is the *input* to virtual contact
- Cues for understanding the nature of contact with objects are typically over-simplified (e.g., sound)

Touch: ibrotactile Cueing Devices

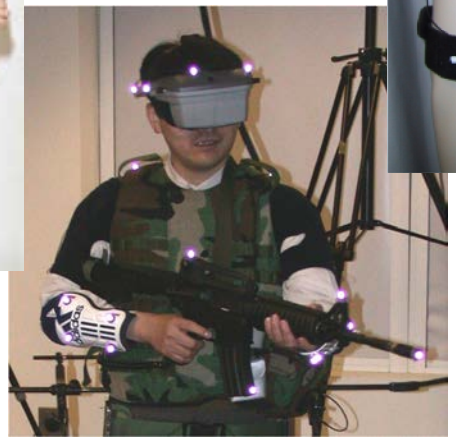
- Vibrotactile feedback has been incorporated into many devices
- Can we use this technology to provide scalable, wearable touch cues?



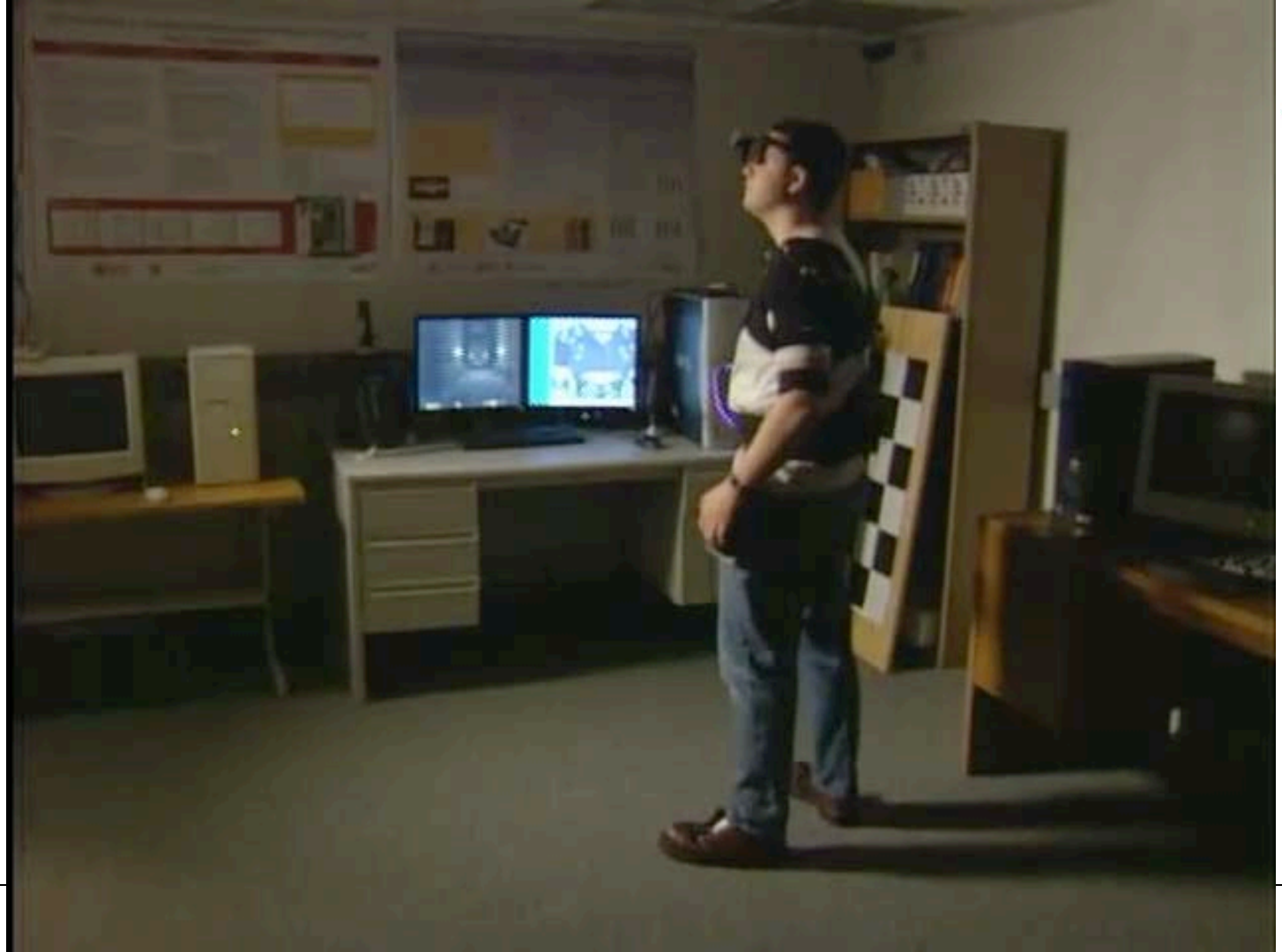


Touch: Vibrotactile Displays (cont.)

US Navy TSAS Project



Mixing in the Environment
(Lindeman, VRST 2004)

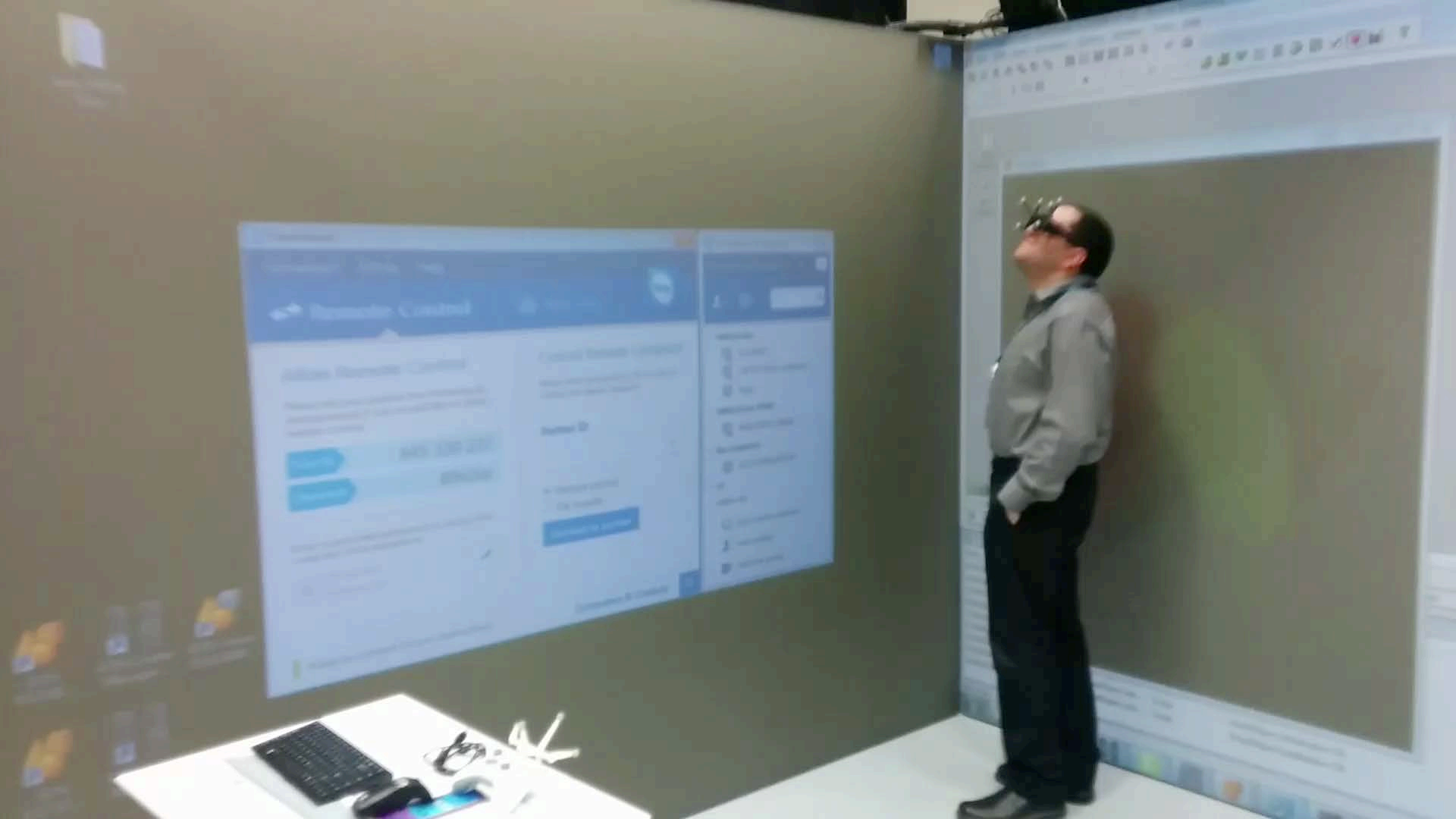


Touch: Force Displays

Mixing in Computer (teleoperation) or in Environment
(Immersion CyberGrasp)

