Virtual Reality & Physically-Based Simulation
Introduction, Immersion, Presence, Fidelity

G. Zachmann

University of Bremen, Germany

cgvr.cs.uni-bremen.de

Brainstorming – What Do You Associate with VR?

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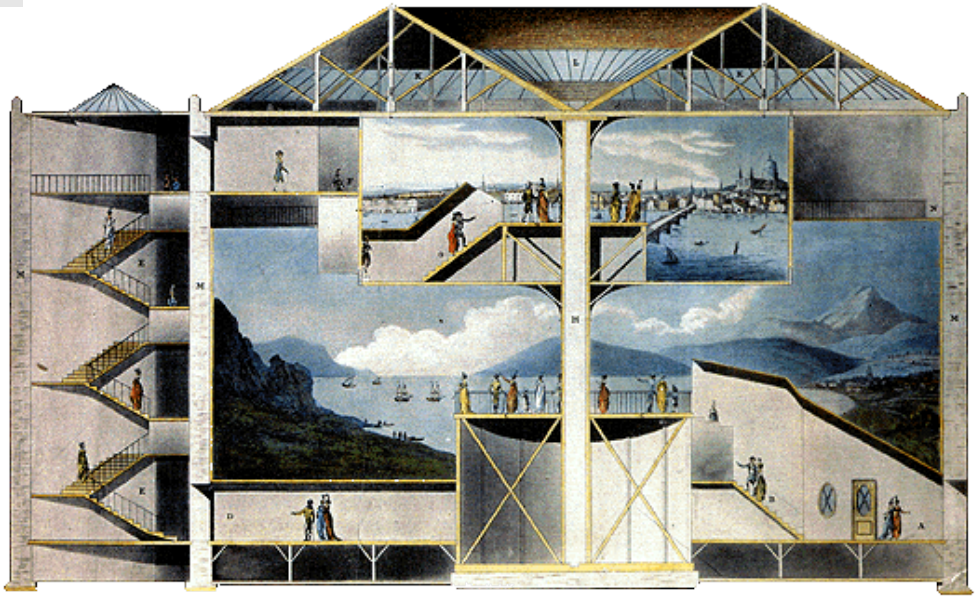
- "[They] are among the happiest of contrivances for saving time and expense in this age of contrivances. What cost a couple of hundred pounds and half a year [...], now costs a shilling and a quarter of an hour. Throwing out of the old account the innumerable miseries of travel, [...] and the insufferable annoyances of [...] an Italian bed. [...] Now the affair is settled in summary manner."

- What does the author of the quote describe? ...

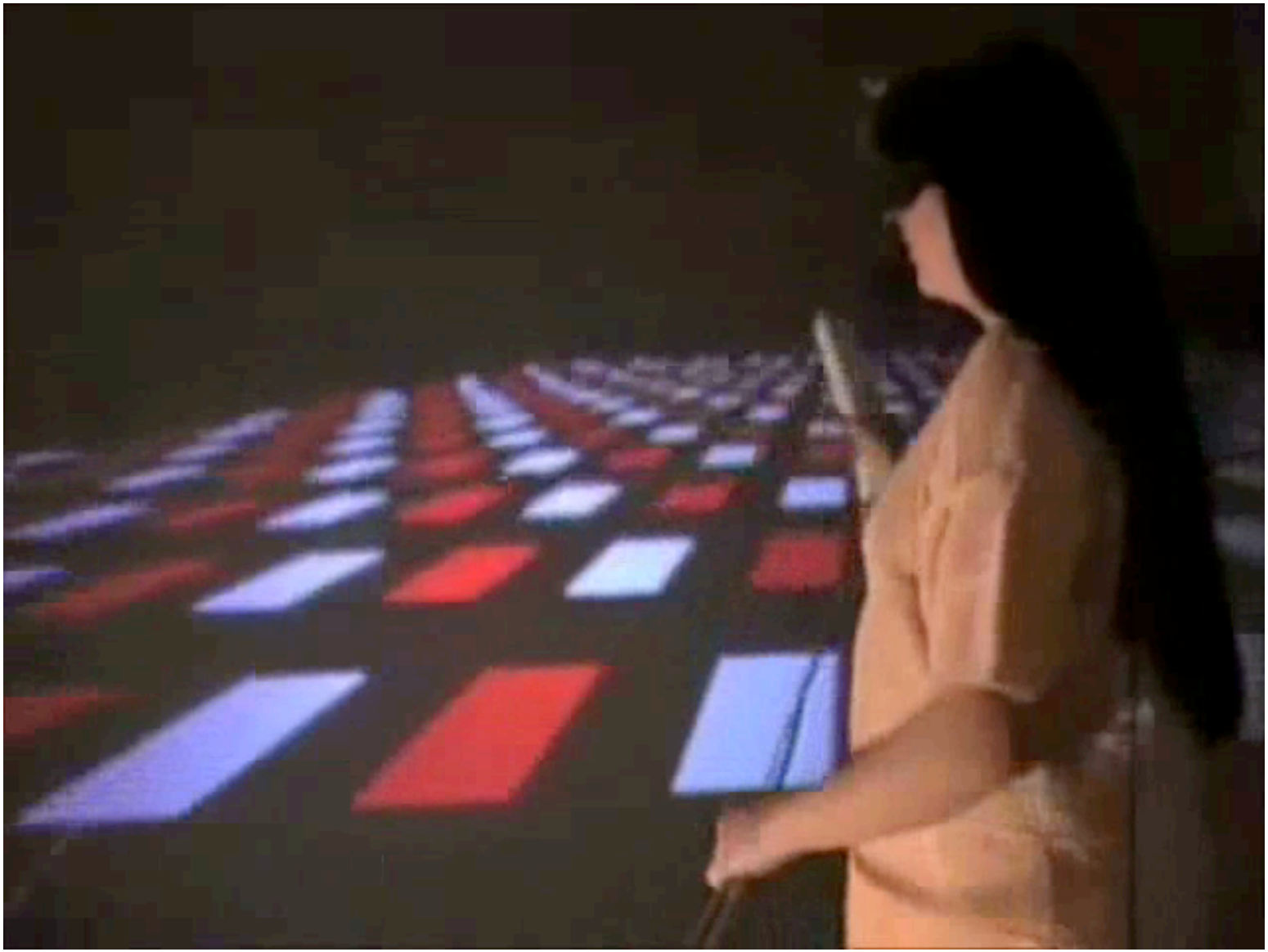
- The *Panorama* !
  [Quote from Blackwood's Edinburgh Magazine, vol. 15, pp. 472, 1824]



Cross section of Robert Barker's Panorama, Leicester Square, London, 1789

Bourbaki Panorama in Luzern

The 2-Minute Introduction to VR



(Originally a "60 second introcution to VR" ☺
Source: www.not-for-wimps.org; Fhg-IGD)

The Goal of Virtual Reality

- More efficient Human-Computer-Interaction (HCI)
  - "Post-WIMP interfaces"
- Better user performance

Goals of VR for Customers

- Intuitive & pleasurable user experience (consumers)
- Shorter time-to-market (manufacturing)
- Helps non-experts with spatial understanding of designs at early stage (visualization, car design, architecture, etc.)
- Platform for communication among teams (CSCW)

Definitions of VR

Steve Bryson:

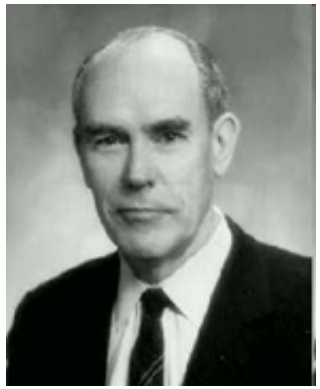
Virtual Reality (VR) refers to the use of three-dimensional displays and interaction devices to explore real-time computer-generated environments.

Carolina Cruz-Neira:

Immersive, interactive, multi-sensory computer-generated experiences.

Ivan Sutherland, 1966:

Indeed, in the ultimate display one will not look at that world through a window, but will be immersed in it.



Myron Krueger:

The promise of artificial realities is not to reproduce conventional reality, or to act in the real world. It is precisely the opportunity to create synthetic realities, for which there are no real antecedents, that is exciting conceptually, and ultimately important economically.

Lynne Dittmar:

VR emulates the information presented to the human visual (aural, tactile) system by the "real world".

In theory of communication:

A medium for communication, consisting of synthetic spaces and people, both of which represent equal and integral components of a digital system.

What is VR *NOT*!

David Mizell:

Every computer graphics system after 1990. ☺

Manufacturing industries (in particular, the executives in those industries):

Interactive, 3D visualizations of simulations (e.g., crash sim.).

Multimedia, like

QuicktimeVR

VRML

David Blatner:

Virtual Reality is a way for humans to visualize, manipulate, and interact with computers and extremely complex data

Business Week:

Virtual Reality is a new tool to amplify the mind

William Gibson (Neuromancer):

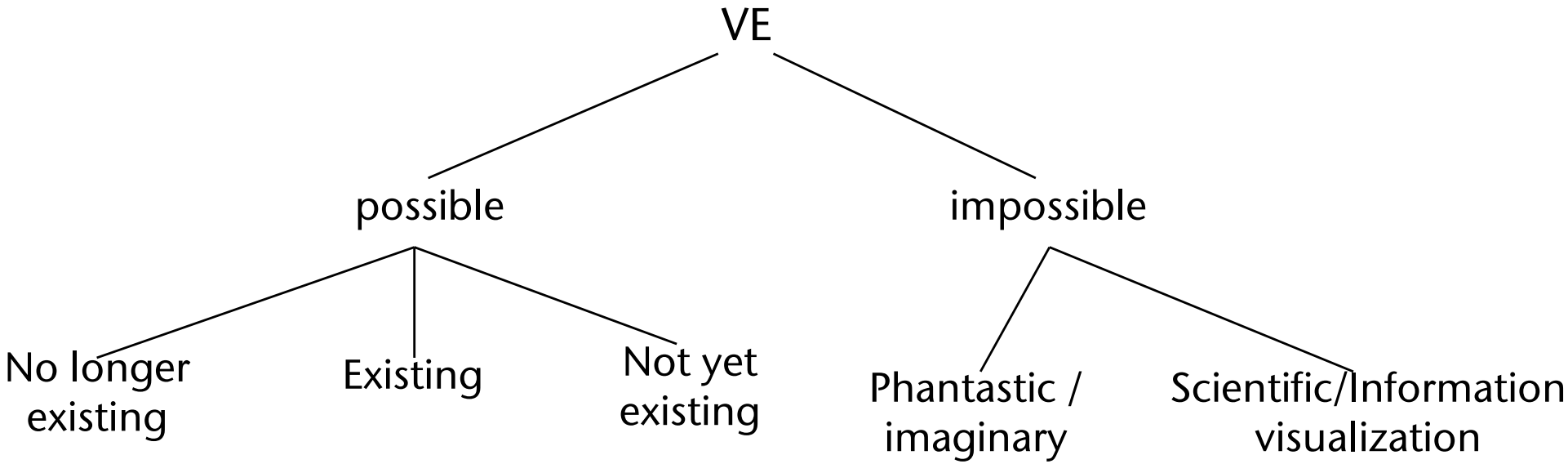
Cyberspace

A 5-Points Definition

[GZ]

