- Assignment 2 due today
- Find your partner for assignment 3
  - If you own your own HMD, you are allowed to use that and work alone if you want
  - Can assign you a random partner if you want
  - HMD logistics coming soon

Immersion, Presence, Self Perception and Avatars

Nature Reviews | Neuroscience

VR First Introduced in a Concept Paper

- Ivan Sutherland 1965: “The Ultimate Display”
- Ivan Sutherland 1968: “A head-mounted three dimensional display”
- Even in this old system, Sutherland says the 3D effect felt “real.”
- Evoking “presence”

https://dl.acm.org/doi/pdf/10.1145/1476589.1476686

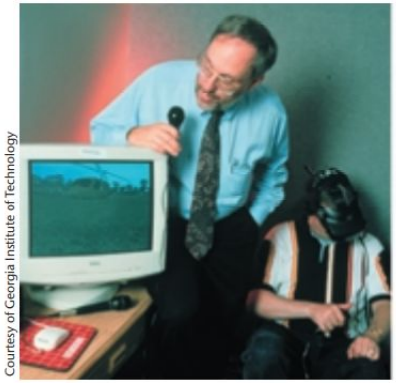
Immersion & Presence

Brooks ‘99: “What’s Real About Virtual Reality?”

- Immersion vs presence
  - **Immersion**: Objective degree to which the VR system provides a convincing and comprehensive illusion of reality
  - **Presence** (aka “being there”): refers to psychological feeling of being in a different place than what you’re physically in
- Brooks describes it as the “illusion” of presence

3 NASA-Houston’s “Charlotte” Virtual Weightless Mass lets astronauts practice handling weightless massy objects.

Courtesy of NASA



Courtesy of Georgia Institute of Technology

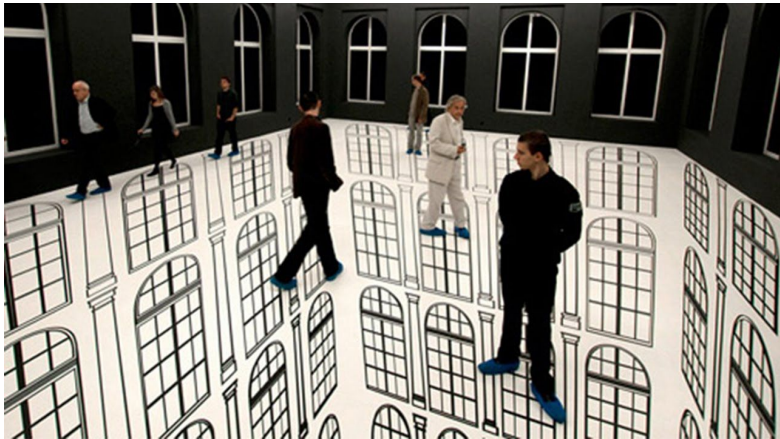
4 Vietnam war simulation at the Atlanta Veterans Administration Hospital (a) in use. (b) Imagery seen by the user.

https://www.cs.unc.edu/~brooks/WhatsReal.pdf

Place & Plausibility Illusions

- Mel Slater 2009: “Place illusion and plausibility can lead to realistic behaviour in immersive virtual environments”
  - Great paper on formalizing VR psychological concepts
- Slater refers to presence as “**place illusion**,” the illusion that you are somewhere else instead of in some lab
- “**Plausibility illusion**”: what is happening in the VE is actually happening, feels real, and you’re not just a third-party observer
  - Being in VR should feel different than watching a movie on a screen