Mixing at Sensory Subsystem
(Novint Falcon)

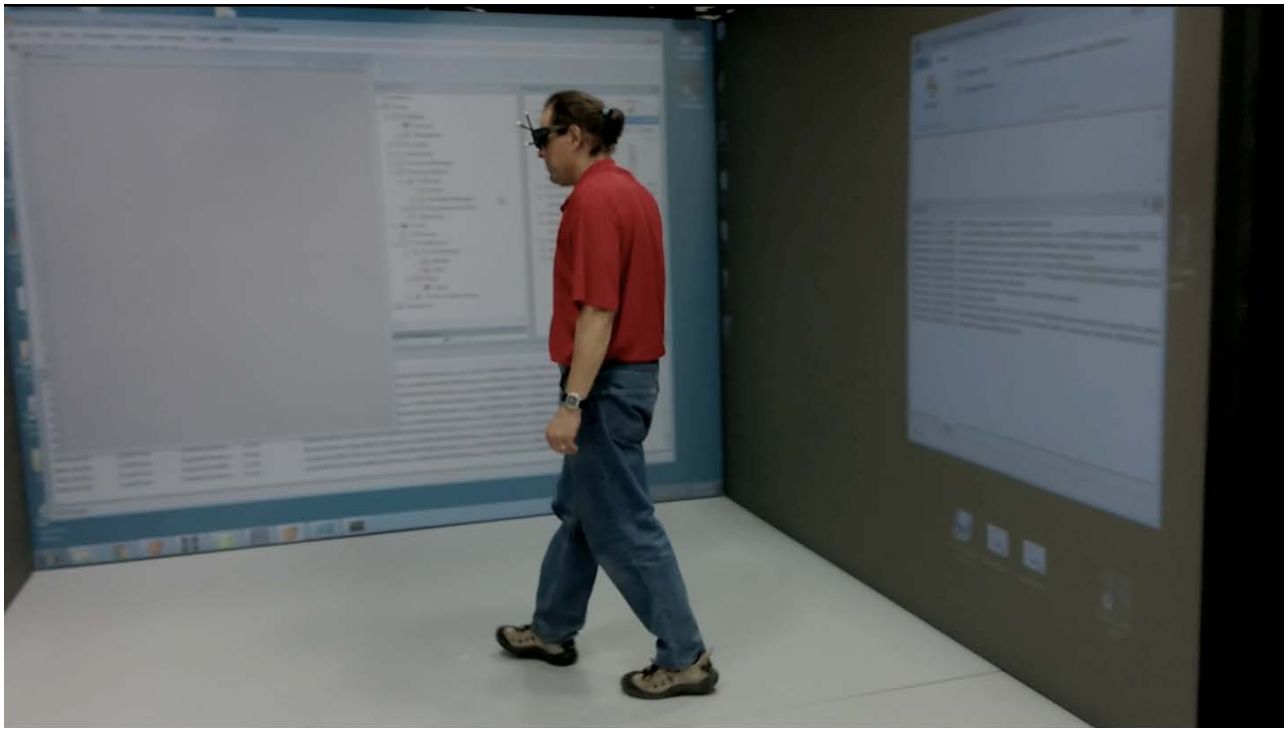
Touch: Adding Wind (Mixing on the skin)