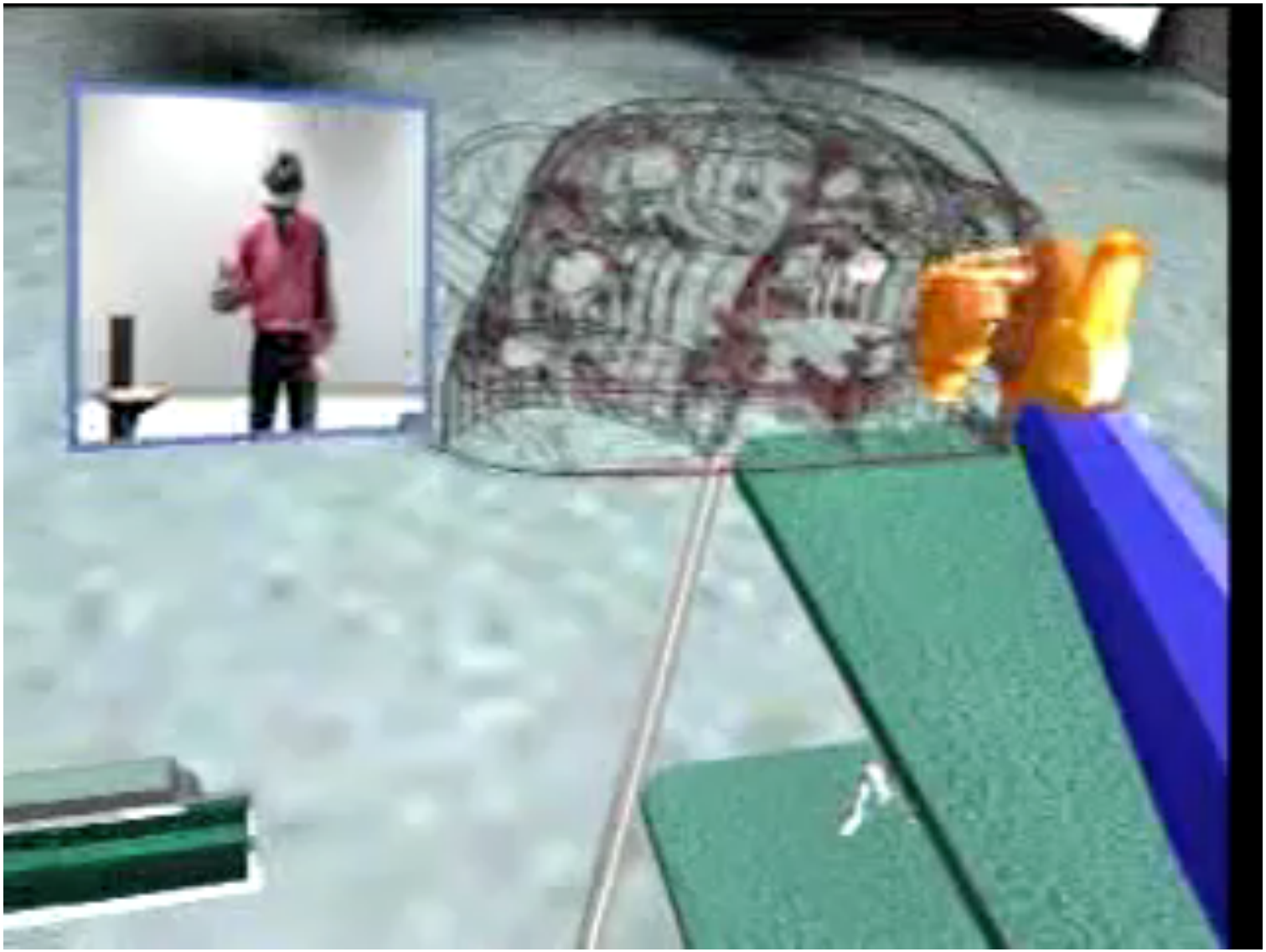
- It is virtual reality, if the following criteria are met:
  1. Rendering in real-time,
  2. Simulation in real-time,
  3. Interaction in real-time,
  4. Intuitive interaction (usually involves post-WIMP input devices),
  5. Immersion: stimulation of as many senses as possible by the computer,
  6. Presence, possibly.
- In order to achieve that, you take ...
  - Post-WIMP, multi-dimensional input devices
  - Visual displays that can present an image with depth
  - Haptic devices (force displays)
  - Graphics hardware (is a commodity today)
  - Speech input & sound output
  - Algorithms!

Classification of Virtual Environments

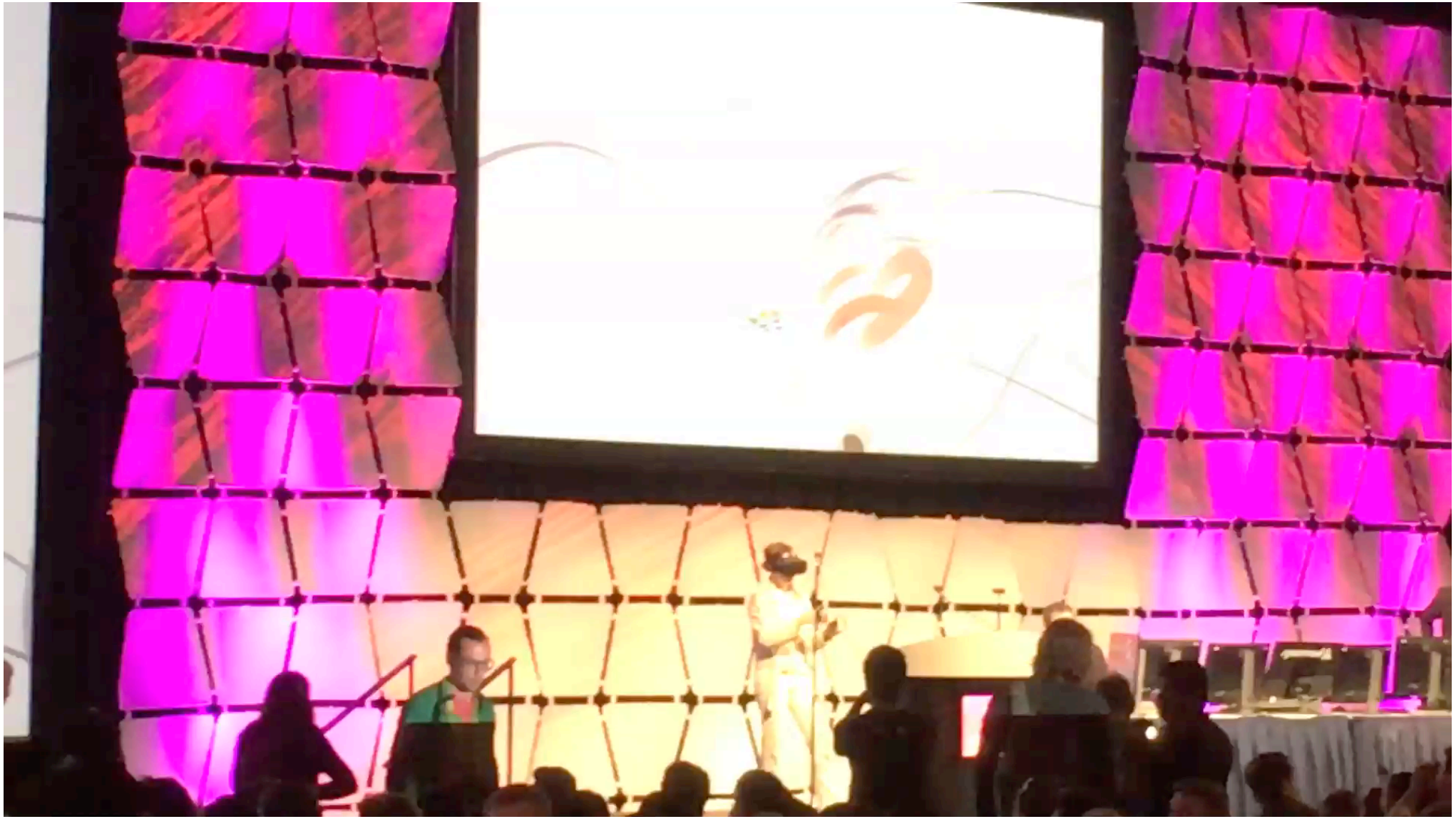


Example for "No Longer Existing VE"

Example for "Not yet Existing"



Further Example



Quill, VR Drawing in the Production of Oculus Story Studio's New Movie,
Inigo Quilez, Wesley Allsbrook, Oculus Story Studio, Siggraph 2016

One of the Most Persistent VR Entertainment Installations

Aladdin's Magic Carpet VR Adventure, installed at DisneyQuest in 1998, is still operating today

Human Flight Simulators

Iron Man Flight Simulator

Icaros

Birdly (Zürich University of Art and Design)
Kinds of feedback: visual, auditory, haptic, wind, smell,

How do You Fool the Mind?

The mind has a strong desire to believe that the world it perceives is real.

- By depth cues:
  - Occlusion (Verdeckung)
  - Perspective
  - Stereo parallax (convergence of eyes)
  - Head motion parallax (Kopfbewegungsparallaxe)
  - Accomodation (Fokussierung)
  - Color/contrast change with increasing distance
- By interaction:
  - Grasping and moving virtual objects
  - Walking in a virtual environment

[Jaron Lanier]

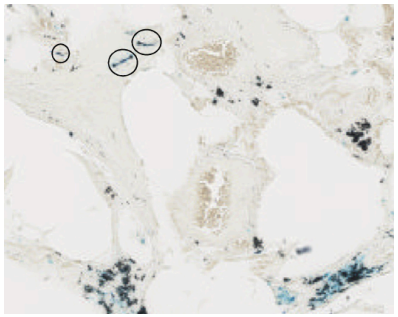
- Proprioceptive queues (Selbstwahrnehmung): if I see something where I *know* my hand must be by proprioception, then this *is* my hand

Immersion

- *Immersion* = "Eintauchen"
- Definitions of immersion:
  1. Complete immersion ⇔ all senses are stimulated consistently
  2. Complete immersion ⇔ user doesn't perceive real world any more
- Can be determined relatively easily:
  - Count number of senses that are stimulated by the computer
  - Count number of senses that are shielded from reality
- Immersion ≠ Plausibility! (ex. SciFi virtual environment)

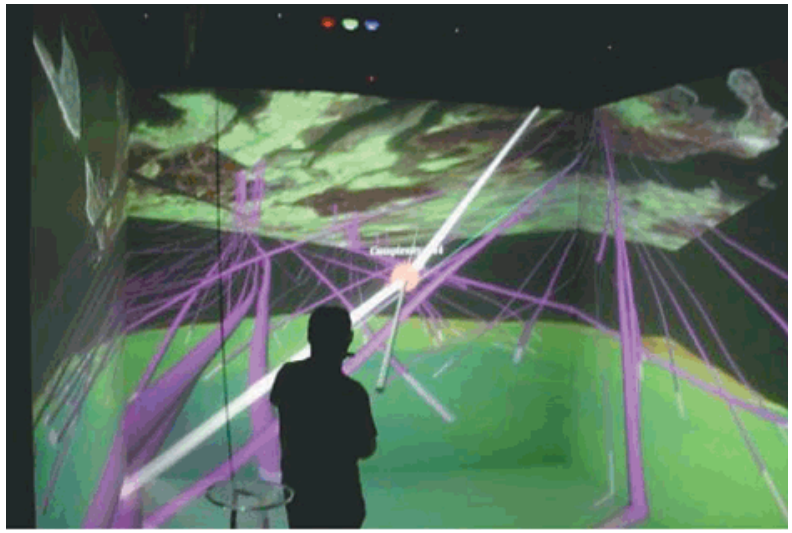
Benefits of Immersion

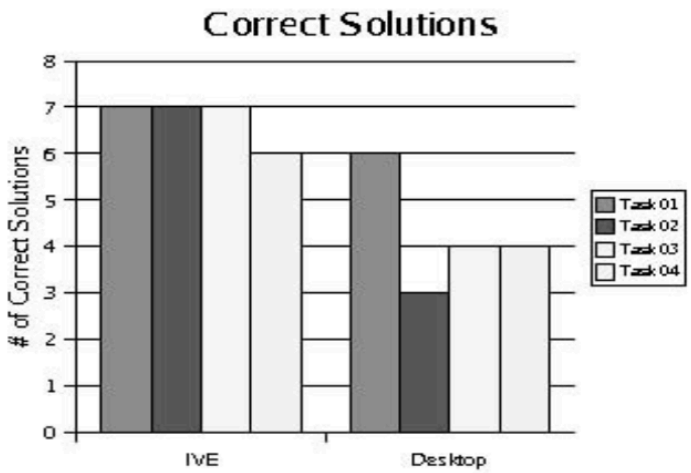
- 2S search task :
  - Three conditions (same input device):
    - 1) Standard monitor,
    - 2) Monitor with 130x70 cm,
    - 3) Large-screen projection with 300x130 cm,
  - Result: size is more important than resolution of the display
  - Task performance is 30% faster with large-screen projection than with (1) and (2)

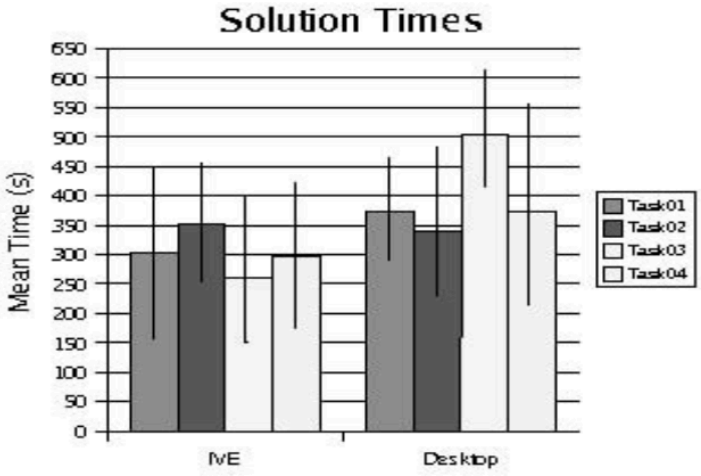


- Scientific visualization:
  - "positive impact on visualizing scientific data with complex 3D spatial relationships" [LaViola et al., 2009]
  - "Body-centric interaction appears to be another important component" [ibid.]

