EPFL

Boulic - Virtual Reality
May 12th 2025

Immersive Virtual Reality, Telepresence and their cognitive foundations

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Immersive and Embodied Virtual Reality

Part 1

Immersive Virtual Reality
Telepresence and their cognitive foundations

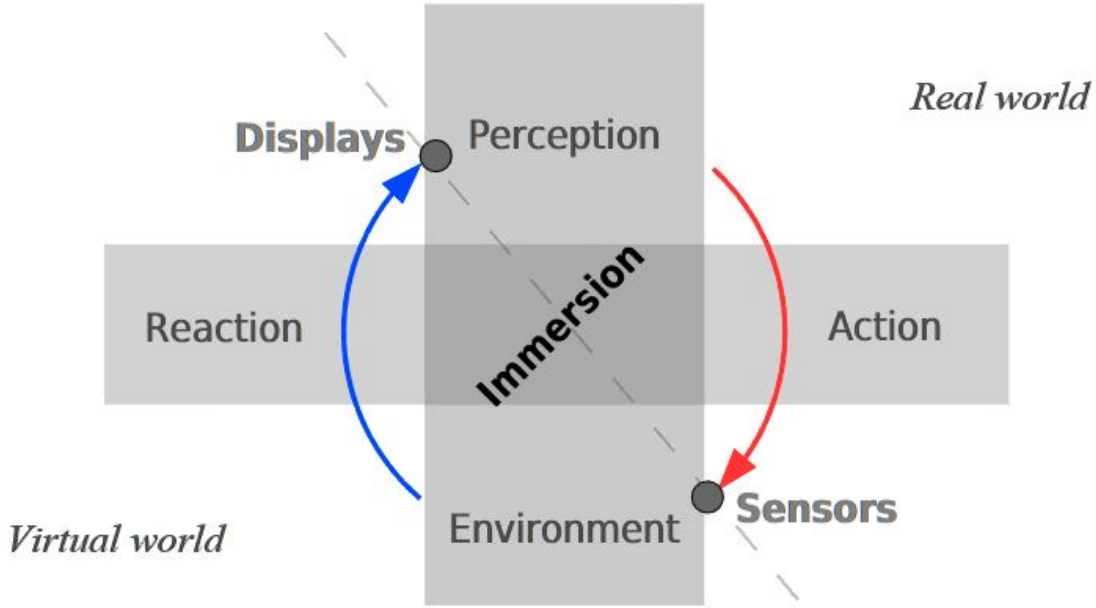
Part 2

Embodied Virtual Reality
Limits and applications

Immersion

- Immersive systems properties
  - HMD field of view
  - Rendering resolution
  - etc.
- **Immersive virtual environment** (IVE)
  (Slater & Usoh 1994)
- Support natural sensorimotor contingencies for perception & action
  (Slater 2018)

Perception-action loop



Immersion

- Definition *

Immersion is a *quantifiable* aspects of a VR technology representing its ability to deliver a surrounding and convincing environment.

Synthesized from Slater (1995, 1999, 2003, 2018)

* Most widely accepted in the VR community

(Tele) Presence

- ‘Out of the body’

  “What you don’t realize until you do it is that tele-presence is a form of **out-of-the-body** experience.”

  Rheingold, H. (1991). Virtual Reality: Exploring the Brave New Technologies. Simon & Schuster Publishing Group.

- ‘Being there’

  “**Second person** VR is an almost outrageous leap of faith, to transfer yourself into a world on the screen.”

  Heeter, C. (1992) ‘Being There: The Subjective Experience of Presence’, *Presence* 1(2), pp. 262–271.

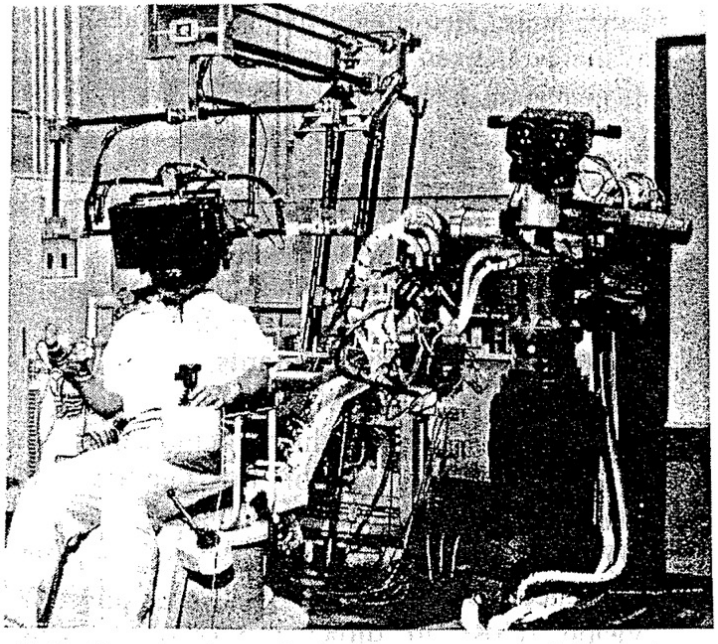


Fig.2 General view of the master system (left) and anthropomorphic slave robot (right).

Tachi S, Arai H. & Maeda T. (1990) Tele-existence Master Slave System for Remote Manipulation, IEEE Conference on Decision and Control (1) 85-90, USA.

Presence

- Definition *

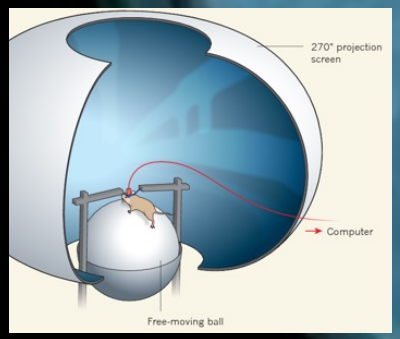
Presence is the strong illusion of being in a place in spite of the sure knowledge that you are not there.

Presence (Place and Plausibility illusions) refers to how people respond to Immersion.

Slater, M. (2009) 'Place illusion and plausibility can lead to realistic behaviour in immersive virtual environments', *Philosophical Transactions of the Royal Society B: Biological Sciences*, 364(1535), pp. 3549–3557.

* Most widely accepted in the VR community

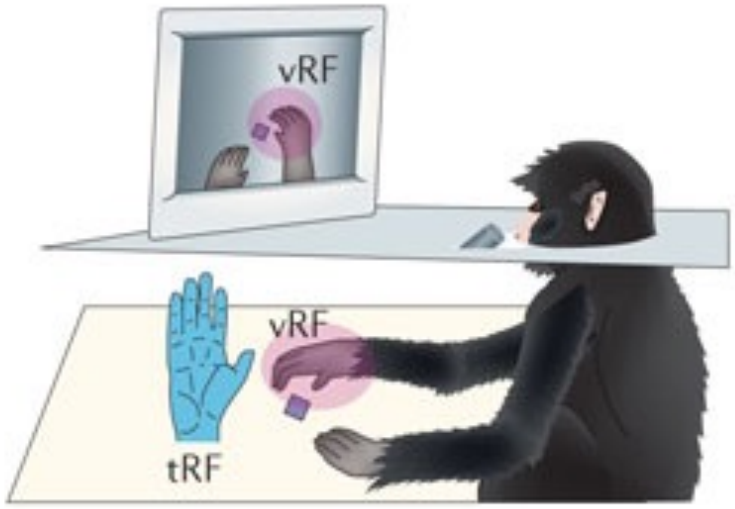
IMMERSION



PRESENCE

Erika Pastrana *Nature Methods* (2010)

‘Just’ being there



“Evolutionary precursors for introspective manipulation of an abstract sign, or eventually a symbolic representation of the own body, might be already reserved as neural machinery in the monkey brain[…]”
Iriki et al. (2001). *Self-images in the video monitor coded by monkey intraparietal neurons*

Question of presence

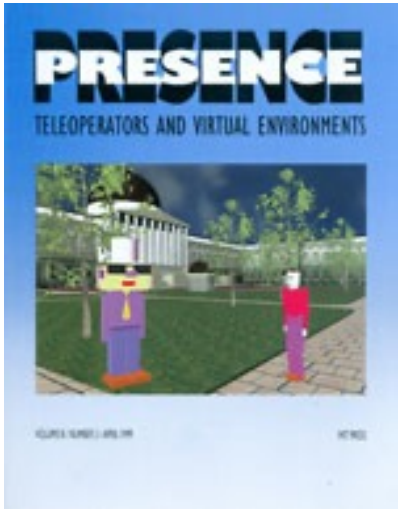
NASA Research (1980)

Sense8 Corp. (~1980)

SIGGRAPH (1992)

Comdex Spring (1992)

(tele) Presence
Sense of Presence



At the core of what defines virtual reality since its origins:

- Suspension of disbelief (Slater 93)
- Sense of spatially “being there” (Barfield 95)
- Experiential bodily experience (Waterworth 96)
- Illusion of non-mediation (Lombard & Ditton 97)
- Successful support of actions in IVE (Zahoric 98)
- Immersion, presence, performance model (Bystrom 99)

Presence Questionnaires

- Slater et al. (1993, 1994) - 3 to 6 items, customized

  To what extent were there times during the experience when the *office space* was the reality for you?
  1 - at no time almost all the time - 7

- Witmer & Singer (1998) - 32 items, the most cited

  How completely were all your senses engaged?
  How involved were you in the virtual environment experience?