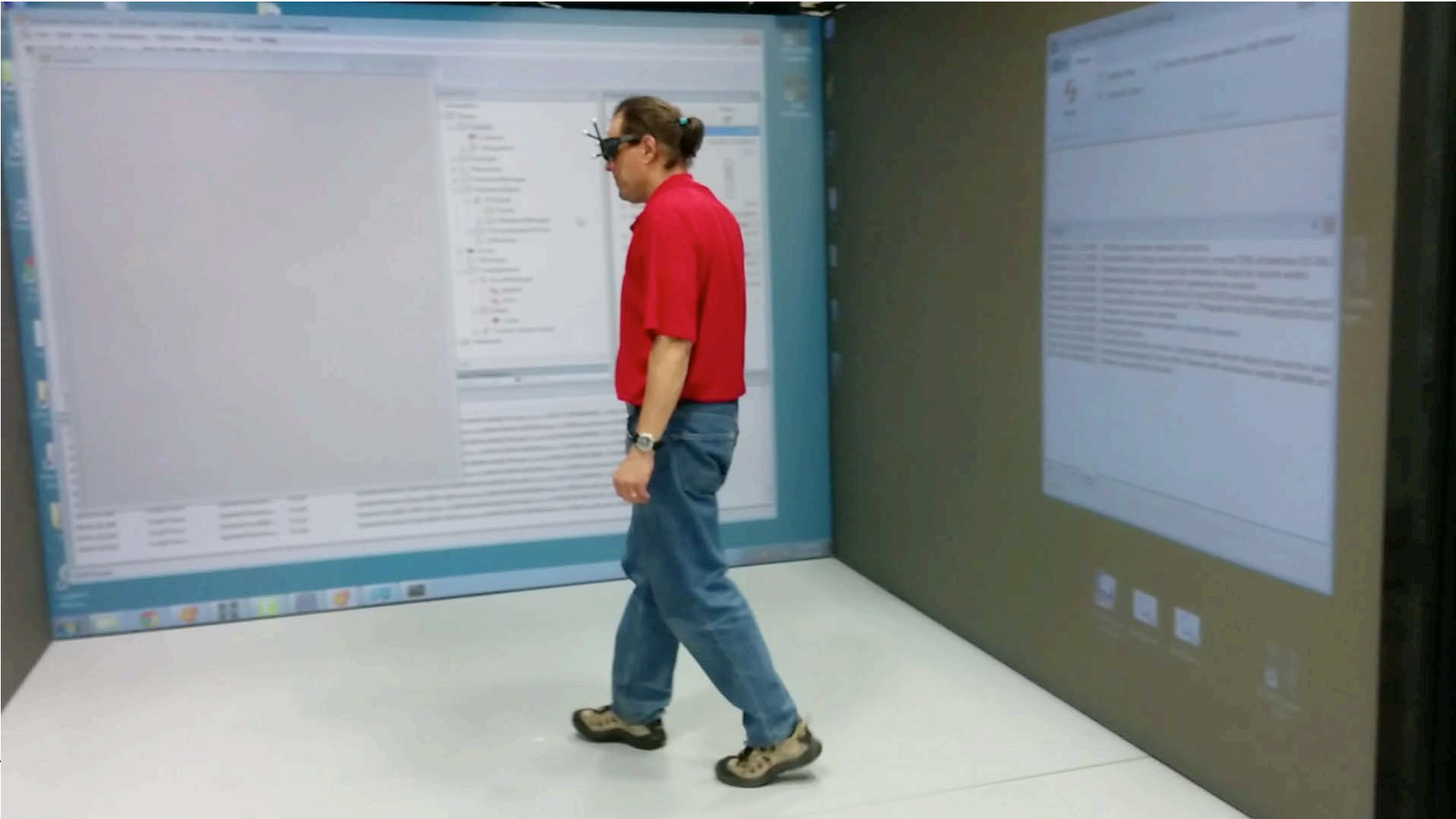


Touch: Adding Floor Vibration (Mixing in the bones)

- Typically, the user sees/hears...
  - Object/object contacts
  - Explosions
  - His/her footsteps
- We add wearable & floor vibration synchronized with the visual/sound cues to complete the experience
- TactaVest vibration based on
  - User contact with environment
  - Explosions

Touch: Adding Floor Vibration (cont.)





Putting It All Together
(HIT Lab NZ 2020)

Taste: "Gustatory" Sense

- Bite interface
  - Really haptics (near)

Iwata, 2004
(photos: Sid Fels)

Taste: Gustatory Displays (cont.)