- Planning of oil well paths:
  - 16 participants, 4 different tasks
  - Two conditions:
    1) immersive VE (cave), 2) desktop
  - Number of correct solutions: 9/16 participants had more correct solutions in VR, one had more at desktop, 6 had same number in both conditions
  - Task completion time: 15/16 were faster in VR



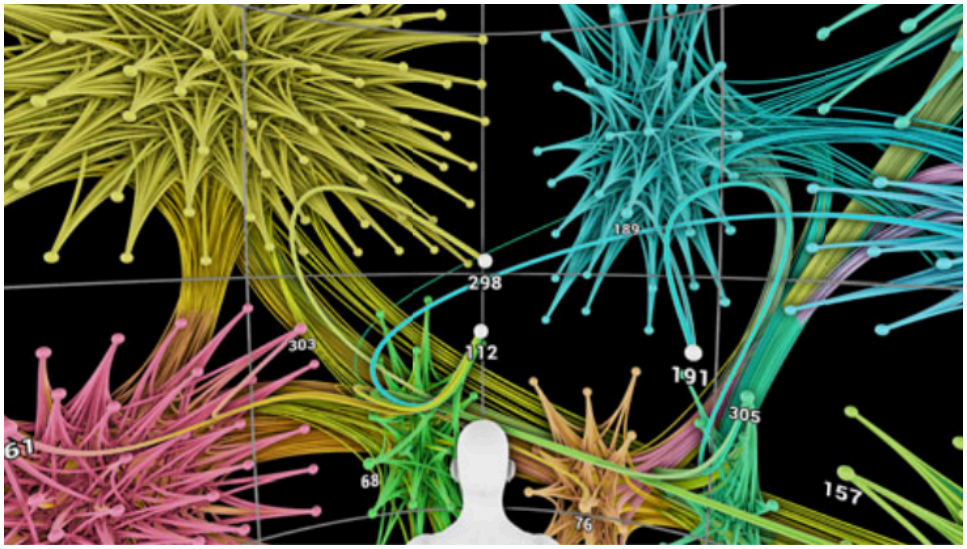


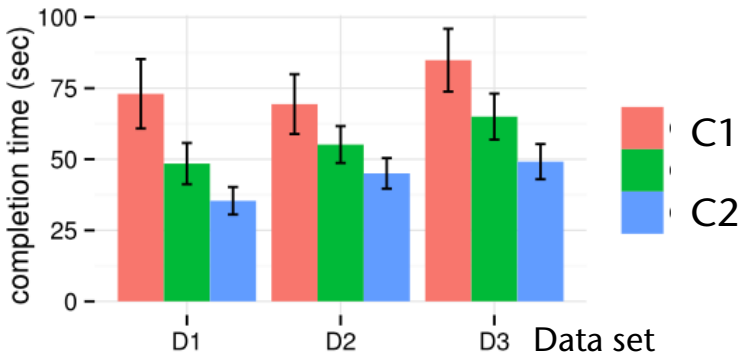


- Graph visualization:
  - Conditions:

    C1) 2D graph layout

    C2) 3D graph rendering
  - Tasks:
    - 1) Find highest degree node
    - 2) Find a path
    - 3) etc.
  - Data sets:
    - 1) small graph: 34 nodes, 78 edges
    - 2) large graph: 300 nodes, 2300 edges
    - 3) in between





  - Result: C2 has significantly shorter task completion time and a significantly fewer number of interactions than C1 for more difficult tasks

Fidelity

- *Fidelity* := objective level of realism of a technological system
  - Ground truth, i.e., 100% fidelity = real world
- The three important components of the fidelity of a VR system:
  1. Rendering fidelity := level of realism of rendering
     - Visual rendering : image resolution, detailed textures, correct lighting, etc.
     - Haptic rendering : do rigid objects feel stiff? Forces on all fingers, or one handle only?
     - Auditory rendering : does the virtual room sound like real rooms?
  2. Interaction fidelity := level of realism of interaction with virtual objects
  3. Simulation fidelity := level of realism of behavior of virtual objects
     - E.g., does the cloak of a virtual character behave like real cloth?
- Note: higher fidelity does not necessarily imply higher user performance!

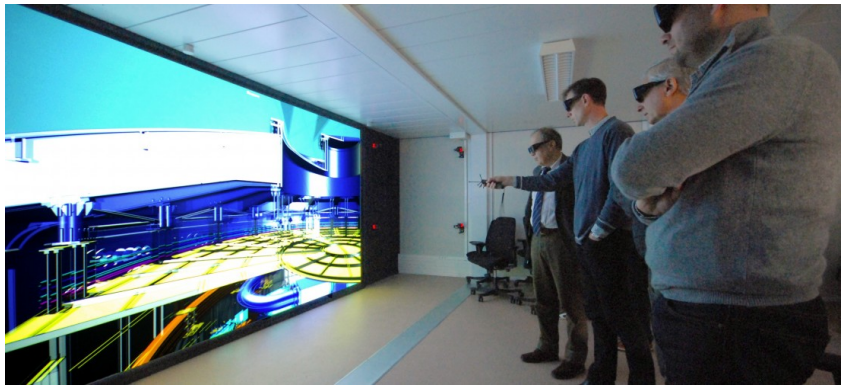
The Feeling of Presence (Präsenz)

1. *You* are there (*you* are part of the virtual environment)
   - VR with presence creates a *"suspension of disbelief that they are in a world other than where their real bodies are located"* (Slater & Usoh).
2. You are *there* (you are *part of the remote environment*)
   - Tele-presence
   - Tele-operation

Big Bang Theory

3. It is *here*
   - Ex.: Karosserie-Styling-Review im virtuellen Showroom
4. *We* are *there* (users are in *one common* virtual environment)
   - Collaborative virtual environments (e.g., Second Life)

Distributed CVE

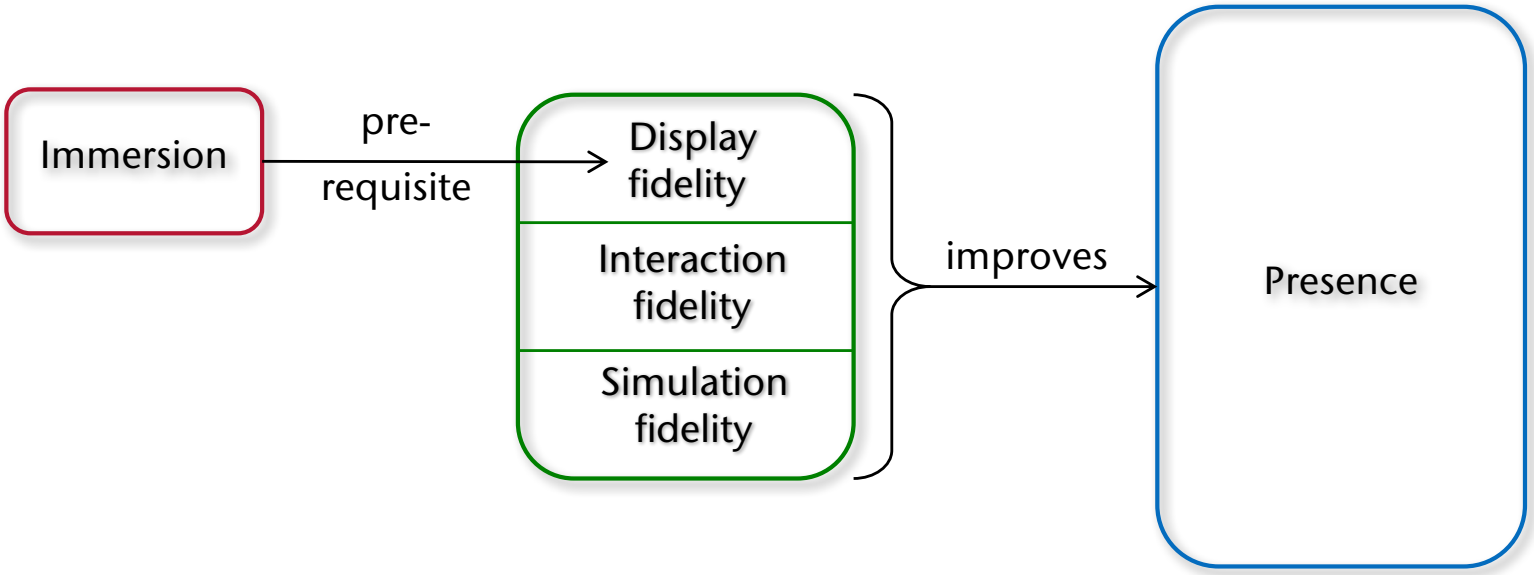


Co-located CVE

- Presence is subjective = user's psychological and/or physiological response to the system ⟶ hard to measure!

- Many other factors can influence the presence of a VR user:
  e.g., the cognitive load;
  cognitive load is high ⟶ presence is high (example: playing Doom)
- A simple test for presence: does the user show reflexes?
- Is the following reaction proof of presence?

Relationship Between Immersion, Fidelity, and Presence



The "Pit Experiment"

- The experiment:
  - Subjects start in a real room, then put on an HMD, see the real room in the virtual environment, walk through the real=virtual door, and are then in the virtual "pit room"
  - Conditions:
    - Real walking
    - Flying by joystick
    - Virtual walking (virtual camera moves up & down)

- Results: high sense of presence when really walking
- Reason: high interaction & display fidelity
  - Real walking (proprioception)
  - Low latency
  - Visual fidelity of the detailed, textured, radiosity-lit scene
  - Stereopsis, spatial audio, passive haptics

On the Origin of the Word "Avatar"

- Avatar in VR = representation of a user in the virtual environments
- Possible representations:
  - Virtual mannequin, ideally deformable / articulated
  - Just the virtual hand (ideally, deformable)
  - Just a cylinder with eyes
  - ...
- Borrowed from Indian philosophy & religion

- Kommt z.B. im "Book of Tea" von Kakuzo Okakura (1906) vor:
  The heaven of modern humanity is indeed shattered in the Cyclopean struggle for wealth and power. The world is groping in the shadow of egotism and vulgarity. Knowledge is bought through a bad conscience, benevolence practiced for the sake of utility. The East and the West, like two dragons tossed in a sea of ferment, in vain strive to regain the jewel of life. We need a Niuka again to repair the grand devastation; we await the great Avatar. Meanwhile, let us have a sip of tea. The afternoon glow is brightening the bamboos, the fountains are bubbling with delight, the soughing of the pines is heard in our kettle. Let us dream of evanescence, and linger in the beautiful foolishness of things.

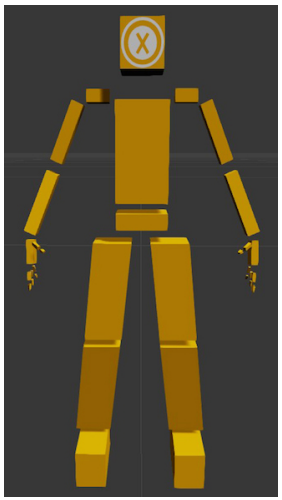
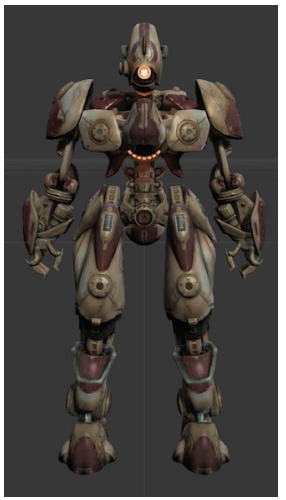
The Rubber-Hand Illusion

Induced Body Ownership

© 3sat, Die Macht des Unbewusstseins 2014

The Illusion of Virtual Body Ownership (IVBO)

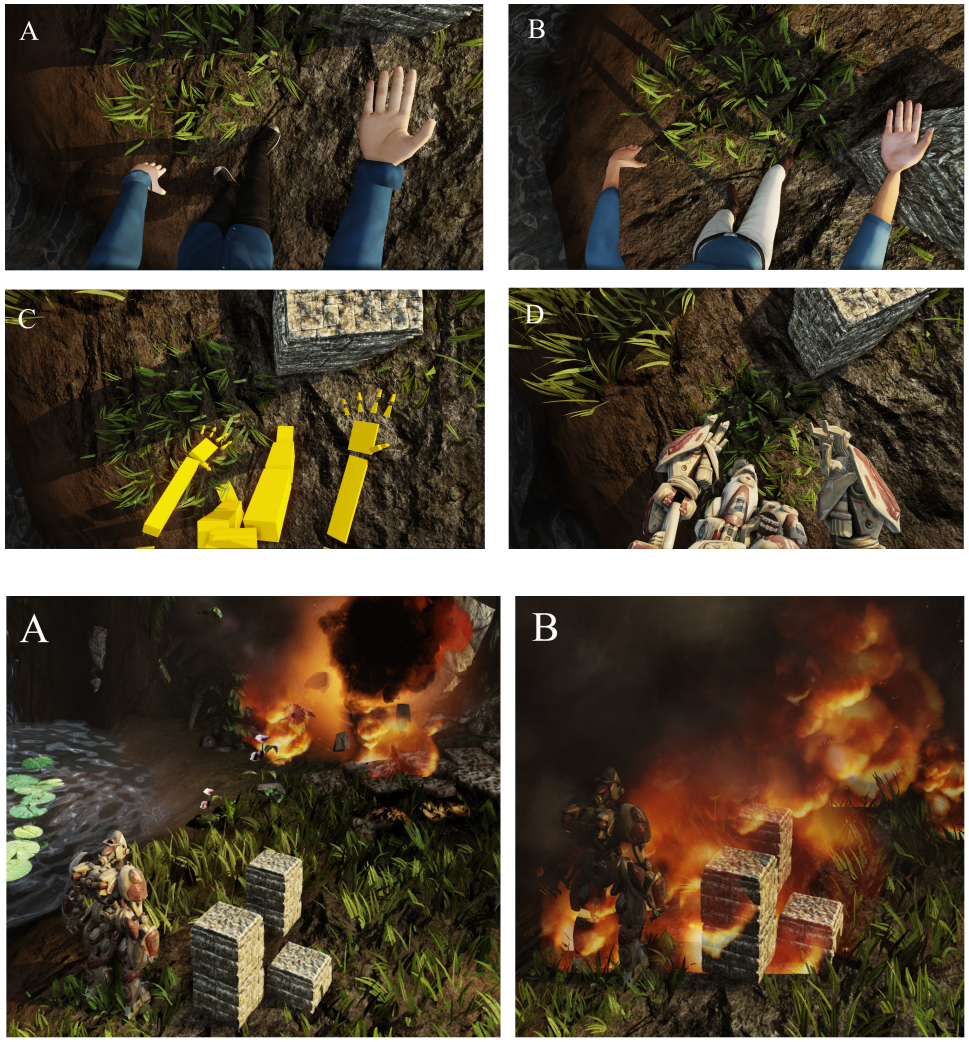
- Definition Illusion of Virtual Body Ownership (IVBO):
  Users accept virtual body parts (or the whole self-avatar) as their own
- One of the reasons: visuomotor synchrony and visuotactile synchrony
- Definition visual anthropomorphism:
  Visually perceived human resemblance of the self-avatar
- Question: does the level of visual anthropomorphism influence the level of IVBO?
- Conditions in the experiment: three levels of anthropomorphism