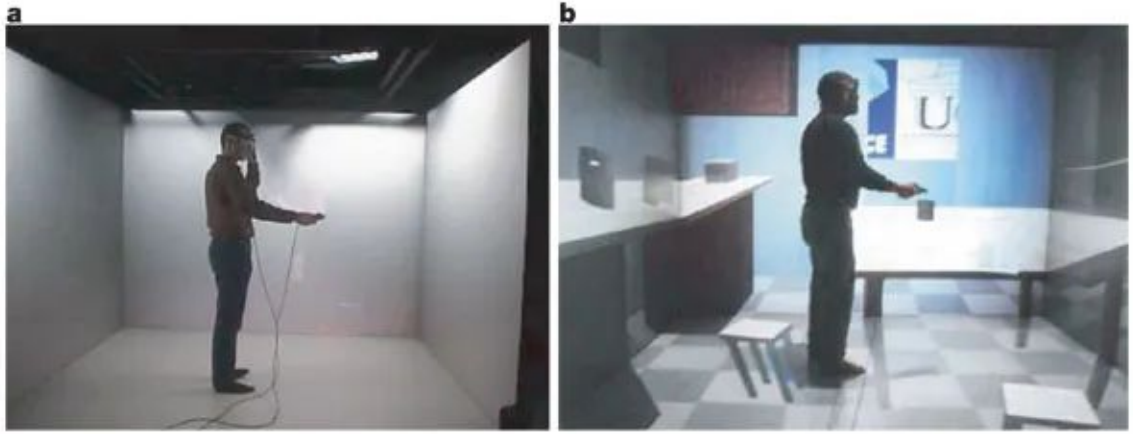
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2781884/



Immersion & Presence

Sanchez-Vives ‘05: “From presence to consciousness through virtual reality” and Meehan 2002: “Physiological Measures of Presence in Stressful Virtual Environments”

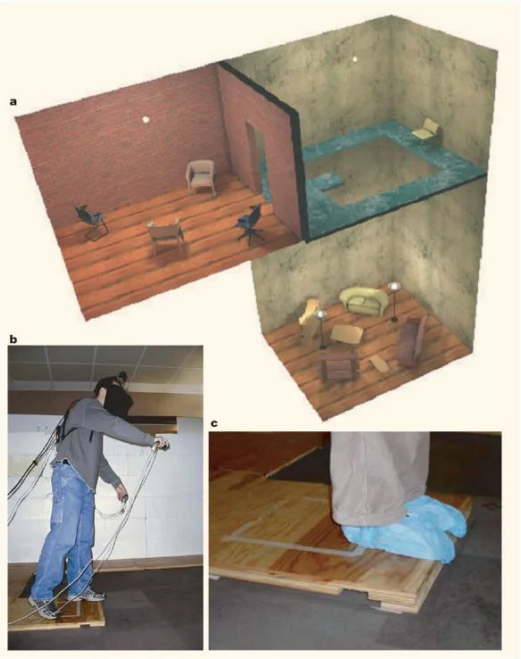
- Argue that presence has strong connection to neuroscience and is measurable
- Sanchez-Vives: Psychological measurement
- Meehan: Physiological measurements



https://www.nature.com/articles/nrn1651
http://www.cs.unc.edu/~whitton/ExtendedCV/Papers/2002-SIGGRAPH-meehan.pdf

Physiological responses

- They had a user drop some items into a pit
- Passive haptics: exact match between virtual and physical object
  - Users standing on a ledge in real life/physical environment (PE) and VE
- Findings:
  - Heart rate and skin conductance (e.g. sweating) good objective indicator of presence (esp. Heart rate), but not skin temperature
    - Some people get cold when stressed, some heat up



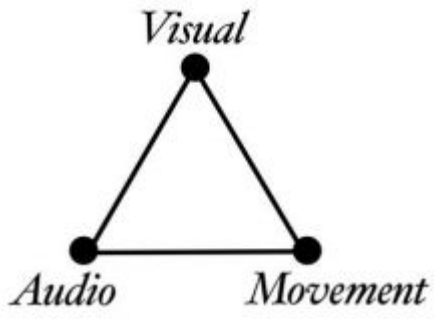
Perception of self

- In general, the more you feel like yourself or the character you're controlling (avatar), the higher presence
  - E.g. You can still be immersed in a low-poly game if you can be convinced that you *ARE* a character in that world
- Can accomplish this in many ways:
  - accurate 1-to-1 perception (motion, vision, audio, etc.)
  - Smoke & Mirrors (trickery and manipulation)
  - physics/impact on world (look at BoneWorks/Alyx)
  - Good avatar design