- Others
  - Baños (2000), Lessiter (2001), IPQ Schubert (2003) http://www.igroup.org/pq/ipq

Slater, M., Usoh, M., & Steed, A. (1994). Depth of presence in immersive virtual environments. Presence, 3(2), 130–144

Witmer, B. G. and Singer, M. J. (1998) 'Measuring Presence in Virtual Environments: A Presence Questionnaire', *Presence* 7(3), 225–240.

Questionnaires

- 86% of studies use subjective measures, 12% use both subjective and objective measure of Presence

Souza, V., Maciel, A., Nedel, L., and Kopper, R. (2022). Measuring Presence in Virtual Environments: A Survey. *ACM Comput. Surv.* 54, 1–37. doi:10.1145/3466817

- Scores are inconsistent if measured during or after immersion

Graf, S., and Schwind, V. (2020). "Inconsistencies of Presence Questionnaires in Virtual Reality," in 26th ACM Symposium on Virtual Reality Software and Technology, 1–3.

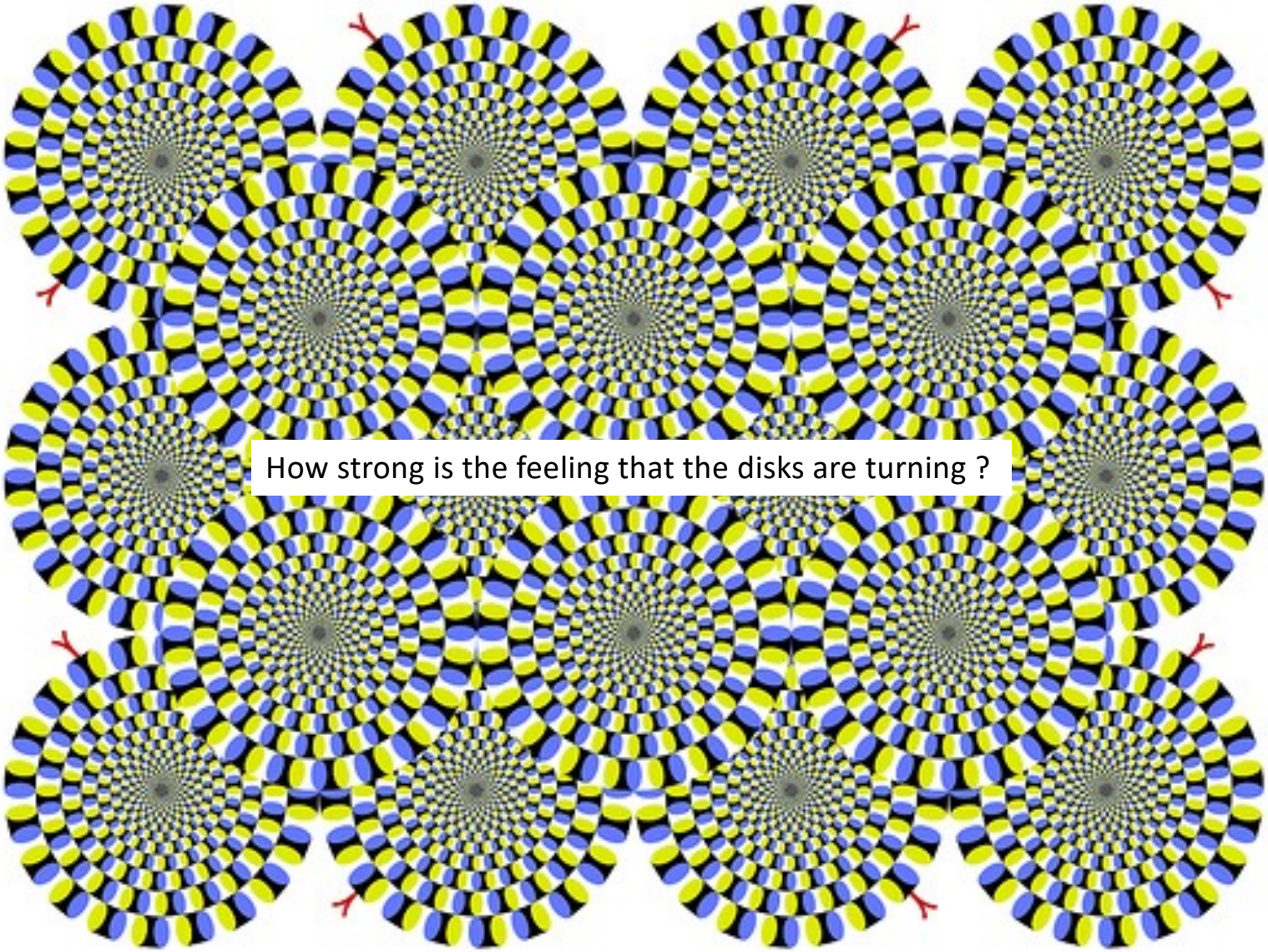
Think of yesterday.
How colorful was your day?

Were there times during the day that you would describe as having been colorful?
1 - not at all a great deal - 7

- Limit of questionnaires
  - We cannot rule out the possibility that the concept exists to our experimental subjects only because questions are asked about it (Slater 2004)
  - No difference in PQ score in real vs. virtual environment (Slater & Usoh 2000)
- Frequent confusions with immersion, involvement, engagement, or sense of reality.

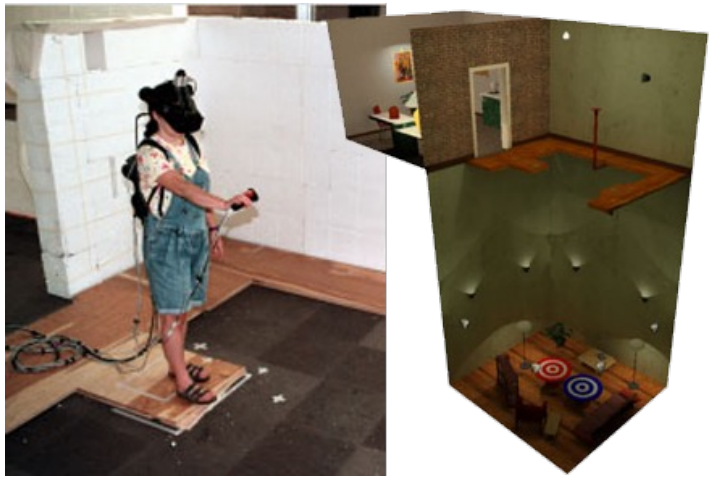
NB: Results of regression analysis (N=74): a "colorful day" is a pleasant and not frustrating day, when one could get up later than usual.

Slater (2004) How colorful was your day? : Why questionnaires cannot assess presence in virtual environments Presence 13:4, 484-493.


How strong is the feeling that the disks are turning ?

‘Surrogates’ for Presence

- If participants experience the illusions, then their reactions will be the same as in reality
  - e.g. threat
- Behavioral & Physiological measure
  - Correlations Presence & copresence scores
    - e.g. Ochs et al (2022)
  - Limited to situations with specific triggers that elicit physiological or brain responses

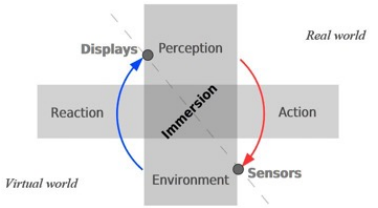


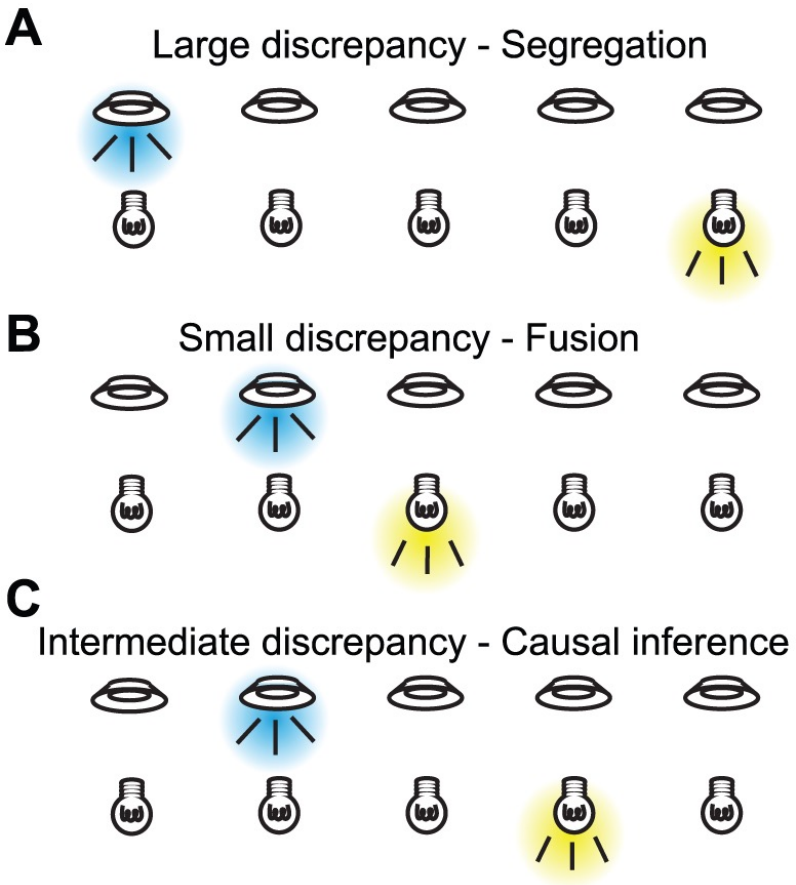
Meehan M, Insko B, Whitton M, Brooks FP Jr (2002) Physiological measures of presence in stressful virtual environments. ACM Trans Graph (tog) 21(3):645–652