[Lugrin, Latt, Latoschik]

The Experiment

- First-person view of the avatars
- Task in the VE (to induce IVBO): collect a number of balls
- Check level of IVBO:
  - Induce stress, e.g., by virtual fire or explosion
  - Questionnaire, e.g. "*I felt like the body I saw in the virtual world was my body*"



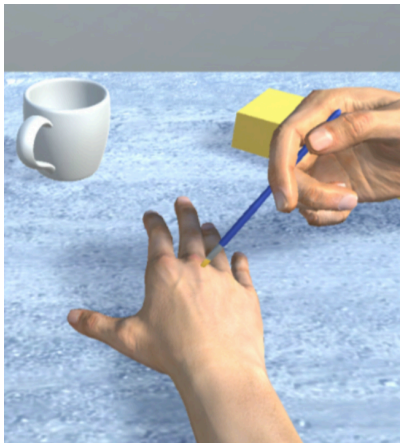
Results

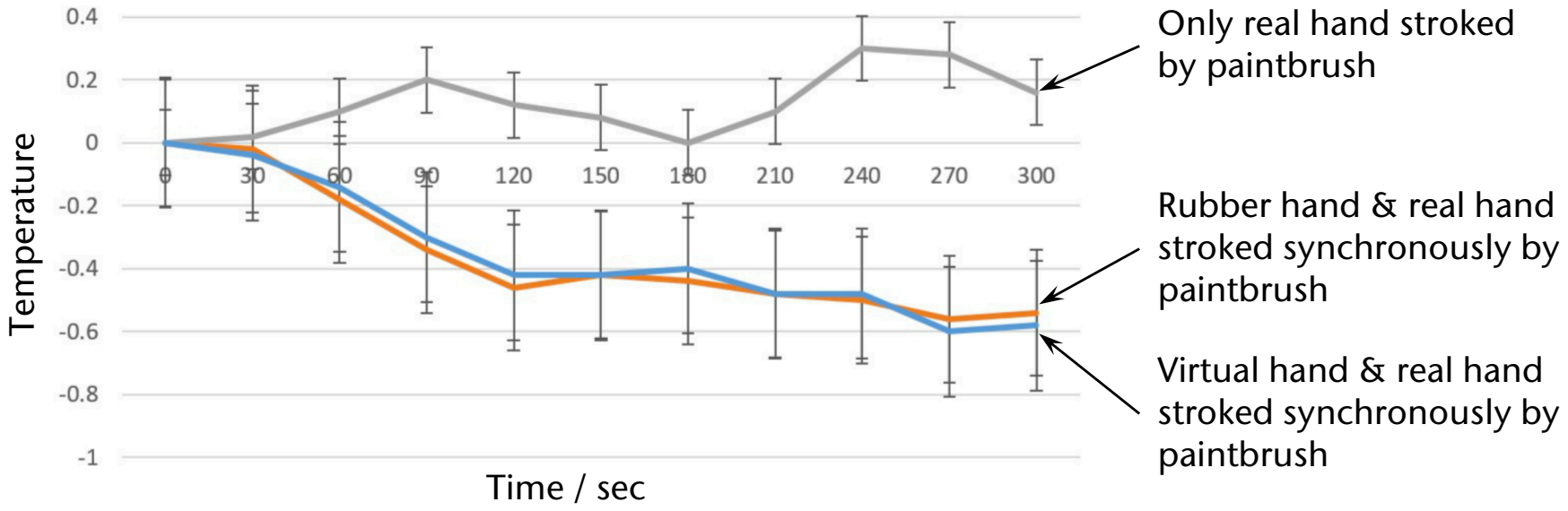
- All three avatars elicited
  - same task response time,
  - same skin conductance,
  - same level of IVBO
- Except: human-like avatars elicited significantly stronger feeling of having *two bodies*!
- Possible reason: Uncanny Valley effect
- Supporting hint: subjects noticed differences between avatar and their real appearance much more than with the unrealistic avatars
  - "*I felt like the length of my arms was not represented correctly*"
  - "*The body did not bear any resemblance to me (physique, hair color etc.)*"

Measuring Virtual Body Ownership Illusion

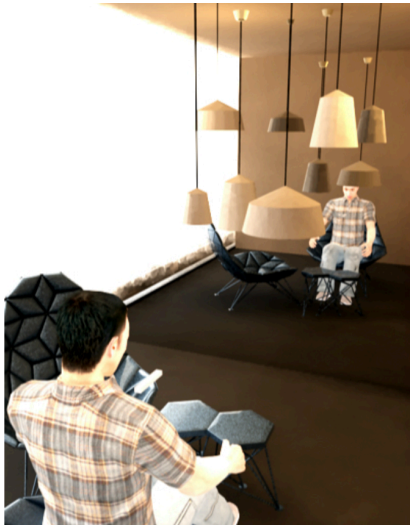
[2017]

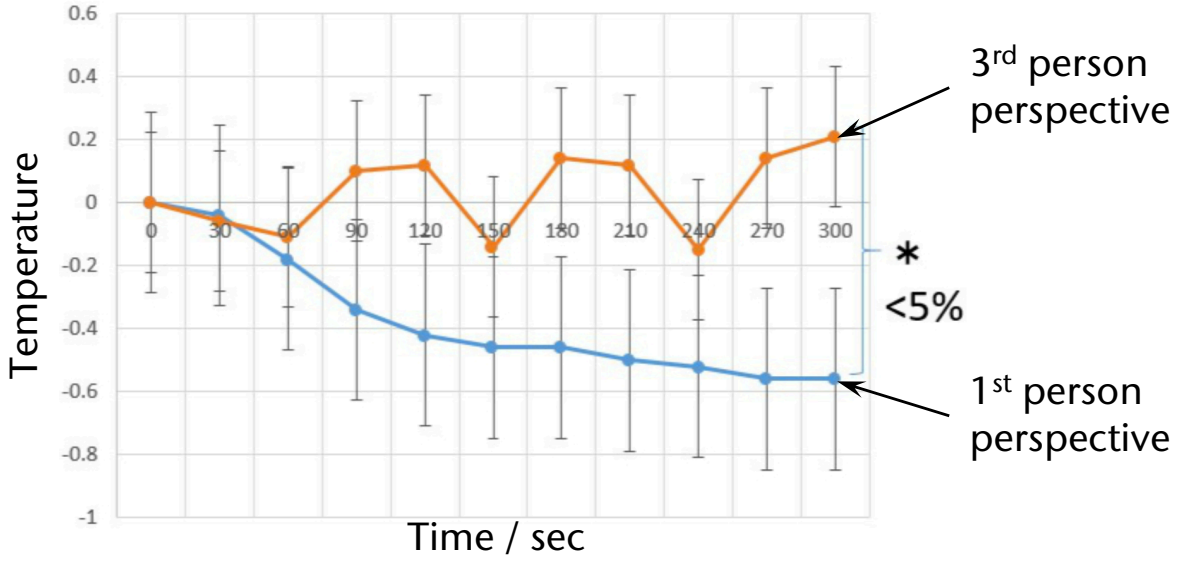
- Objective measure: skin conductance?
  - Evidence is inconclusive, whether skin conductance is a reliable indicator of arousal (e.g., under stress)
- Temperature drop indicates: brain adopts virtual body (does not really matter where it is measured)
- Experiment: virtual rubber hand illusion





- Experiment: full body ownership illusion
  - First and third person perspective of virtual (self-) avatar
  - Synchronous stroking of both real and virtual body on chest





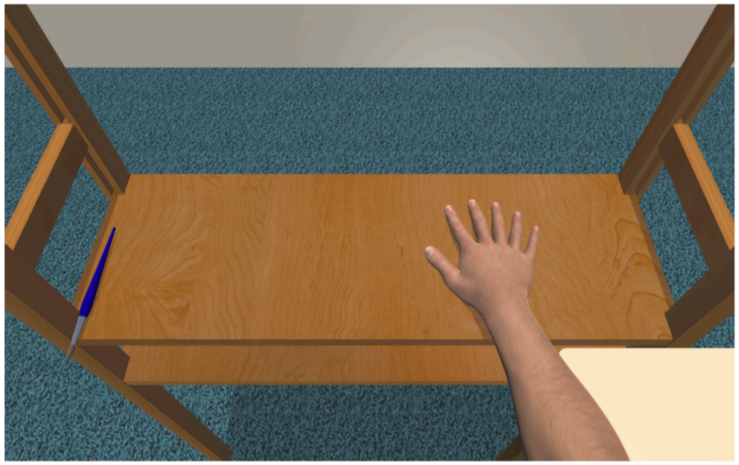
  - Works with different virtual body sizes as well
    - Virtual body size = 140 cm, ..., 500 cm

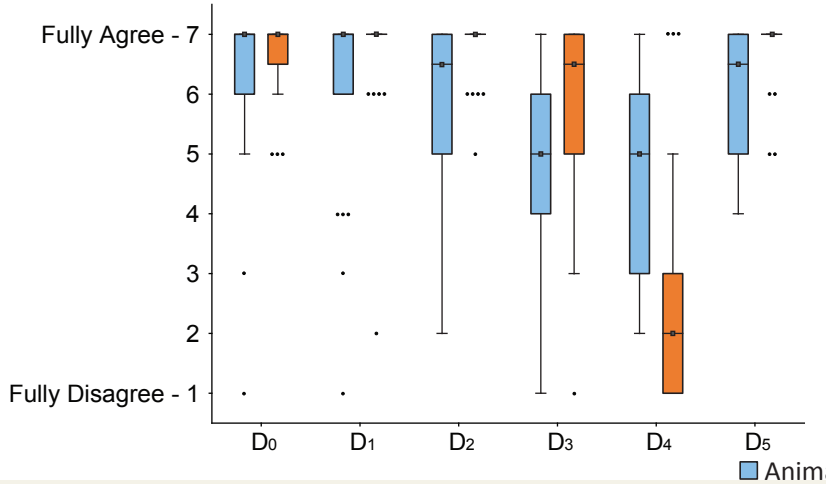
Barbie-Doll Illusion

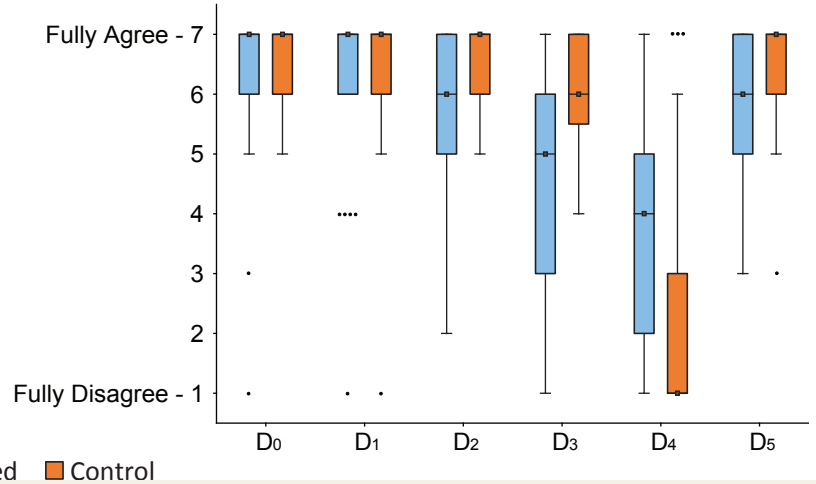
van der Hoort, Guterstam, Ehrsson, 2011, Karolinska Institutet

The 6-Fingered Hand

- Do people accept virtual self-avatars as their own, even if it is different (for instance, a structural change, such as 6 fingers)?