- General approach to evoking presence:
  - 1. Trick people into thinking they're someone else (an avatar)
  - 2. Trick people into thinking they're somewhere else (an immersive VE)
  - State-of-the-art research suggests people are mentally more flexible than you would expect

“The Immersive VR Self” Schwartz 2018 (Oculus)

- Elements of the accurate virtual avatar
  - **Visual**: perspective-correct visual representation
  - **Audio**: spatialized sounds
  - **Movement**: physical body gestures



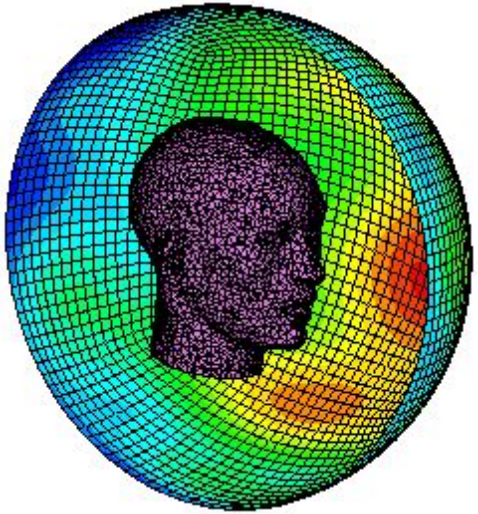
https://research.fb.com/wp-content/uploads/2018/02/the-presentation-of-self-in-immersive-virtual-environments.pdf

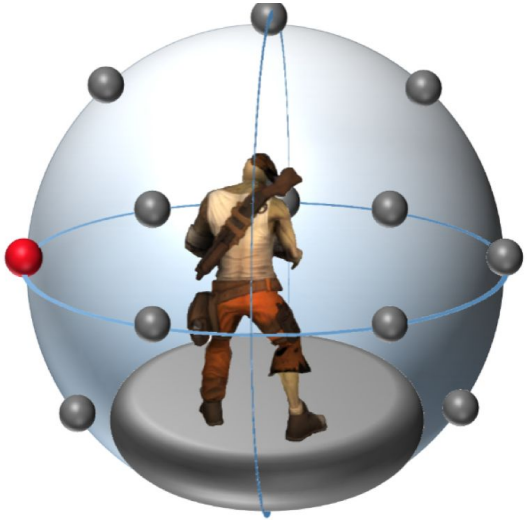
Visuals

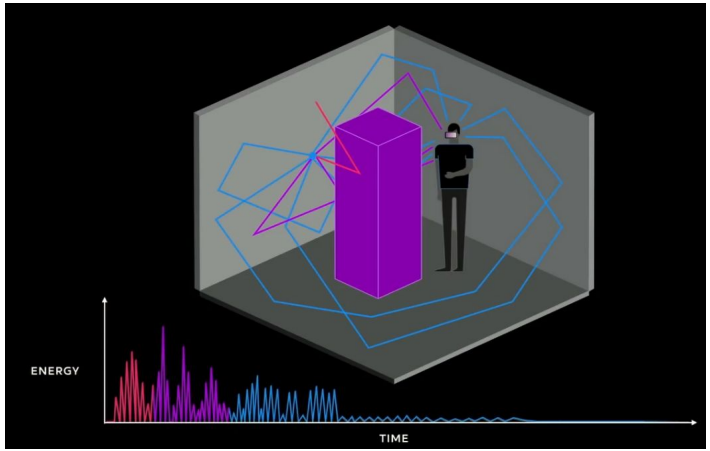
- High-resolution
  - Prevent “screen door effect”, where resolution is so low, individual pixels are visible and make you feel like looking through a screen door
- High frame rates
  - At least 60 fps for most cases
  - 90 fps+ even better
- In many cases, high visual fidelity/nice graphics (but not necessary)

Audio (Review)