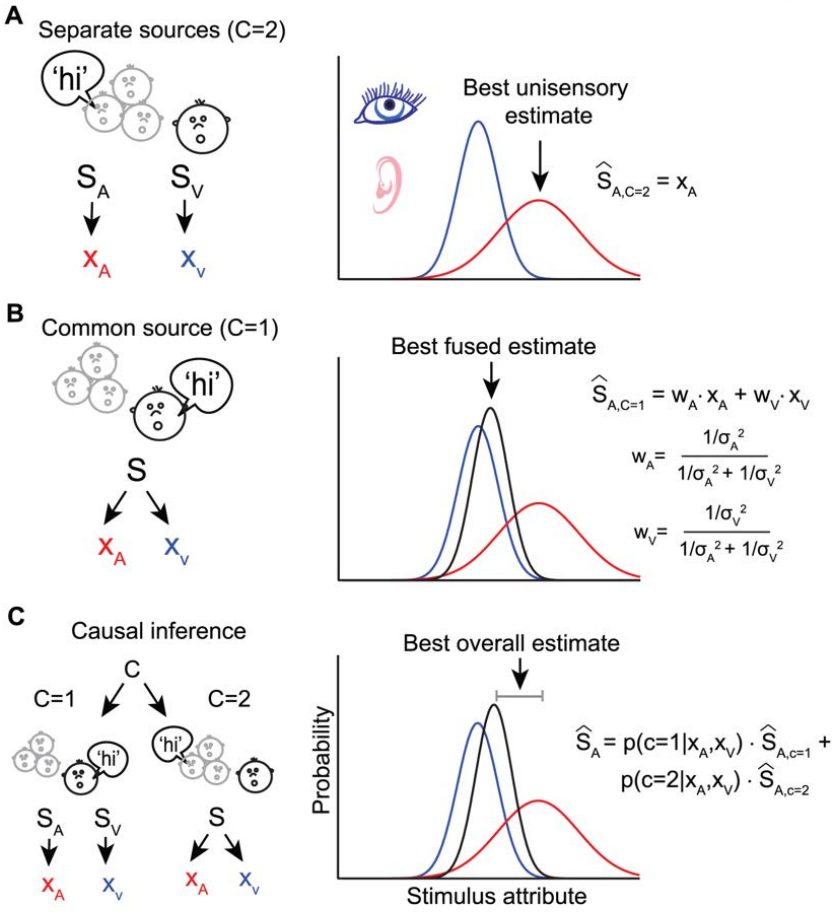
Ochs, M., Bousquet, J., Pergandi, J.-M., and Blache, P. (2022). *Front. Comput. Sci.* 4.

The congruency hypothesis

Multisensory integration







Kayser, C., & Shams, L. (2015). Multisensory Causal Inference in the Brain. *PLOS Biology*, *13*(2), e1002075. https://doi.org/10.1371/journal.pbio.1002075

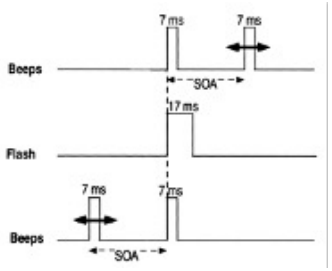
Multisensory integration: VR and illusions

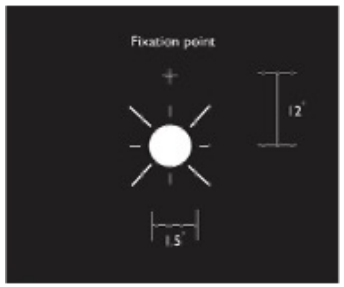
Mc Gurk effect
(The ventriloquist illusion)

McGurk H. and MacDonald J. (1976).
Hearing lips and seeing voices,
Nature 264, 746-748 (1976).

http://www.youtube.com/arnte

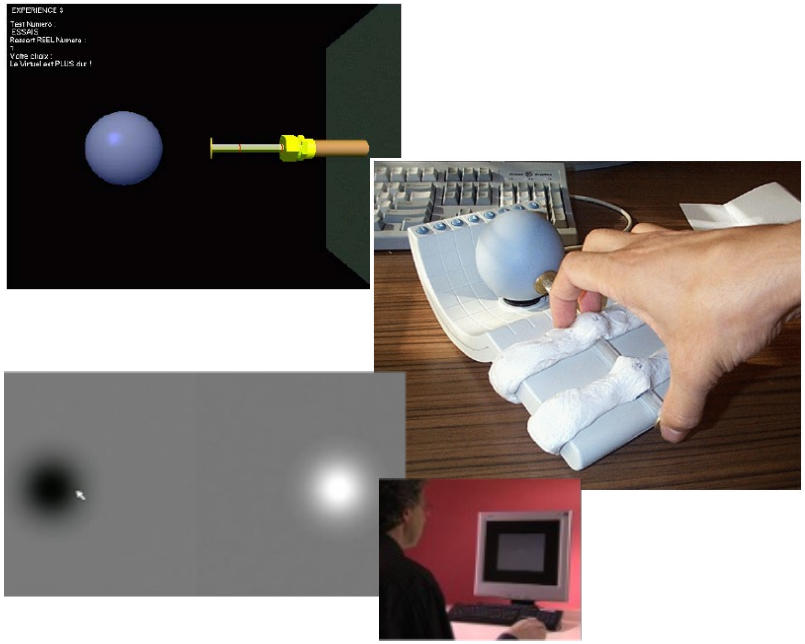
Sound induced flash illusion





Ladan Shamsa, Wei Ji Ma and Ulrik Beierholm. Sound-induced Flash illusion as an optimal percept, AUDITORYANDVESTIBULAR SYSTEMS, NEUROREPORT, Vol 16 No 17 28 November 2005, pp1923-1927.

Pseudo-haptic feedback



Lecuyer A., Coquillart S., Kheddar A., Richard P. and Coiffet P. (2000). Pseudo-Haptic Feedback : Can Isometric Input Devices Simulate Force Feedback?, VR '00: Proceedings of the IEEE Virtual Reality 2000 Conference, Washington, DC, USA.

Redirected Touch

Visual dominance over touch

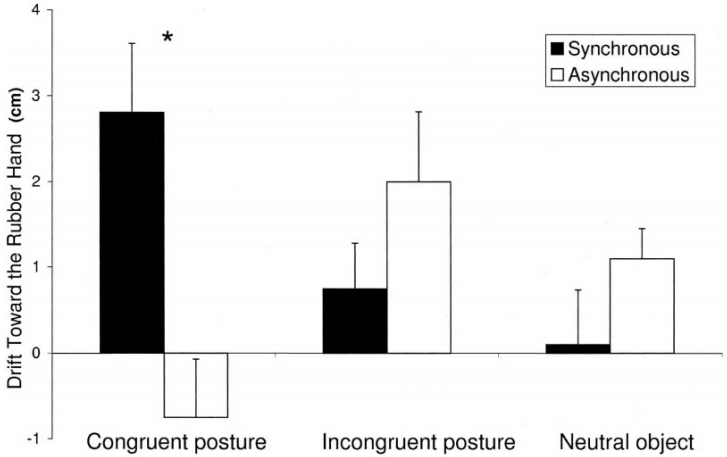
The ‘this is me’ hypothesis

Disclosure (1994)