Animated Control

An Out-of-Body Experience

© BBC Horizon

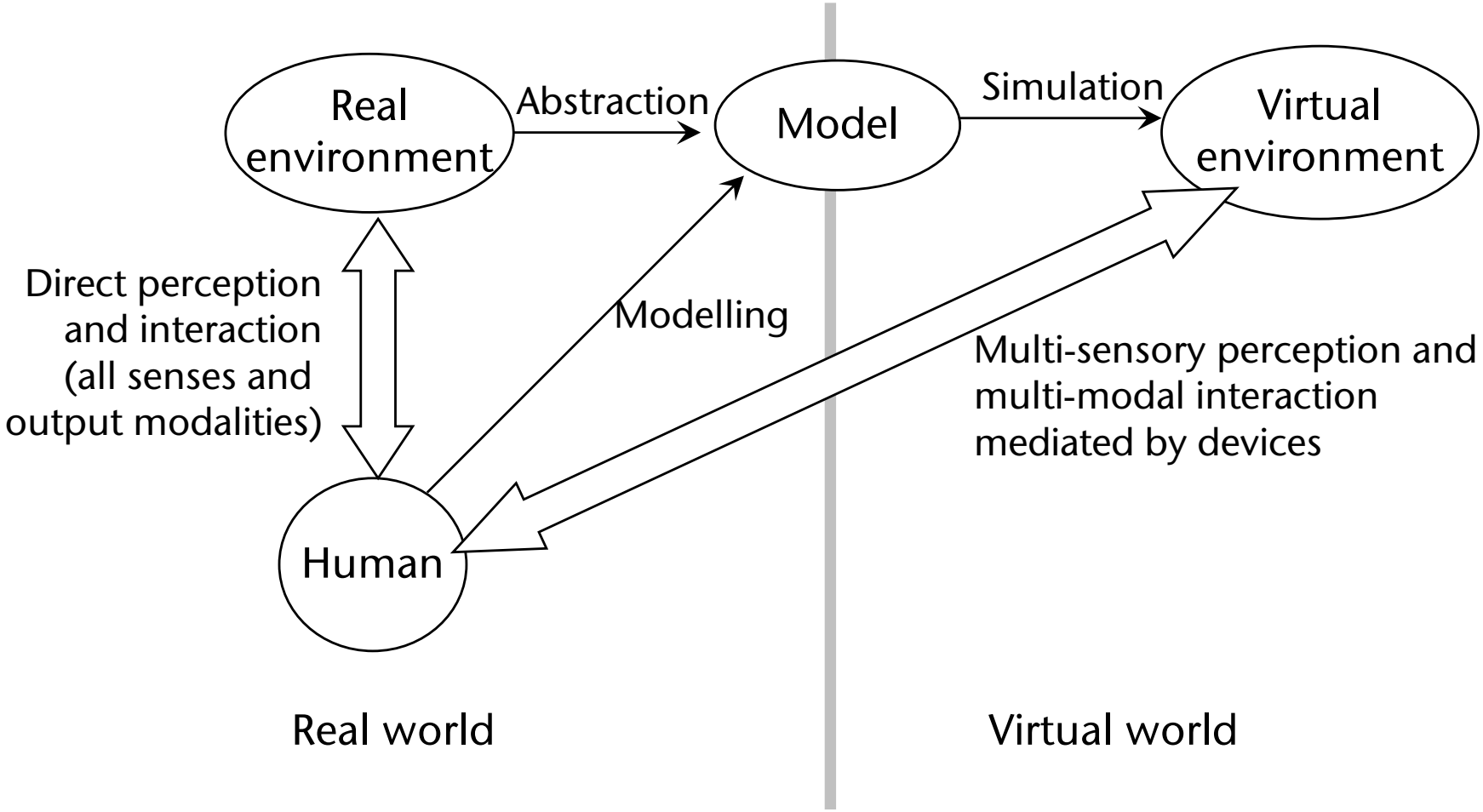
H. Henrik Ehrsson, Karolinska Institutet

Virtual Reality and Games Have a Lot in Common

- Very high demands on rendering:
  - VR: 1. high polygon count, 2. high frame-rate, sometimes quality
  - Games: 1. high frame-rate, 2. special effects
- Interaction: efficient, "non-intrusive", natural,
- Object behavior:
  - Physcally-based
  - Autonomous (aka. AI in games)

- Differences:
  - Size of market
  - Costs
  - Respective market segment targeted by each technology/industry

Virtualization



Laufen,
Greifen,
...

Sehen,
Hören,
Riechen,
Fühlen, ..

Interaktions-
metaphern

Sehen,
Hören,
(Riechen?)
(Fühlen?)

Quick Survey

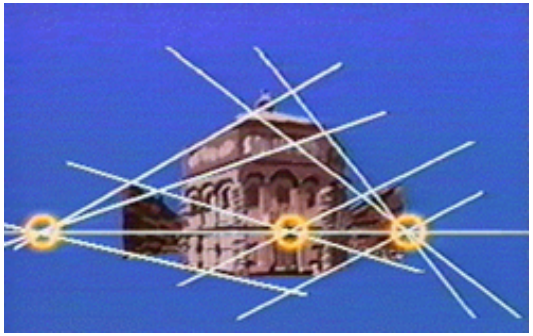
- How many of you were born
  1. before VR was invented?
  2. after VR was invented?
- Correct answer to follow in a few minutes …

The Increasing Virtualization of Our World ...

2 strands: first it happened in the arts, then technology took over

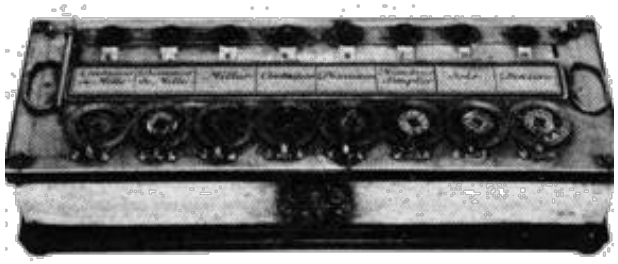
30,000 v. — Caves of Lascaux

400 v. — Abacus

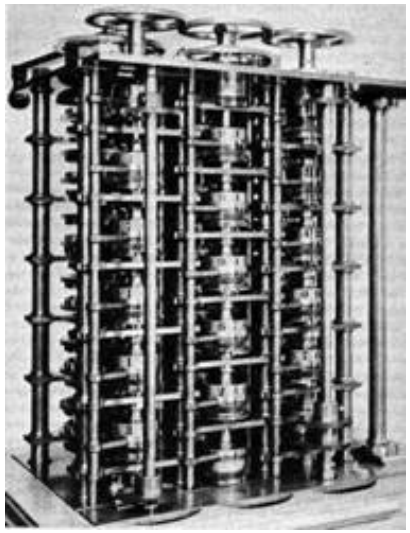


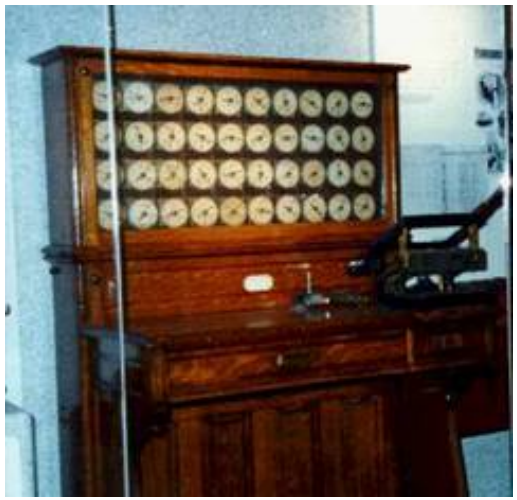
15. Jh. — Central perspective (Brunelleschi)

1642 — Mechanical calculators by Schickard & Pascal



1801 — Jacquard's loom with punched cards





1834 – Difference / Analytical machine (Babbage)

1854 – Boole "discovers" the binary numbers

1890 – Census in USA uses Hollerith's card tabulators

1924 – Founding of IBM

1929 – First flight simulator (Link trainer)

1936 – Turing maschine

1938 – Z1

1958 – Z60: precursor of CAD systems

1963 – Sutherland's "Sketchpad"

1962 — Sensorama by Morton Heilig

1981 — Dataglove by Zimmermann

1983 — First commercial HMD

1985 — "Virtual Environment Display System" program of NASA

More Examples for Virtualization

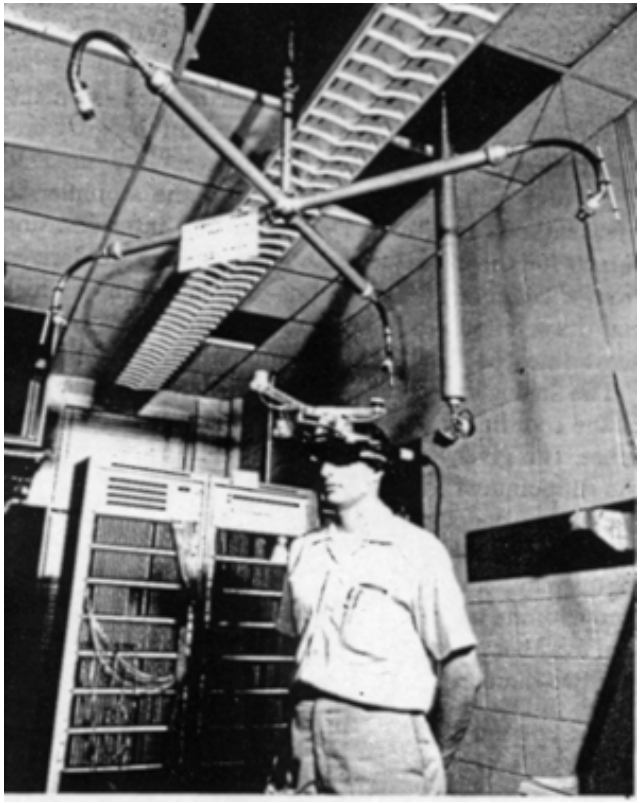
- Ca. 1900: Telephone
- Ca. 1950: TV
- Ca. 1980: MUDs (text-based multi-user adventures)
- Ca. 2000: Shopping via internet
- Ca. 2005: "Social" platforms (Facebook, et al.)
- Ca. 2008: Second Life
- ...

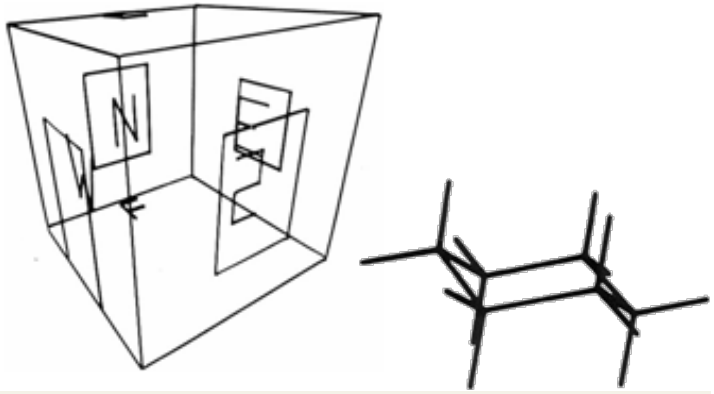
The Idea of VR is Not New

- Aldous Huxley: "feelies" in *Brave New World,* 1932
- Vannevar Bush: As We May Think, 1945
- Ray Bradbury: *The Veldt*, 1950
- Morton Heilig: El cine del futuro, 1955
- Donald Sutherland: *The Ultimate Display*, 1965, Proc. Of IFIPS congress
- Many more SciFi authors: Vernor Vinge, William Gibson, Neal Stephenson, ...

"The Ultimate Display .." / Sword of Damokles [Sutherland'68]

- First HMD [1968]
- Quotes from the paper [1965]:
  - "If the task of the display is to serve as a looking-glass into the mathematical wonderland constructed in computer memory, it should serve as many senses as possible."
  - "I want to describe for you a kinesthetic [= force-feedback] display."
  - "Machines to sense and interpret eye motion can and will be built."
  - ".. We have little ability to have the computer produce meaningful sounds."
  - "The ultimate display would, of course, be a room within which the computer can control the existence of matter."





Ivan Sutherland's "Head-Mounted Three-Dimensional Display"

Augmented Reality: Just Mentioning it Here

- Augmented Reality's goal: consistent coexistence of real as well as virtual objects in the same perceived space
- Approaches:
  - Overlay real imagery with computer-generated images
  - Project computer-generated imagery onto real-world objects
- Devices:
  - Optical see-through displays (e.g. Google Glass)
  - Video see-through displays
  - Smartphones & tablets
  - Monitor & webcam

Examples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Milgram's Reality–Virtuality Continuum

REAL ENVIRONMENT — **MIXED REALITY (MR)** — **VIRTUAL ENVIRONMENT**

Tangible User Interfaces (TUI)

A TUI uses real physical objects to both represent and interact with computer-generated information (Ishii & Ullmer, 2001).