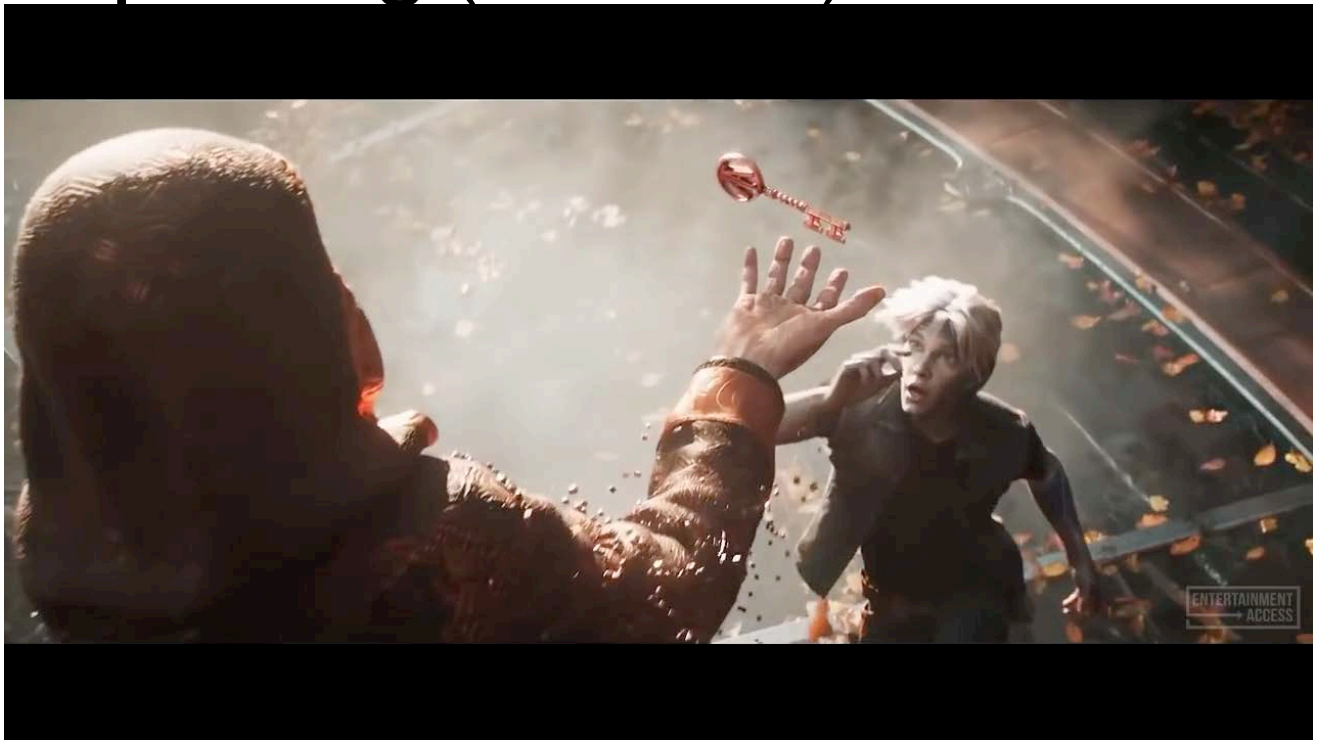
- Edible bits
- Straw-like interface
  - Mixing in the env.

(Maynes-Aminzade, 2005)

(Nakamoto, 2007)

Taste: Gustatory Displays (cont.)

Ready Player One, Ernest Cline, Steven Spielberg (Director)



World Builder (2007), Bruce Banit

Sight (2012), Eran May-Raz

Basic Interaction Tasks in VR (Bowman *et al.*)

- Object Selection & Manipulation
  - What do I want to manipulate?
  - How can I manipulate it?
- Navigation
  - Wayfinding: How do I know where I am, and how to get where I am going?
  - Travel: How do I get there? (locomotion)
- System Control
  - How do I change system parameters?
- Symbolic Input
  - Inputting text and numbers
- Avatar Control (Lindeman)
  - How do you control you?

Oh, I forgot One (Lindeman)

- Throwing things!

Final Thoughts

- What about a 3D printer+robot arm?
- RW stimuli
  - High fidelity / low control
- CG stimuli
  - Low(er) fidelity / complete control
- Later mixing point = more "personal" stimuli
  - Closer to the brain
- Multi-sensory approaches are interesting
  - Compensate for weaknesses in one sense with another sense
  - Use speakers for environmental, bone-conduction for virtual characters

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Hangarau Tangata, Tangata Hangarau
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Questions?

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