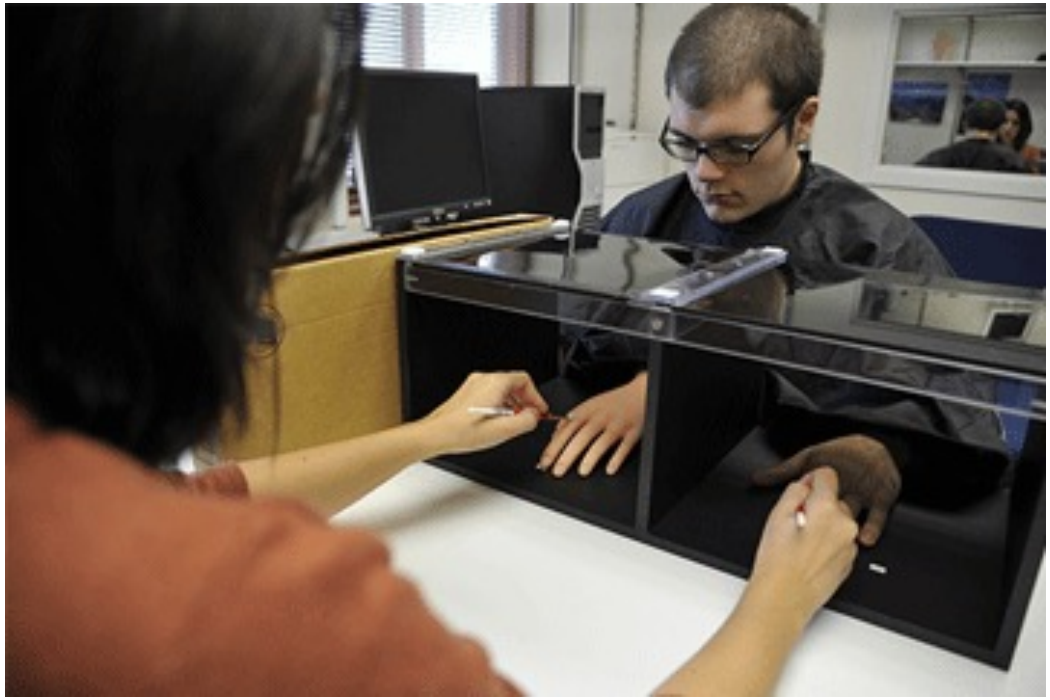
Rubber Hand Illusion

During bodily illusions like the “rubber hand illusion”, a fake body part is felt as the real one. This occurs after a few seconds of synchronous stroking of the hand; “if I feel touch on this hand, it must be mine!!”.

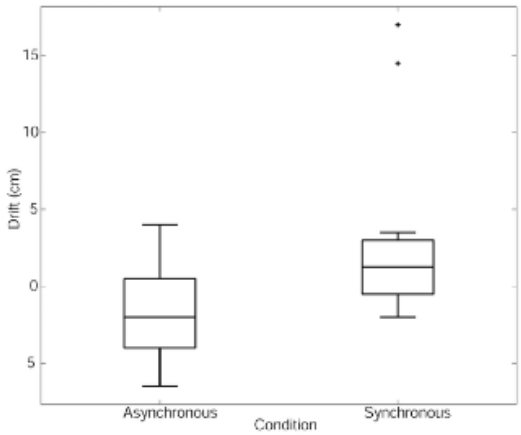
(Botvinick and Cohen, *Nature*, 1998)



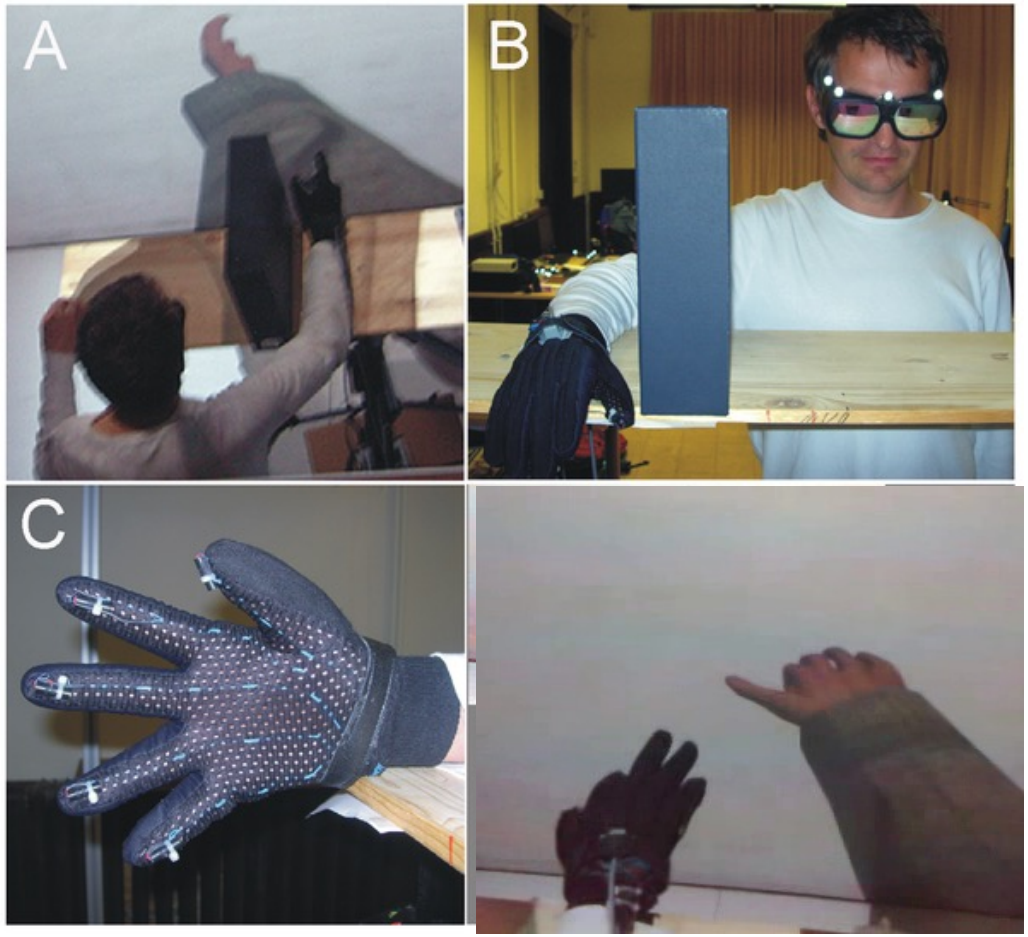
M Tsakiris, P Haggard - Journal of Experimental Psychology, 2005