Using physical objects to create a virtual model (Ichida, Itoh, & Kitamur, 2004). As a user adds a physical 'ActiveCube' to the construction, the equivalent virtual model is automatically updated.

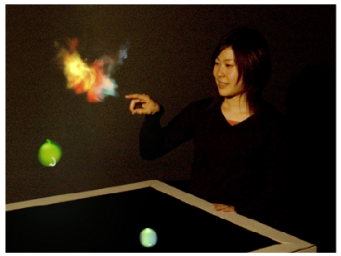
Projection Augmented models (PA model) are a type of Spatial AR display, and are closely related to TUIs

Augmented Reality (AR)

AR 'adds' computer-generated information to the real world (Azuma, et al. 2001).

Spatial AR

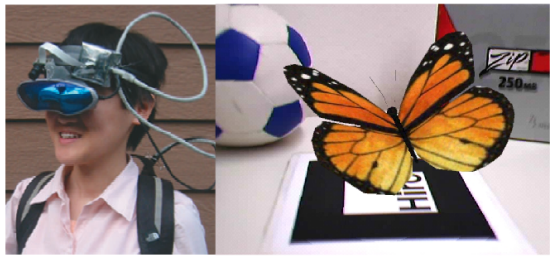
Spatial AR displays project computer-generated information directly into a user's environment (Bimber & Raskar, 2005).



The 'Bubble Cosmos' – 'Emerging Technology' at SIGGRAPH'06. The paths of the smoke-filled bubbles are tracked, and an image is projected into them as they rise.

'See-through' AR (either optical or video)

A user wears a head-mounted display, through which they can see the real world with computer-generated information superimposed on top (Cakmakci, Ha & Rolland, 2005; Billinghurst, Grasset & Looser, 2005).



See-through AR: the butterfly is computer-generated, and everything else is real (Fischer, Bartz & Straßer, 2006; Kölsch, Bane, Höllerer, & Turk, 2006).

Augmented Virtuality (AV)

AV 'adds' real information to a computer-generated environment (Regenbrecht, et al. 2004).

Semi-immersive VR

A semi-immersive VR display fills a limited area of a user's field-of-view.

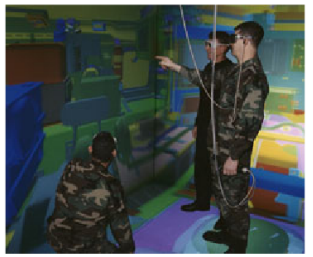
Semi-immersive VR using the Barco Baron workbench (Drettakis, Roussou, Tsingos, Reche & Gallo, 2004).

Virtual Reality (VR)

VR refers to completely computer-generated environments (Ni, Schmidt, Staadt, Livingston, Ball, & May, 2006; Burdea & Coffet 2003)

Immersive VR

Immersive VR, which uses either a head-mounted-display or a projection-based system, completely fills the user's field-of-view.

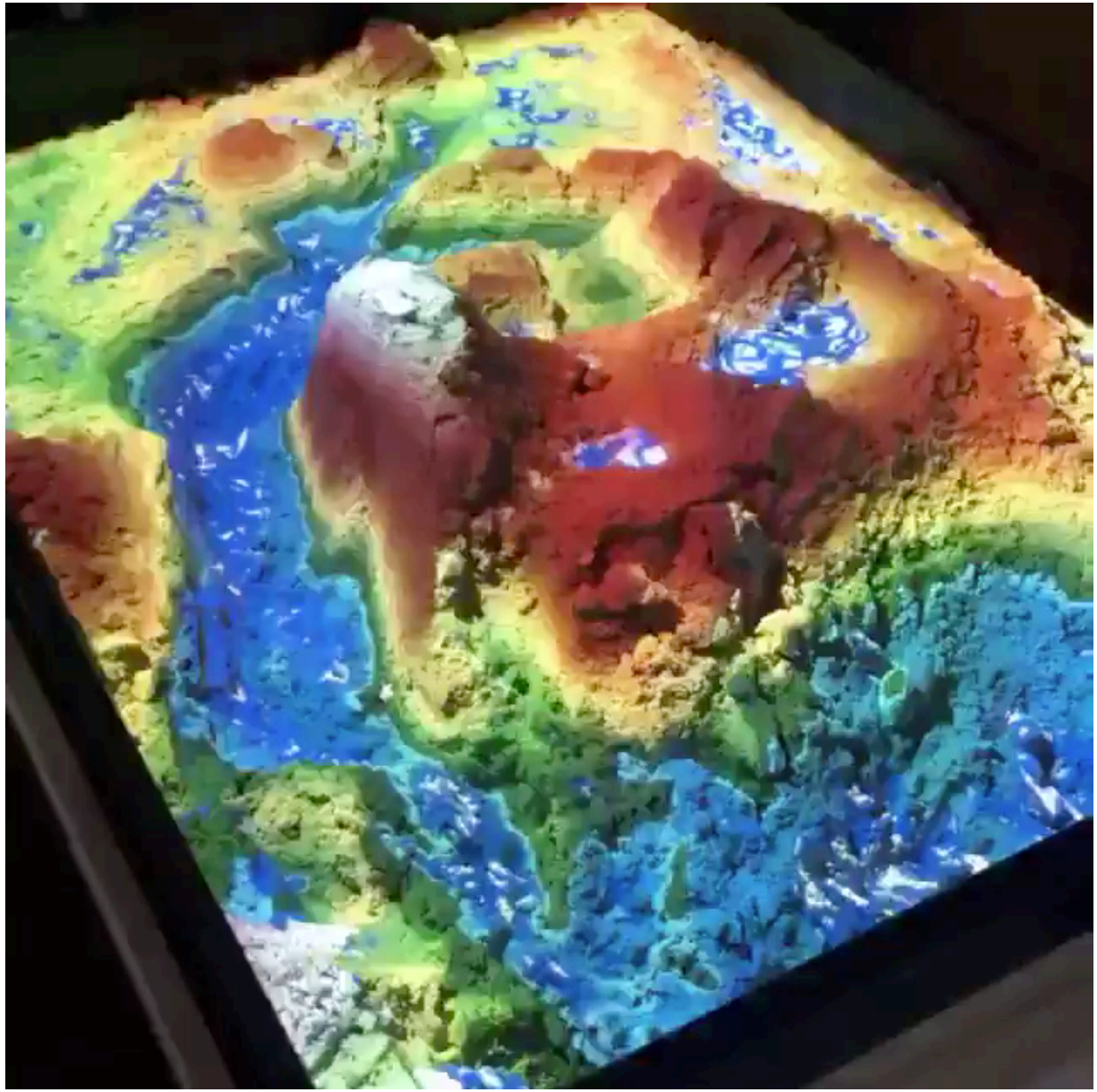


Projection-based immersive VR. The users are fully immersed in the 'CAVE' (FakeSpace, 2006; Cruz-Neira, Sandin & DeFanti, 1993).

Example of Augmented VR

David Nahon

Example of Projection/Spatial Augmented Reality

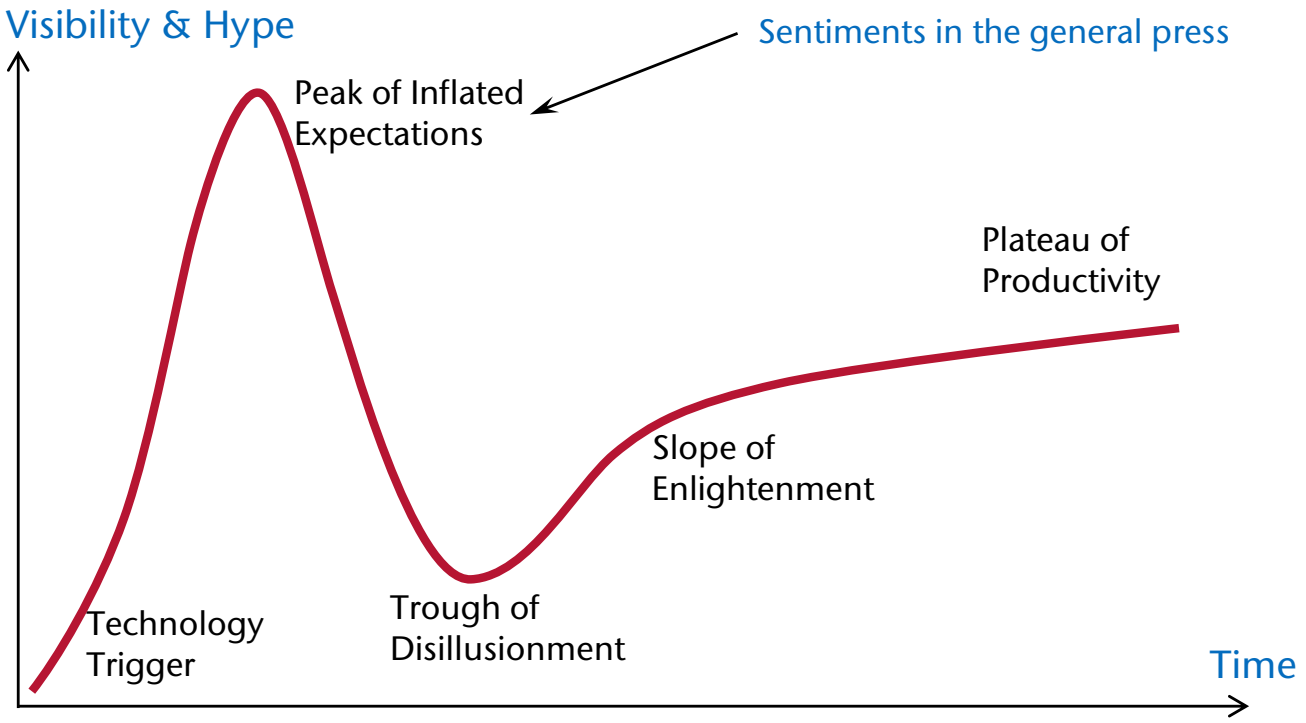


Vision: the Windowless, See-Through Airplane

© CPI

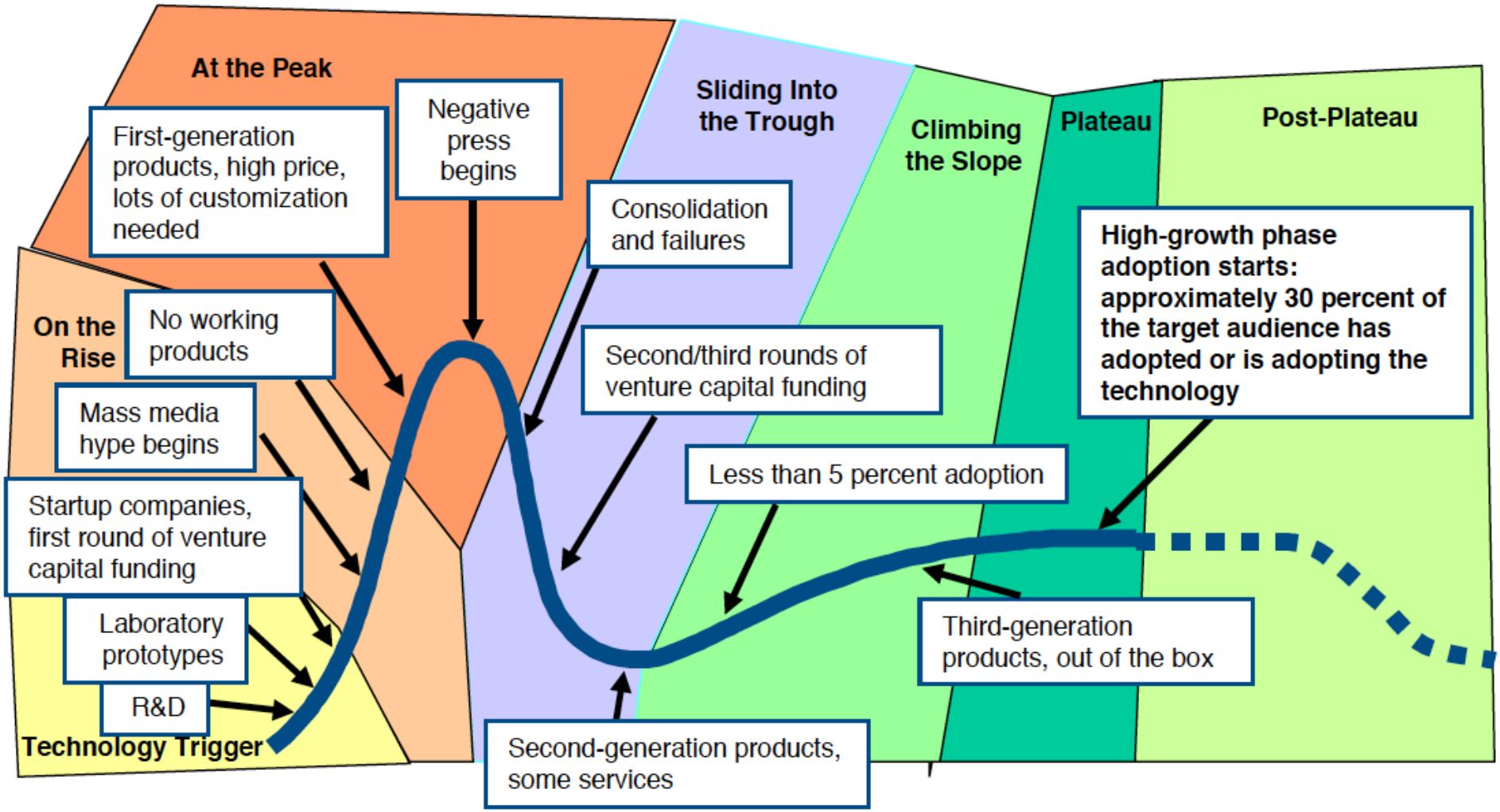
Gartner's Hype Cycle for Emerging Technologies