- Accurate HRTFs that estimate ear parameters and how audio bounces
- 3D spatialized audio (audio source always sounds like it’s in the right place)
- Propagation/Filters (audio responds accurately to dynamics & parameters of the environment)







Movement/Motion Accuracy

- Reconstruction of limbs
  - Hands/head in right place
  - Resolution (or frame rates) reasonable
  - Later in lectures, we'll introduce inverse kinematics (IK)
  - Handling clipping
- Accurate 1-to-1 motions
  - More like 1-to-(1 minus threshold) motions….usually some leeway
  - Any kind of distortion should never be noticeable
  - Alterations of the scene should not be obvious
    - E.g. Change blindness
  - Phantom limbs & extra appendages are possible if we convince the user they are controlling them
  - The term "ownership" often used

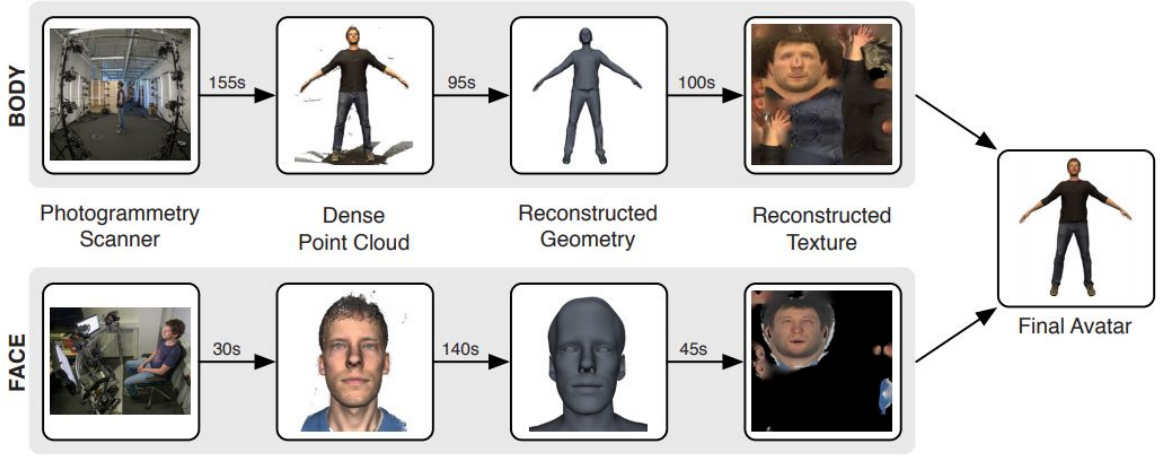
“Multimodal”

- Appealing to multiple senses…. Or “modes” of interactions
- Multimodal applications tend to be the most immersive….goal of VR is to replace sensory data with synthetic stimuli

Avatars and “Ownership”

From Waltemate 2018: “The Impact of Avatar Personalization and Immersion on Virtual Body Ownership, Presence, and Emotional Response”

- Personalized avatars significantly increase feeling of ownership
- Ownership and presence correlated
- Doesn’t need to be perfect



https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=8263407

Smoke & Mirrors

- Trickery to create sense of presence, place illusion, & plausibility illusion

Smoke & Mirrors

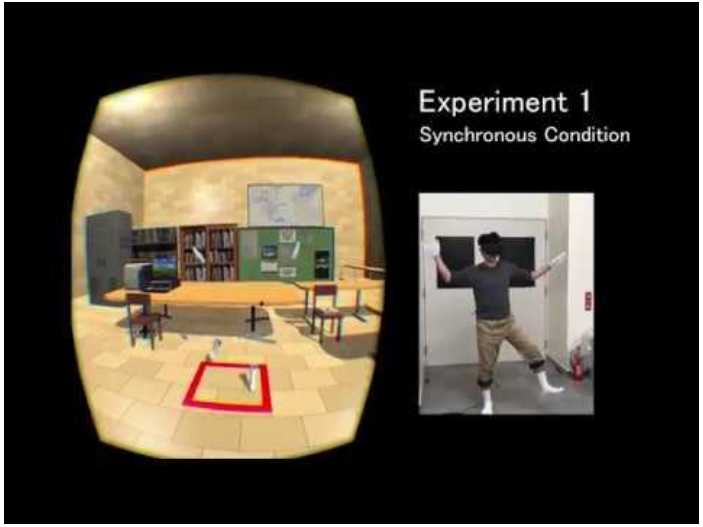
- Used for pain management
  - Transitioning from having a limb to not having one
  - Burn victims: convince them they're somewhere cold
  - Stroke recovery (Lupu 2016): Try to replicate a target pose and provide feedback