Virtual Hand Illusion

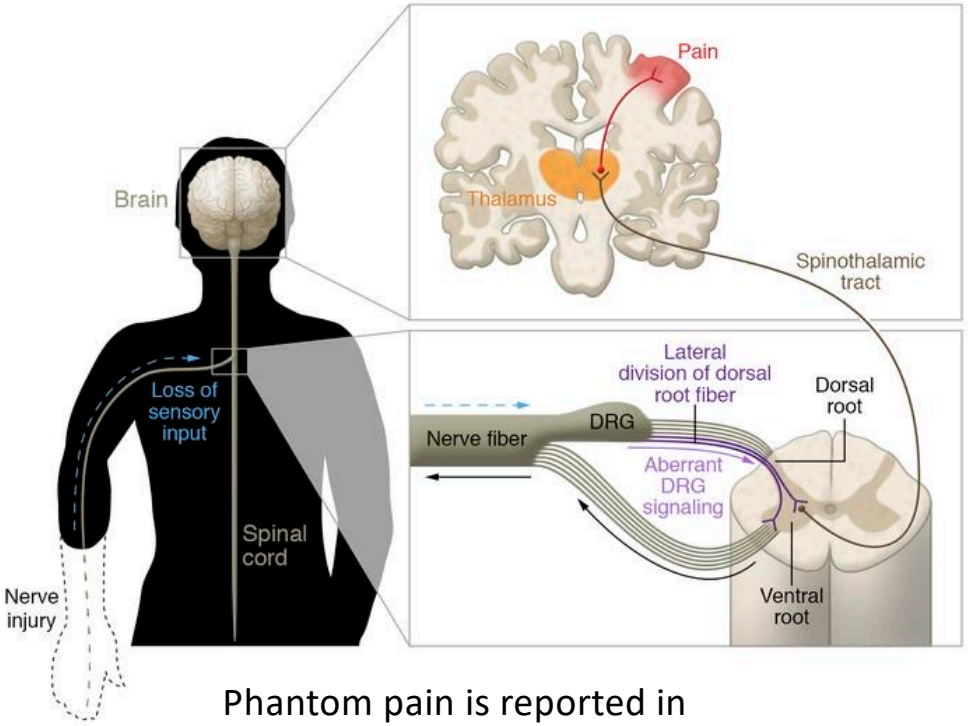


Sanchez-Vives, Spanlang, Frisoli, Bergamasco, Slater. PloS one, 2010

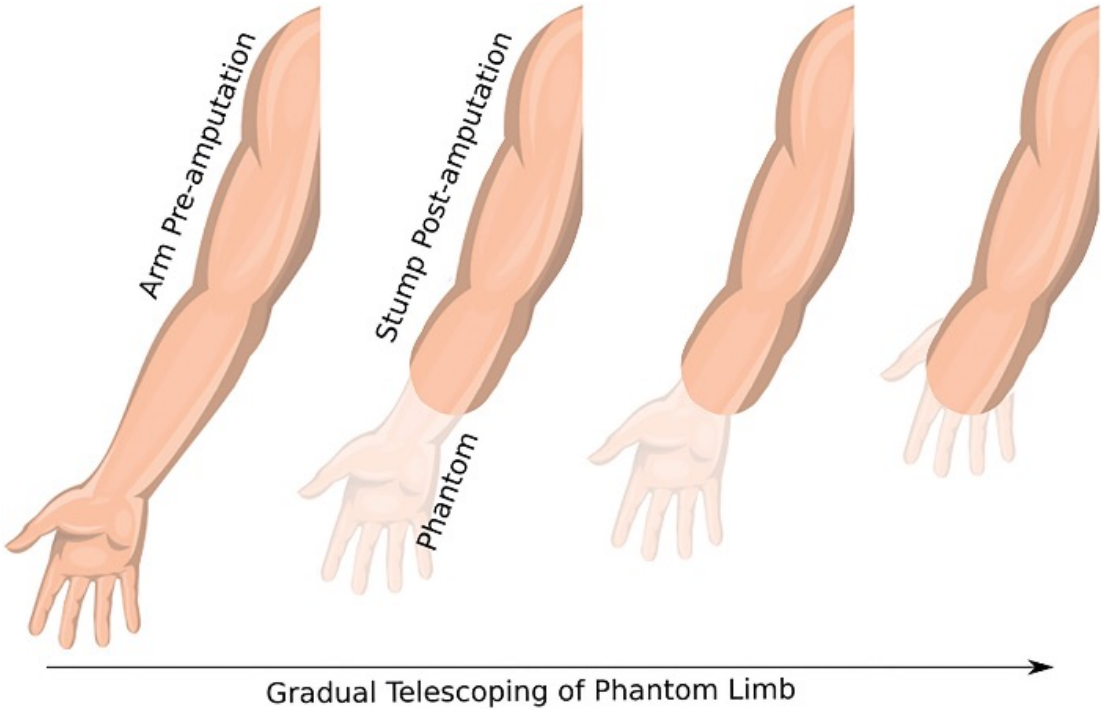



Combined VR and neuroprosthetic approach for improving abnormal phantom limb perceptions in upper-limb amputee
Blanke et al., J Neurol Neurosurg Psychiatry, 2018

Phantom limb

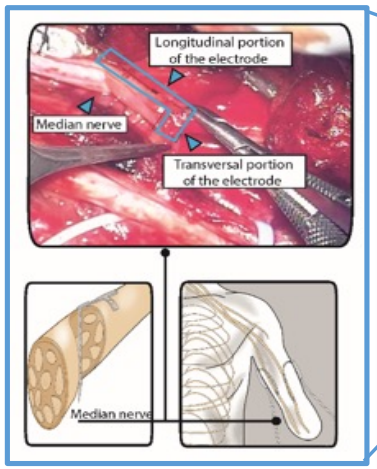


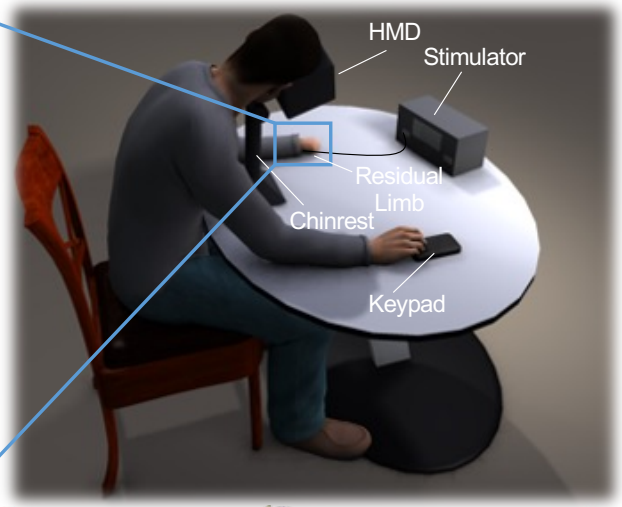
Phantom pain is reported in
80% of amputees

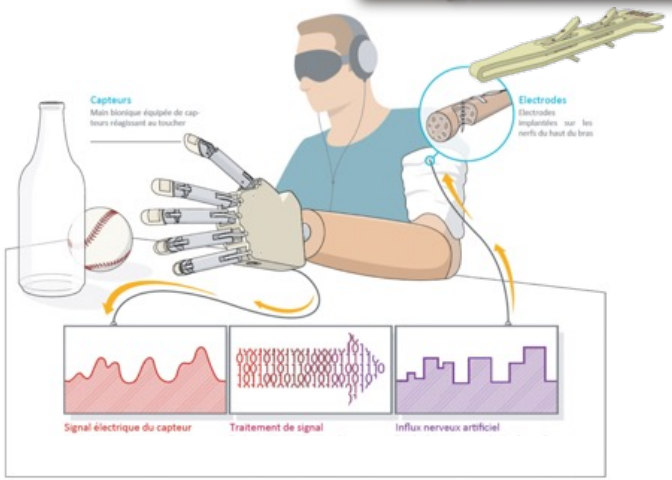


30% of amputees experience telescoping,
the gradual shortening or retraction of the phantom limb

Neurotactile stimulation





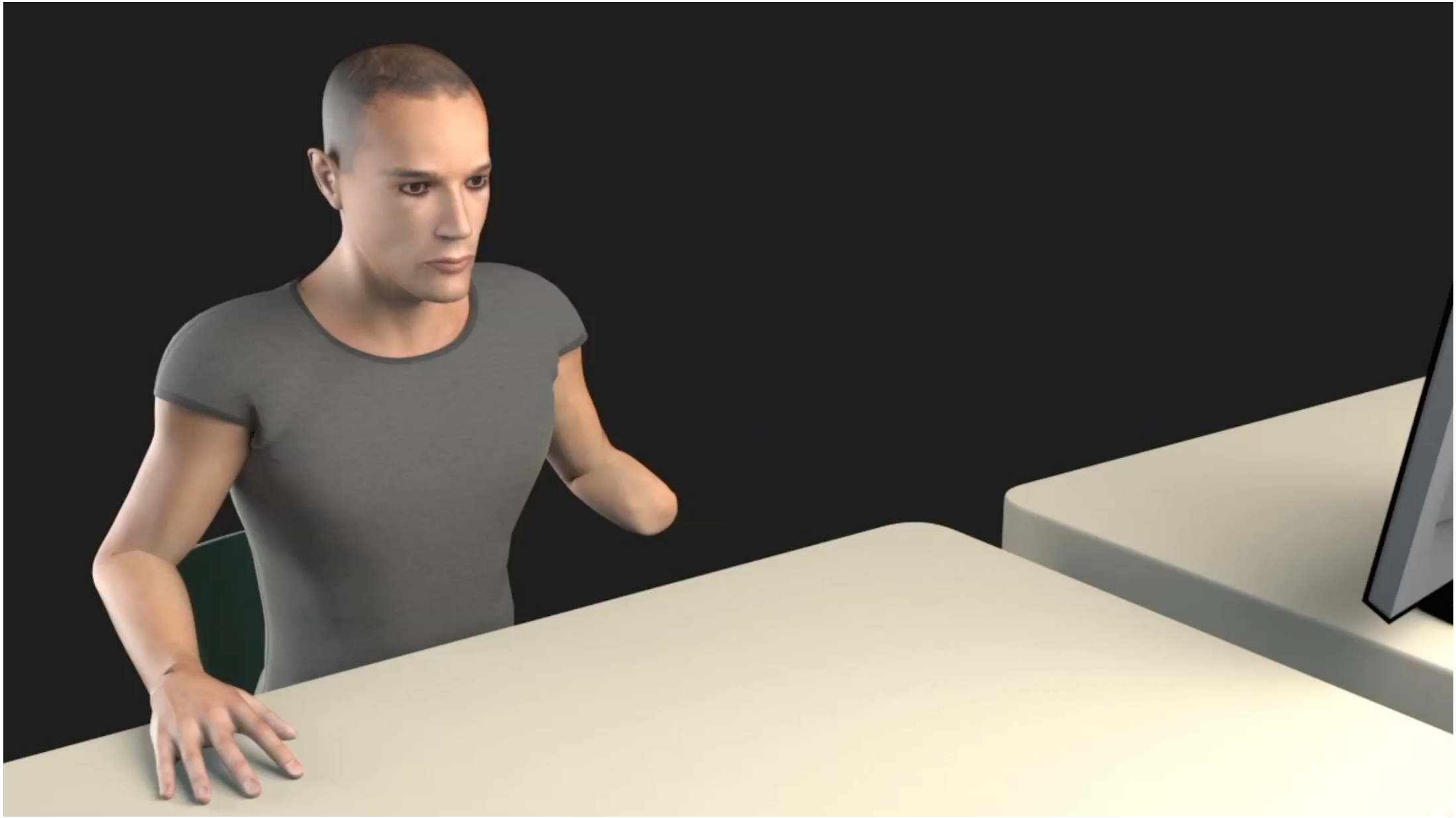


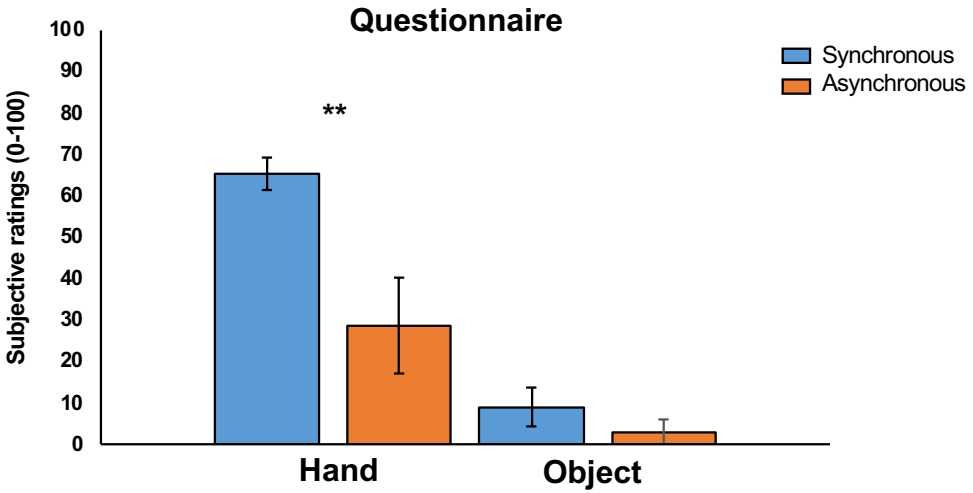
Virtual stimulus (HMD) :