- Hype cycle = graphic representation of over-enthusiasm, disillusionment, and eventual realism that accompanies each new technology

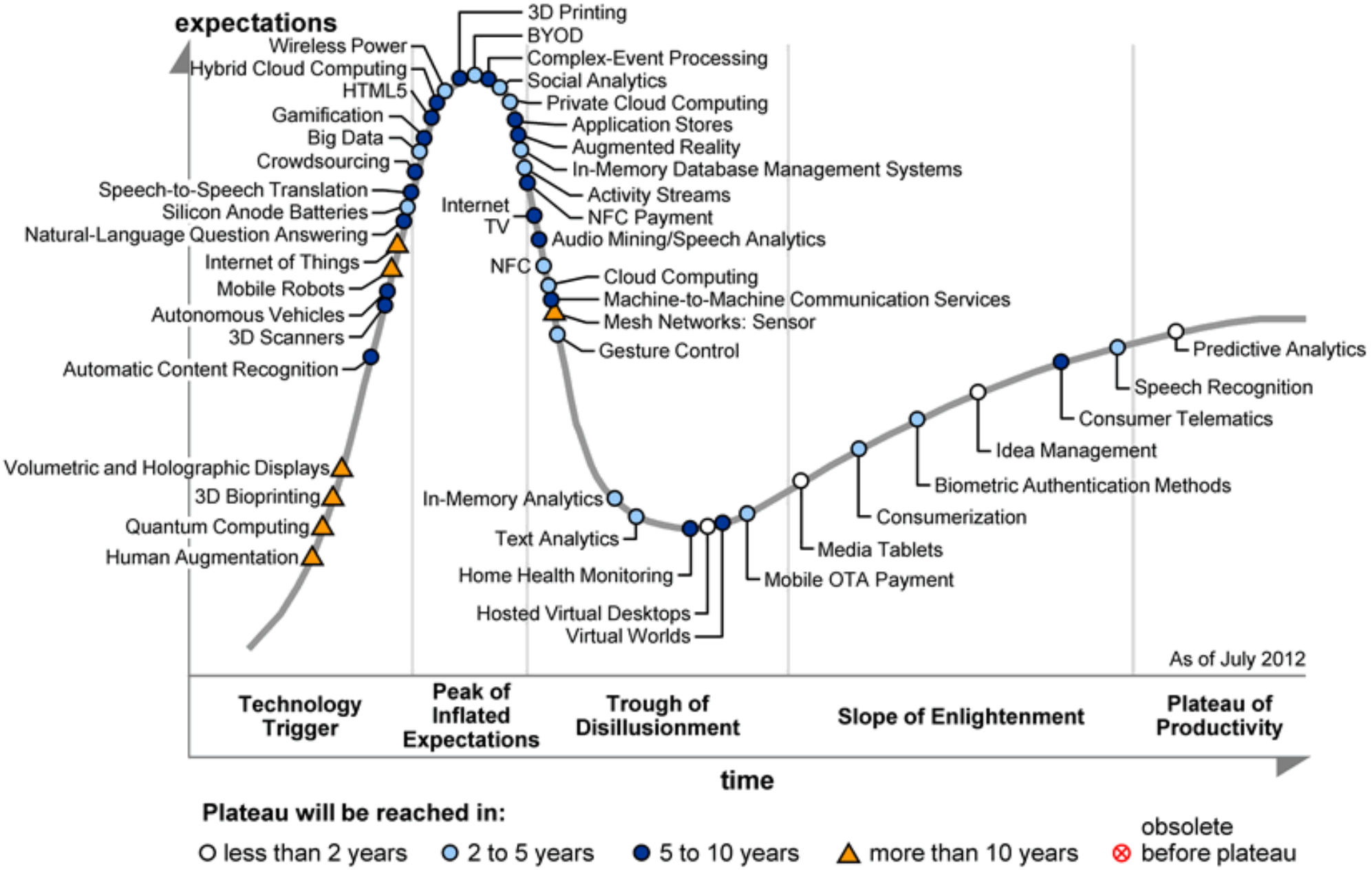


Jackie Fenn, 1995

In more detail

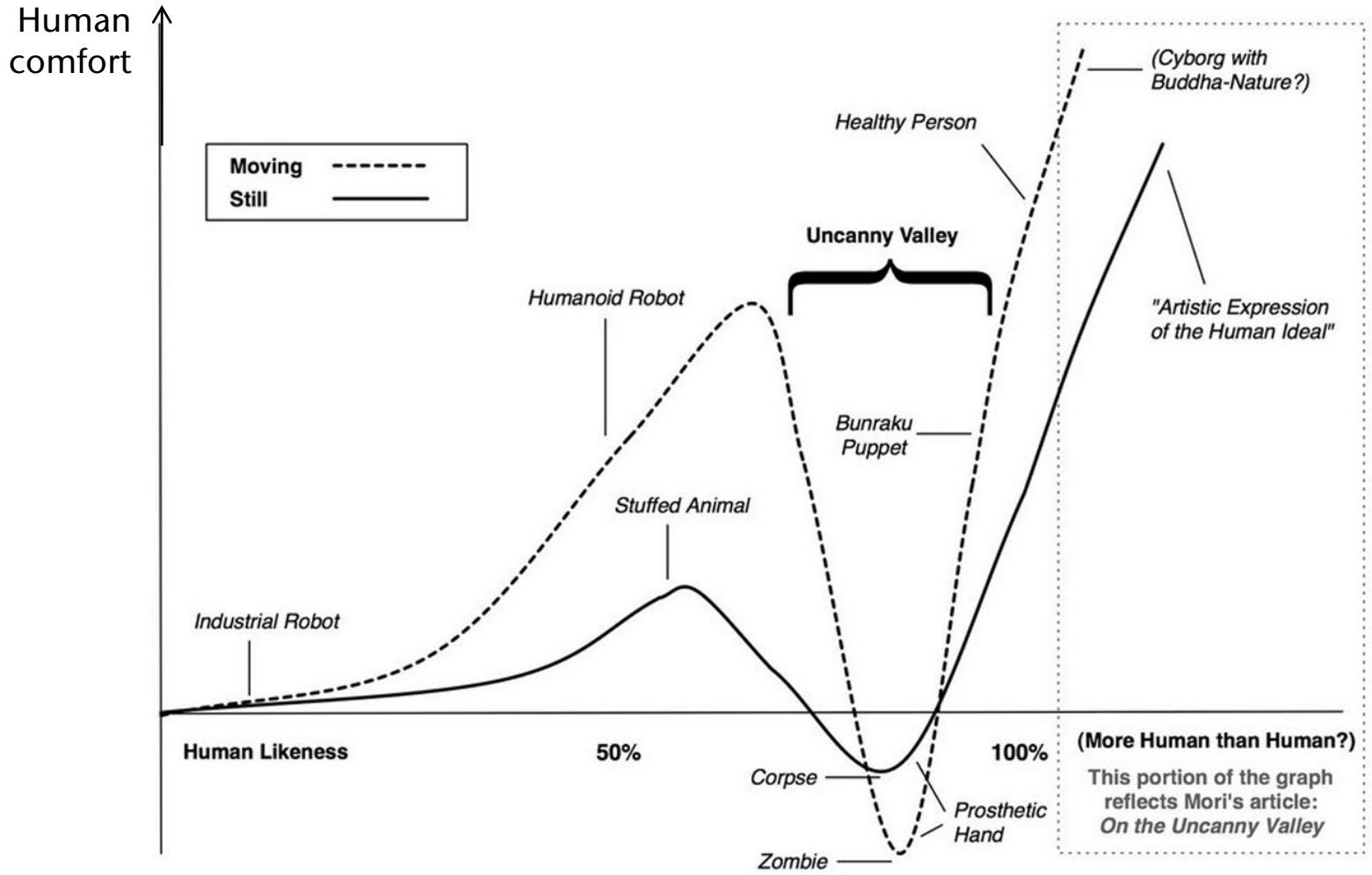


A Few Examples



The Uncanny Valley

"When human replicas look and act almost, but not perfectly, like actual human beings, it causes a response of revulsion among human observers."