(not Lupu 2016 but similar non-VR idea)

https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=7790681

Smoke & Mirrors

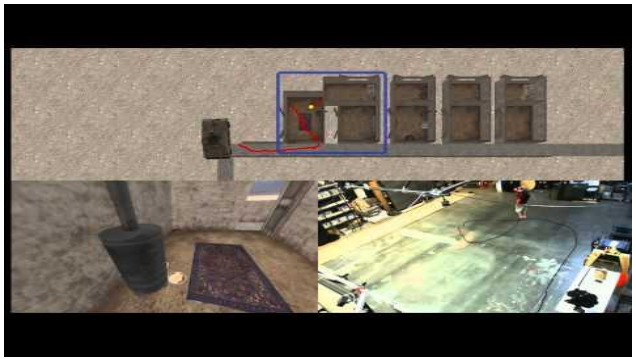
- Used to convince user of body ownership
  - E.g. weird paper, “Human Tails” Steptoe 2013
  - Found that the body motion itself was good enough to convince user of ownership
- Low-latency reconstruction of entire body best to get best ownership
  - (“Illusory body ownership of an invisible body interpolated between virtual hands and feet via visual-motor synchronicity” by Kondo ‘18)



https://ieeexplore.ieee.org/document/6479185
https://www.nature.com/articles/s41598-018-25951-2

Smoke & Mirrors

- Objects of interest & distortion
- Lack of interest in parts of the scene can be used to distort it
  - E.g. Change blindness



  - Can mess with mental maps (e.g. Peck 2011: “The Design and Evaluation of a Large-Scale Real-Walking Locomotion Interface”)

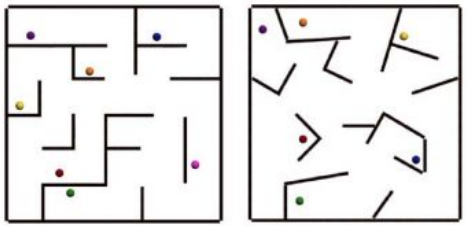


Fig. 5. The 15.85 m × 15.85 m virtual mazes used in this study. Left: the maze used during the naive search with seven targets. Right: the maze used during the primed search with six targets. Participants started each maze in the bottom left corner.

Telepresence

- Related to VR & presence….more on it when we talk about AR
- Idea that multiple people can be in different physical places but feel like they're sharing the same place
- E.g. Raskar 1999: "The Office of the Future"
- E.g. Holoportation by Microsoft

Figure 1: A conceptual sketch of the *office of the future*. By replacing the normal office lights with projectors, one could obtain precise control over all of the light in the office. With the help of synchronized cameras, the geometry and reflectance information can be captured for all of the visible surfaces in the office so that one can project images *on* the surfaces, render images *of* the surfaces, or interpret changes *in* the surfaces. The inset image is intended to help differentiate between the projected images and the real objects in the sketch.

http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.84.2781&rep=rep1&type=pdf

How do we measure presence?