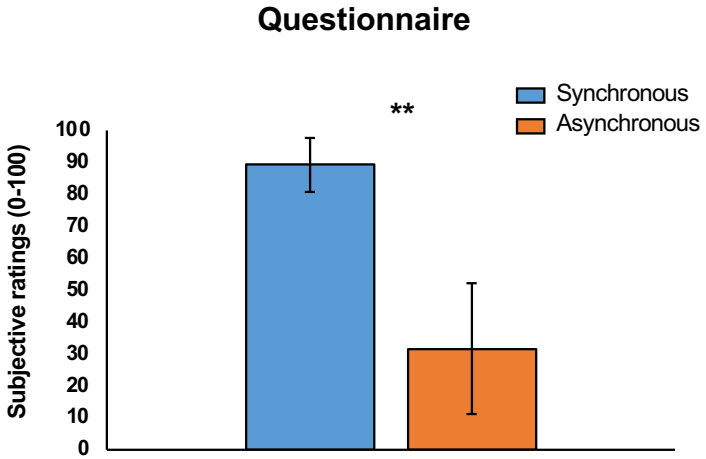
Patient 1
(Artificial hand)

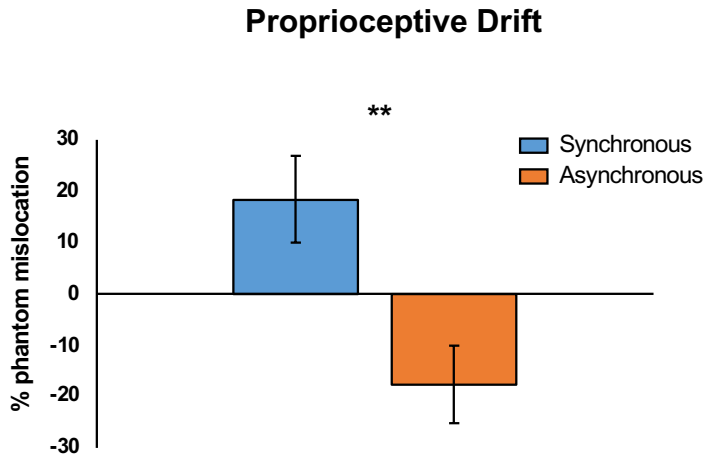
Patient 2
(Prosthetic hand)

(Nature Rev Neuroscience 2012, Science Translational Medicine 2013; Human Brain Mapping 2014; eLife 2014)