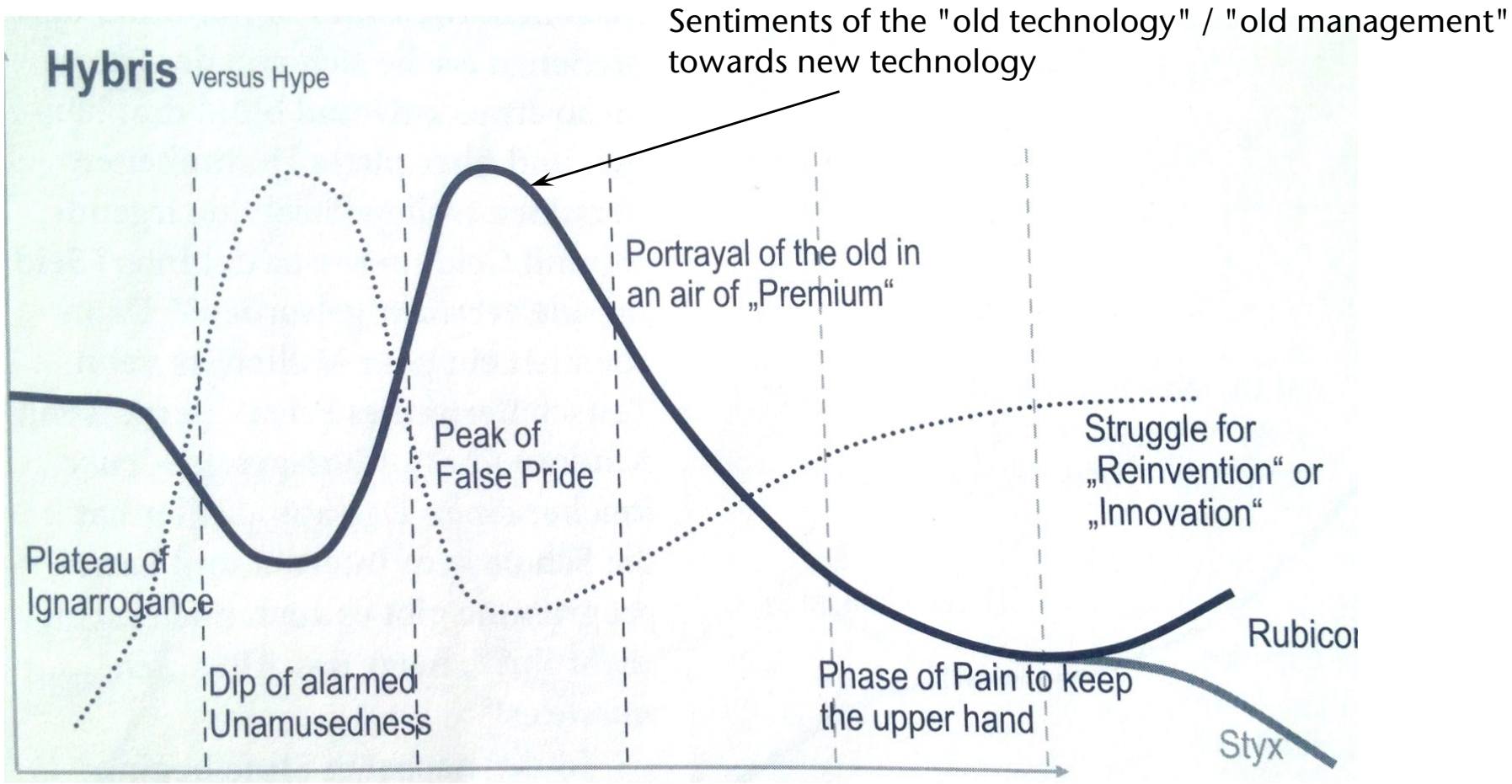


Biennale Venice 2015

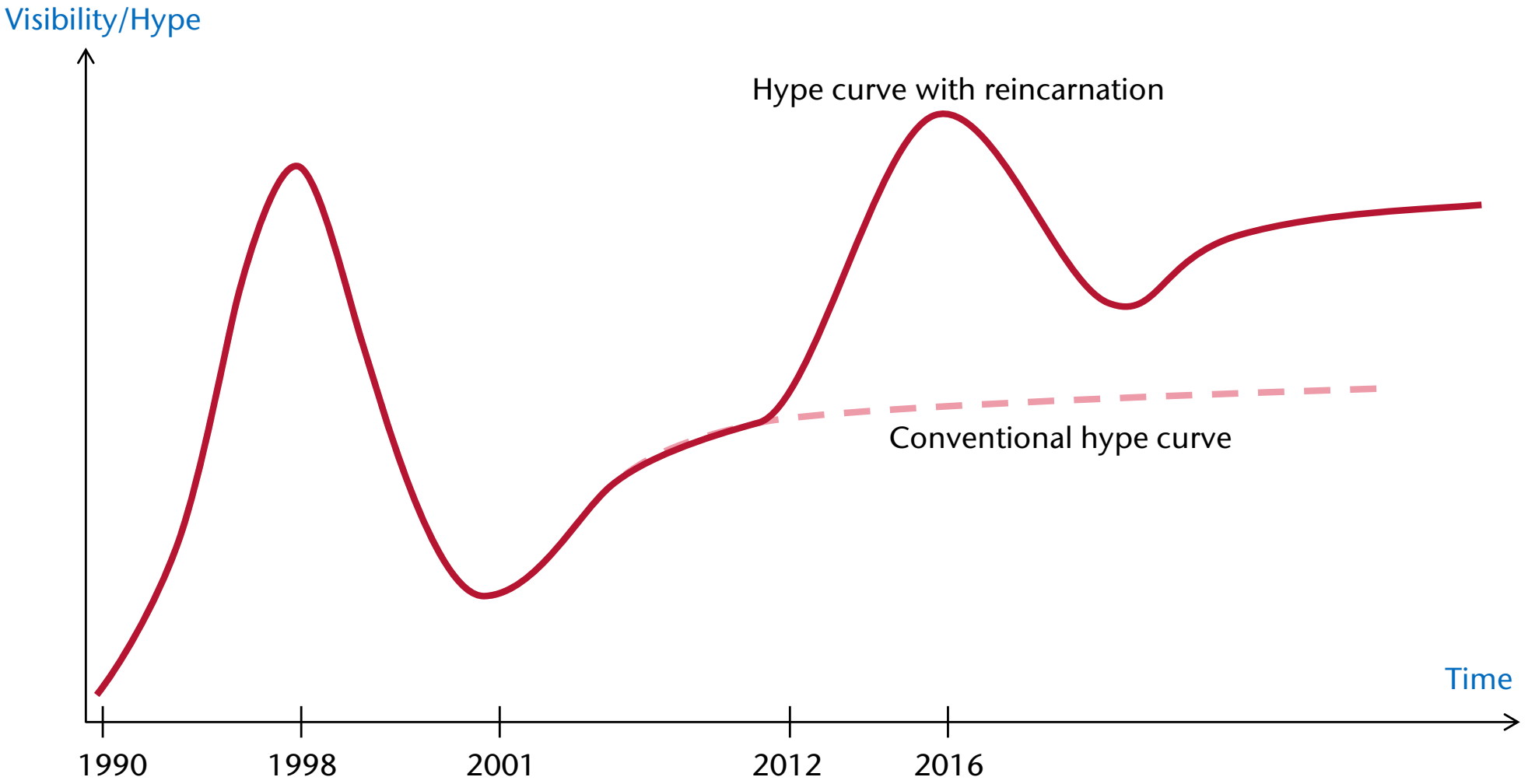
Examples (IMHO)

Ex Machina (2015)

Gunter Dueck's Hybris Curve



My Curve of Reincarnation of VR



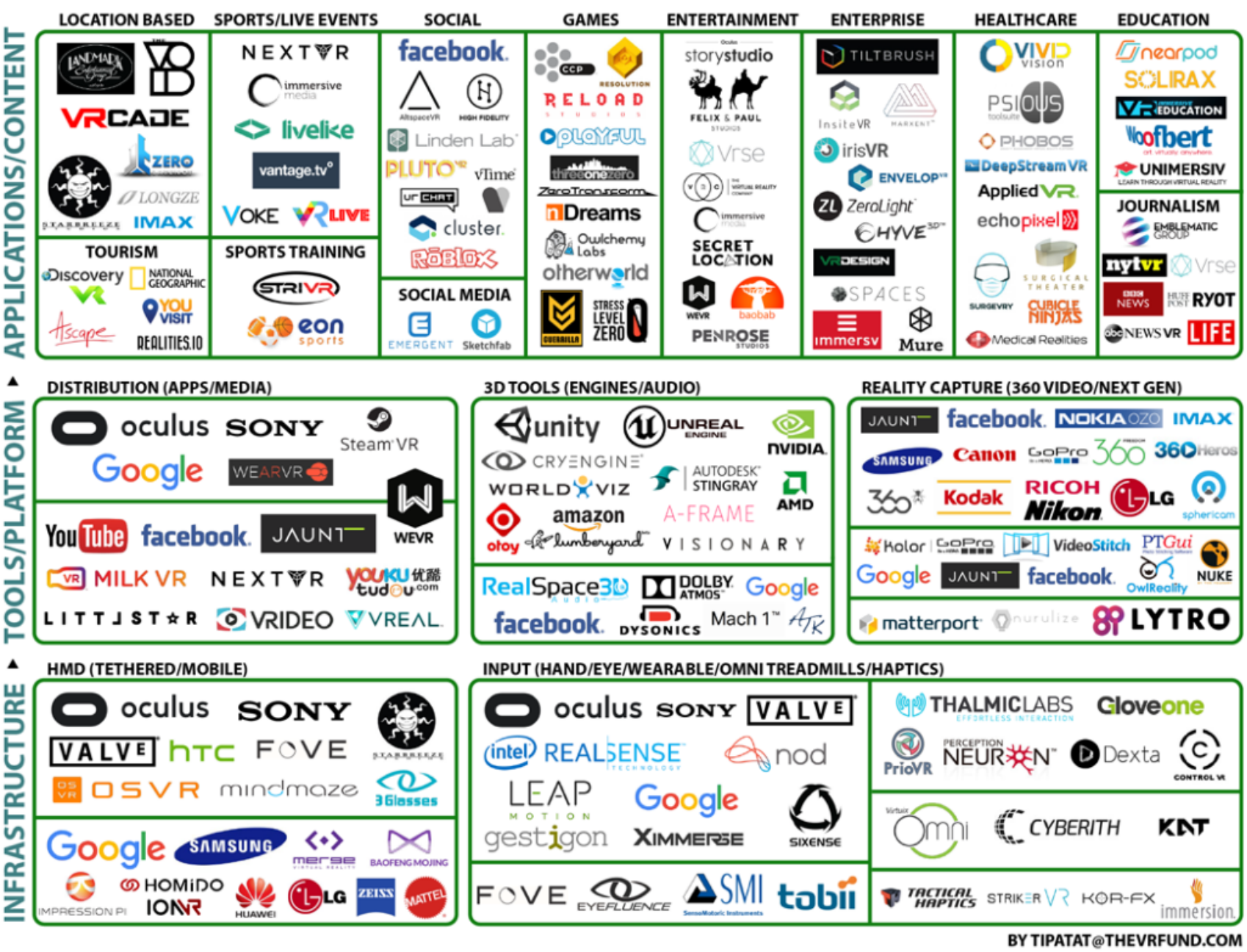
Gabriel Zachmann, 2016

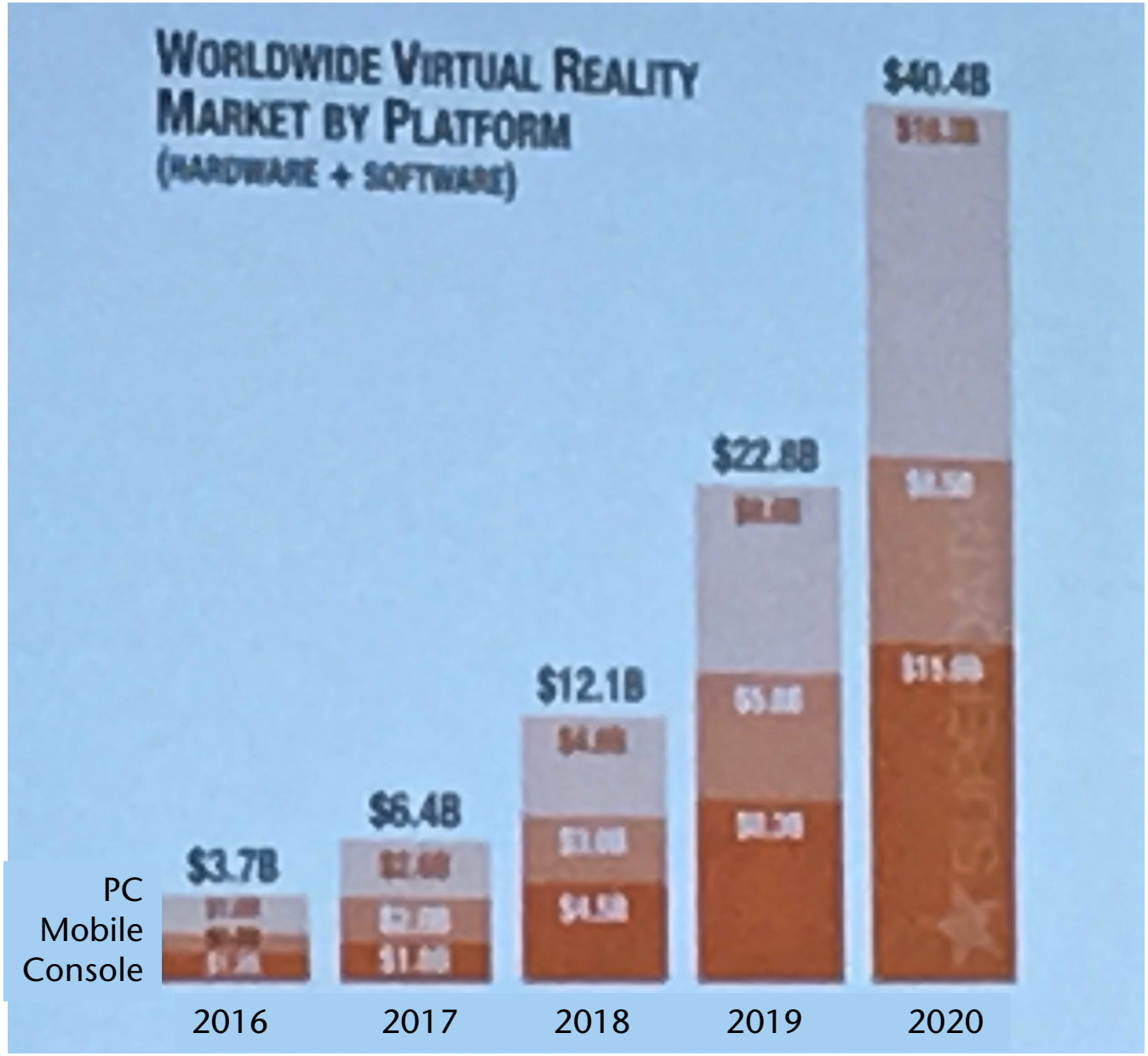
A Prognosis on the Market Size

Studien, die im VDC-Newsletter Dezember 2015 erwähnt werden:

Markt für Virtual Reality verzehnfacht sich bis 2020 Laut einer neuen Prognose des Marktforschungsunternehmens Trendforce soll der weltweite VR-Markt bis 2020 auf ein Volumen von 70 Milliarden Dollar

Vorhersagen über VR und AR bis 2025 Der VR-Entwickler Jesse Schell hat insgesamt 40 Thesen aufgestellt, wie die Branche sich bis zum Jahr 2025 entwickeln könnte.


THE VR FUND 2016 VR INDUSTRY LANDSCAPE JUNE v1.6
APPLICATIONS/CONTENT
LOCATION BASED
SPORTS/LIVE EVENTS
SOCIAL
GAMES
ENTERTAINMENT
ENTERPRISE
HEALTHCARE
EDUCATION
TOURISM
SPORTS TRAINING
SOCIAL MEDIA
JOURNALISM
TOOLS/PLATFORM
DISTRIBUTION (APPS/MEDIA)
3D TOOLS (ENGINES/AUDIO)
REALITY CAPTURE (360 VIDEO/NEXT GEN)
INFRASTRUCTURE
HMD (TETHERED/MOBILE)
INPUT (HAND/EYE/WEARABLE/OMNI TREADMILLS/HAPTICS)
BY TIPATAT@THEVRFUND.COM


WORLDWIDE VIRTUAL REALITY MARKET BY PLATFORM
(HARDWARE + SOFTWARE)
$3.7B
$6.4B
$12.1B
$22.8B
$40.4B
PC
Mobile
Console
2016
2017
2018
2019
2020

SciFi Literature Containing a Large Amount of VR

- Aldous Huxley: *Brave New World*, 1932
- William Gibson: *Neuromancer*, 1984
- Neal Stephenson: *Snow Crash*, 1992
- Tad Williams: *Otherland*, 1996-2001
- Ernest Cline: *Ready Player One*, 2011
- Any important book missing? ...