- Any ideas?
- Ask the users!
- Record physiological data
- Measure task performance

Measuring Presence: Slater-Usoh-Steed (Usoh 2000)

- Standard presence questionnaire

1. Please rate *your sense of being in the* office space, on the following scale from 1 to 7, where 7 represents your *normal experience of being in a place*.
   I had a sense of "being there" in the office space:
   1. Not at all ... 7. Very much.
2. To what extent were there times during the experience when the office space was the reality for you?
   There were times during the experience when the office space was the reality for me...
   1. At no time ... 7. Almost all the time.
3. When you think back about your experience, do you think of the office space more as *images that you saw*, or more as *somewhere that you visited*?
   The office space seems to me to be more like...
   1. Images that I saw ... 7. Somewhere that I visited.
4. During the time of the experience, which was strongest on the whole, your sense of being in the office space, or of being elsewhere?
   I had a stronger sense of...
   1. Being elsewhere ... 7. Being in the office space.
5. Consider your memory of being in the office space. How similar in terms of the *structure of the memory* is this to the structure of the memory of other *places* you have been today? By 'structure of the memory' consider things like the extent to which you have a visual memory of the office space, whether that memory is in colour, the extent to which the memory seems vivid or realistic, its size, location in your imagination, the extent to which it is panoramic in your imagination, and other such *structural* elements.
   I think of the office space as a place in a way similar to other places that I've been today...
   1. Not at all ... 7. Very much so.
6. During the time of the experience, did you often think to yourself that you were actually in the office space?

Data

- I get this data
  - Independent variable: which group they're in (in this case, 45° or 90° FOV)
  - Dependent variable: answers to questions

	A	B	C	D	E	F	G	H
1	User ID	FOV	Q1	Q2	Q3	Q4	Q5	Q6
2	1	45	1	2	2	3	3	4
3	2	45	4	4	2	1	1	2
4	3	45	3	2	1	1	2	6
5	4	90	7	7	6	6	7	7
6	5	90	7	6	5	5	6	7
7	6	90	6	5	7	7	7	5

Count Highs/Binary

- Count highs & convert to binary
  - 6-7 is the “high” response, the one I’m trying to prove. So 6-7 maps to 1 and others map to 0
  - We bias the questionnaire in favor of **null hypothesis**: hypothesis that this condition does NOT matter. 4-5 are iffy/uncertain so they are NOT high responses.
  - Like in court (unless you’re rich), burden of proof lies on us so biased against the accuser

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	User ID	FOV	Q1	Q2	Q3	Q4	Q5	Q6	Q1Binary	Q2Binary	Q3Binary	Q4Binary	Q5Binary	Q6Binary
2	1	45	1	2	2	3	3	4	0	0	0	0	0	0
3	2	45	4	4	2	1	1	2	0	0	0	0	0	0
4	3	45	3	2	1	1	2	6	0	0	0	0	0	1
5	4	90	7	7	6	6	7	7	1	1	1	1	1	1
6	5	90	7	6	5	5	6	7	1	1	0	0	1	1
7	6	90	6	5	7	7	7	5	1	0	1	1	1	0

Measuring Sickness: Simulator Sickness Questionnaire (Kennedy 1993)

- Ask these questions before and after study

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

Measuring Sickness: Simulator Sickness Questionnaire (Kennedy 1993)

- Calculate categories (nausea, oculomotor, disorientation, total sickness)
- ([weights]*[user's responses from 0-3])*value provided below (9.54, 7.58, 13.92, 3.74)
- Run analysis on resulting categories

SSQ Symptom	Weight		
	N	O	D
General discomfort	1	1	
Fatigue		1	
Headache		1	
Eyestrain		1	
Difficulty focusing		1	1
Increased salivation	1		
Sweating	1		
Nausea	1		1
Difficulty concentrating	1	1	
Fullness of head			1
Blurred vision		1	1
Dizzy (eyes open)			1
Dizzy (eyes closed)			1
Vertigo			1
Stomach awareness	1		
Burping	1		
Total	[1]	[2]	[3]

$$N = [1] \times 9.54$$
$$O = [2] \times 7.58$$
$$D = [3] \times 13.92$$
$$TS = ([1] + [2] + [3]) \times 3.74$$

More statistics/analysis resources

- “Discovering Statistics Using R” by Andy Field
- CMSC 634: Empirical Research Methods w/ Michelle Mazurek