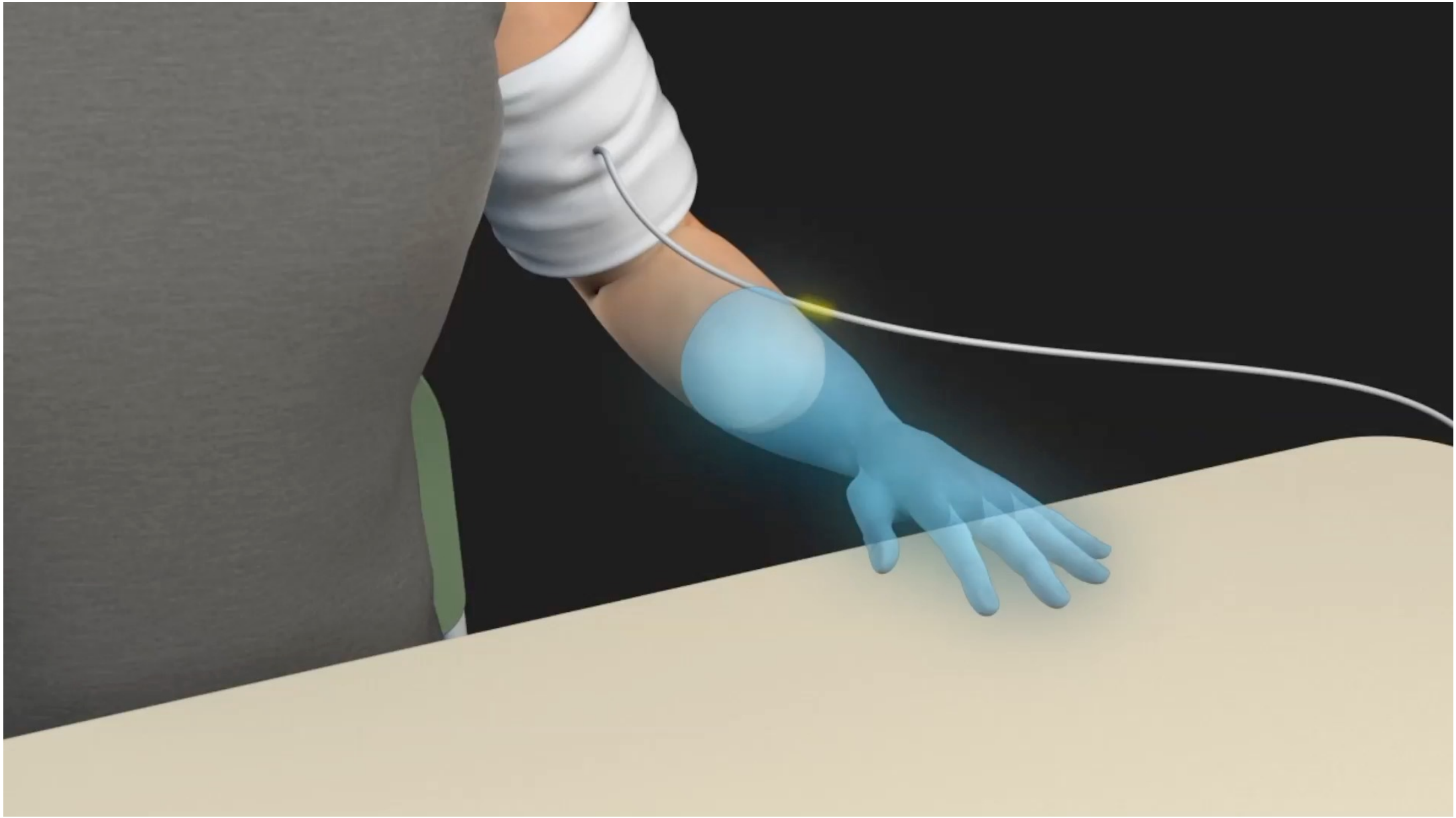




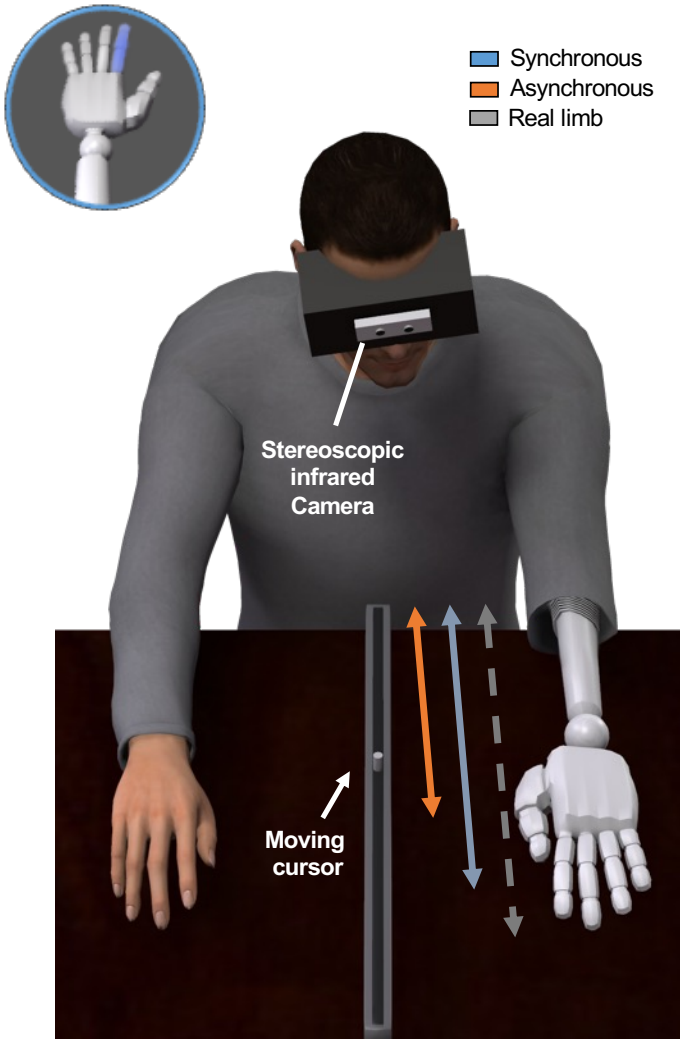




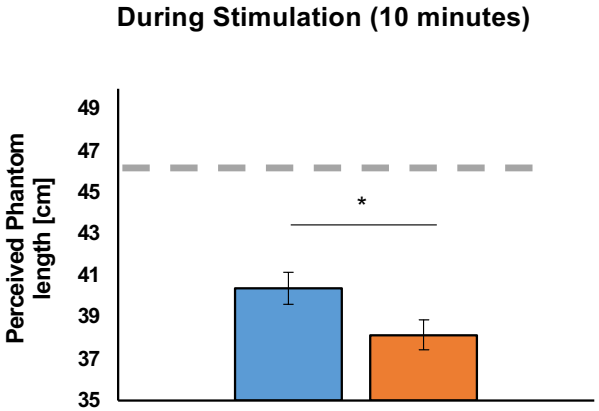
Raspopovic et al., Sci Trans Medicine 2014; Rognini et al. (submitted)



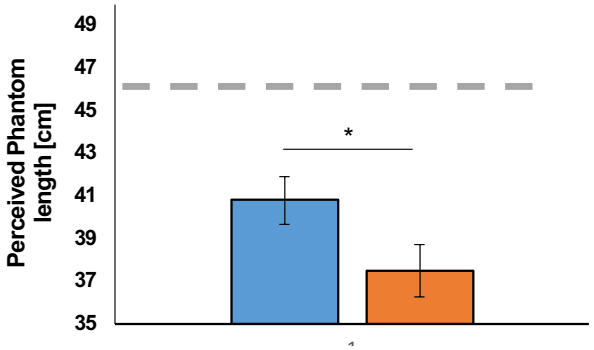
A


Synchronous
Asynchronous
Real limb
Stereoscopic infrared Camera
Moving cursor

B


During Stimulation (10 minutes)
Perceived Phantom length [cm]
49
47
45
43
41
39
37
35
*

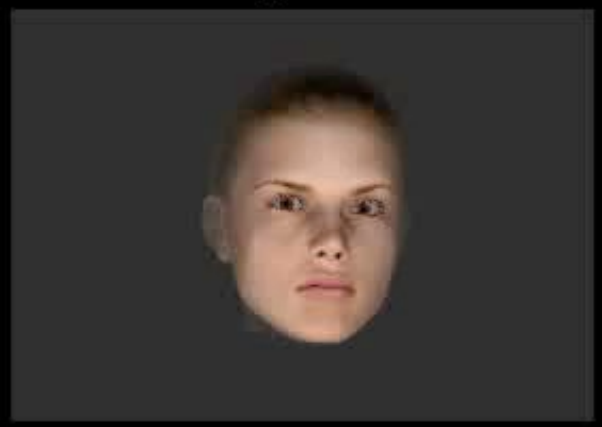
C

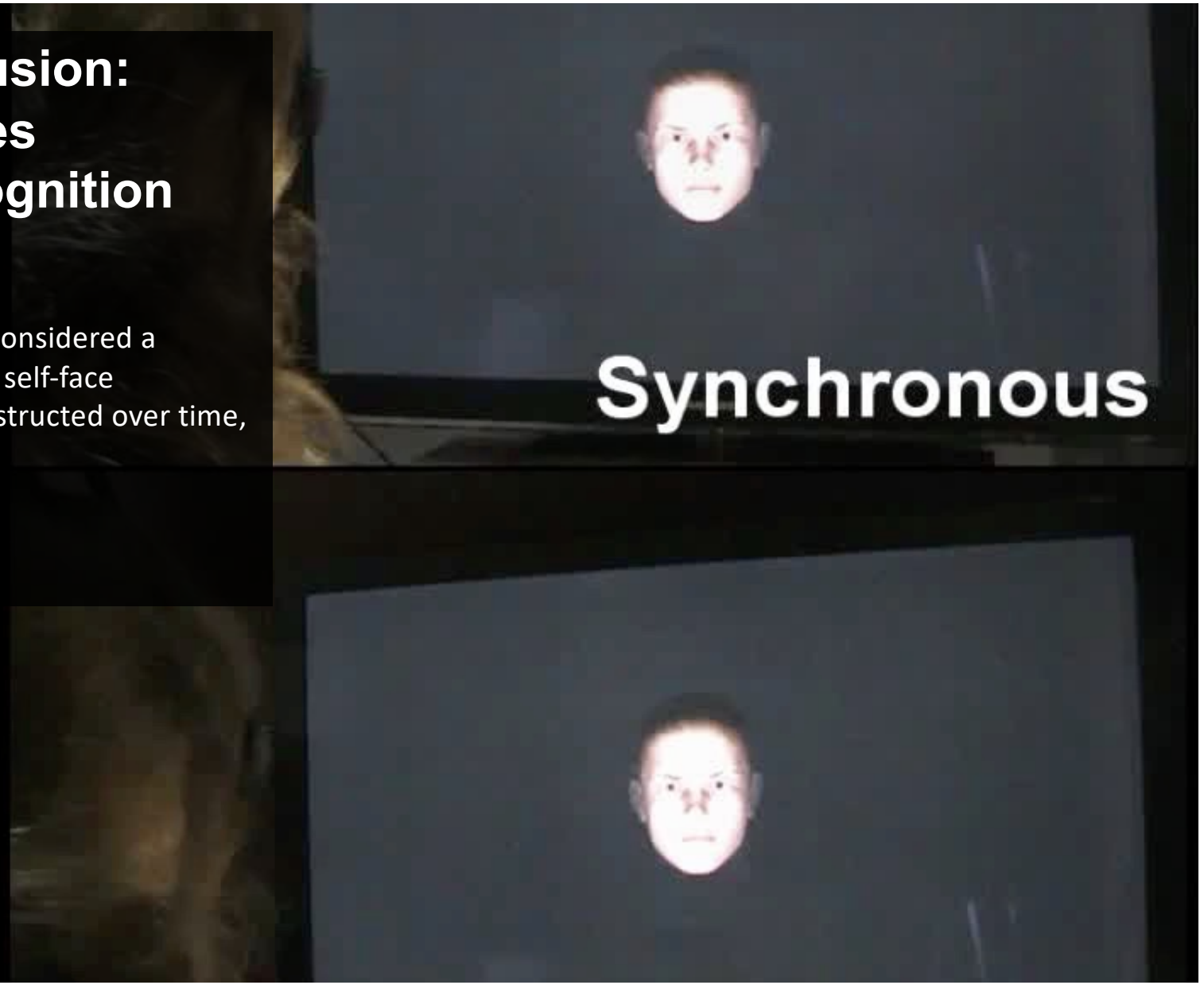

After 10 minutes without stimulation
Perceived Phantom length [cm]
49
47
45
43
41
39
37
35
*

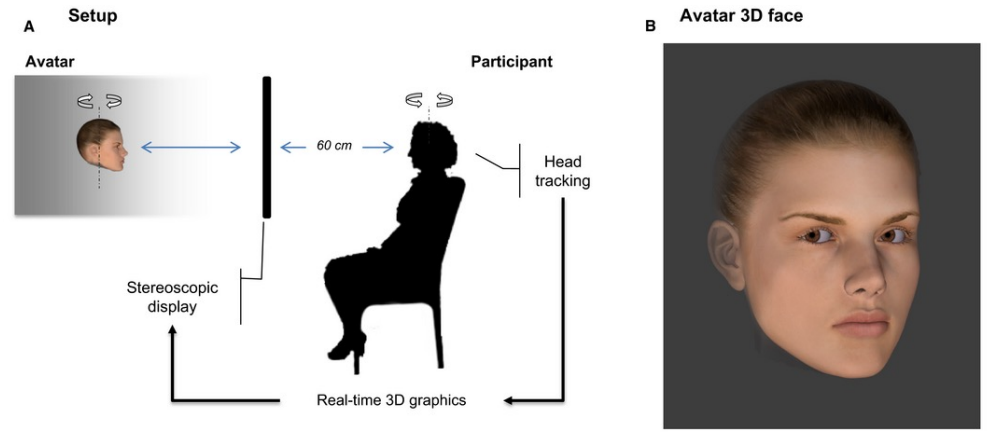
The Enfacement illusion: Virtual mirror causes erroneous self-recognition

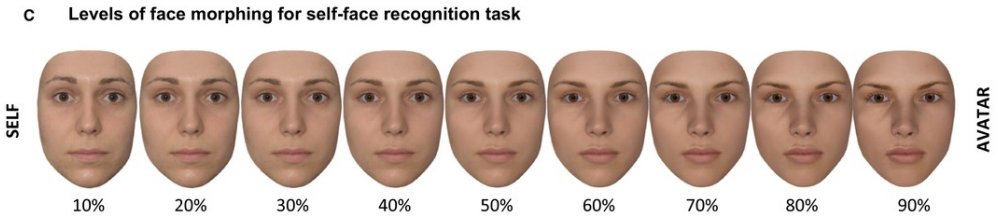
Recognizing a face as one's own is considered a hallmark of self-awareness. But the self-face representation is not fixed, but constructed over time, depending on experience.

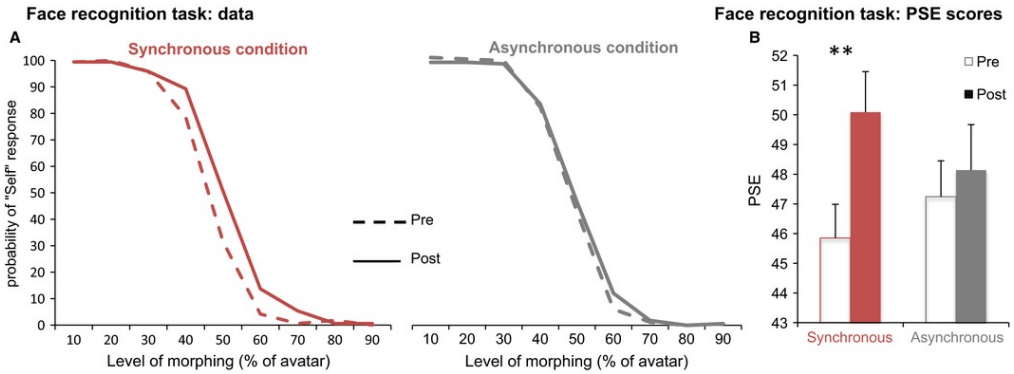
Serino, Sforza et al. J.Neuro, 2015.





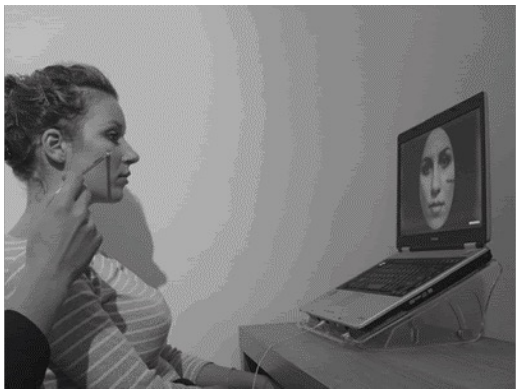






The virtual mirror

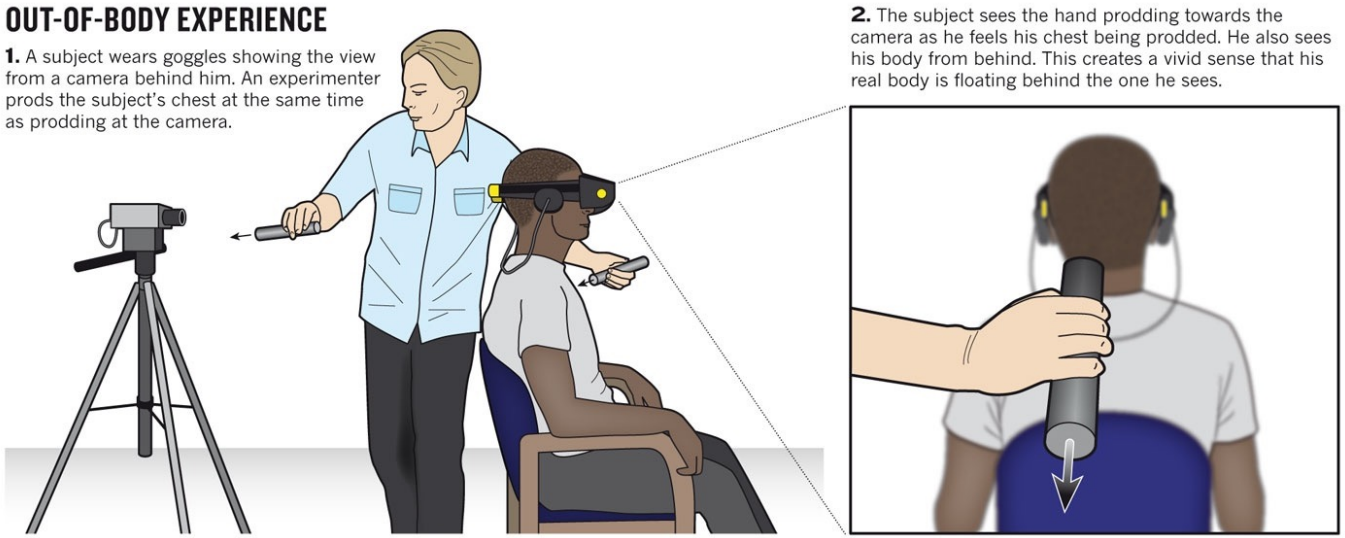
EPFL-LNCO



Sforza AL, Bufalari I, Haggard P, Aglioti SM. (2009). My face in yours: visuo-tactile facial stimulation influences sense of identity. Social Neuroscience, 7: 1-15.

The ‘I am here’ hypothesis

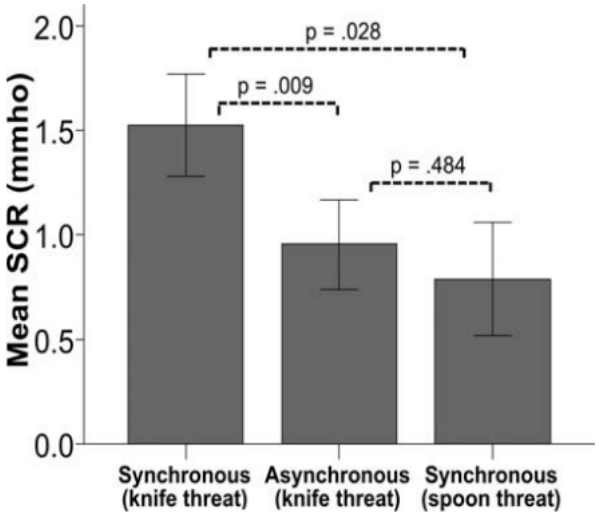
TRON (1982)



Ehrsson. Science 2007.

Petkova & Ehrsson. PLoS One, 2008.

The illusion is caused by the first-person visual perspective in combination with the correlated visual and tactile information from the body.



Out of Body Experience

Conflicting visual-somatosensory input in virtual reality disrupts the spatial unity between the self and the body: participants feel as if a virtual body seen in front of them is their own and mis-localize themselves to a position outside their bodily borders.

Lenggenhager et al. Science, 2007.

Science

Blanke Lab - Video Ergo Sum 2007

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

First-person experience of body transfert in VR

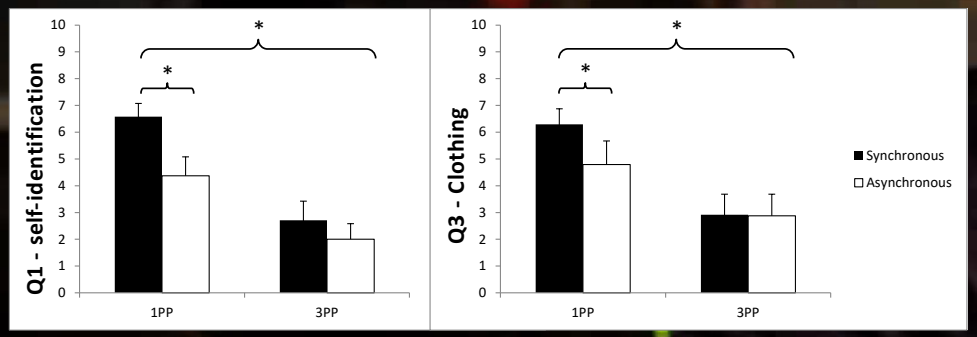
EXPERIMENTAL PROTOCOL for EEG RECORDING

ventLab / Nov. 2010

External multisensory congruency determines my bodily presence

First person view defines where my self is in the world, and the complementary multisensory experience builds up the illusion of embodiment.

Slater, Spanlang, Sanchez-Vives & Blanke
First person experience of body transfer in virtual reality, **PloS one, 2010.**



Body ownership illusion

- The **“illusion that the virtual body is their own —even though they know for sure that it is not.”**

Next part : Embodied Virtual Reality

Synthesis

- VR Immersion and (tele)Presence in VR
  - Cognitive mechanisms comparable to perceptual illusions
  - Cognitive sciences informs VR on the mental mechanisms behind VR Presence

- VR technology is about engineering illusions
  - Not a replication of reality
  - Benefit from *imperfections* of human perception

Acknowledgements

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If you are curious..

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