Neuroscience of self-consciousness

Olaf Blanke http://cnp.epfl.c

Laboratory of Cognitive Neuroscience
Center for Neuroprosthetics

Cognitive neuroscience of the self

The self seems distinct from the environment and other humans and may be described as an entity to which certain mental events and actions are ascribed. [David & Kircher, 2003]

Autobiographical Memory

Thought-Languag

Visual Mirror Recognition

Social, conceptual, other approaches

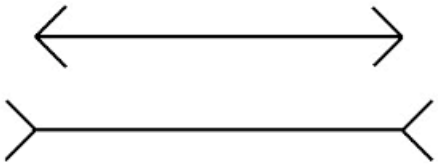
→ Bodily Self

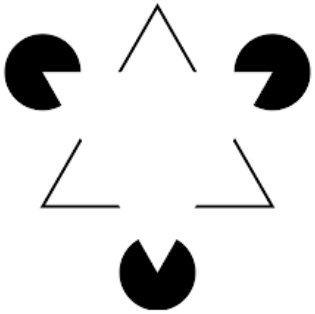
I will argue that self-consciousness is based on brain representations encoding multisensory body signals (Bodily self-consciousness)

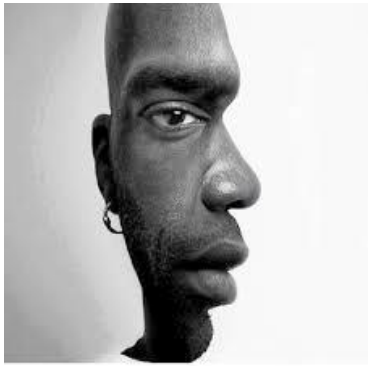
Bodily self-consciousness is a low-level account of self-consciousness (next to multisensory also motor-interoceptive brain mechanisms).

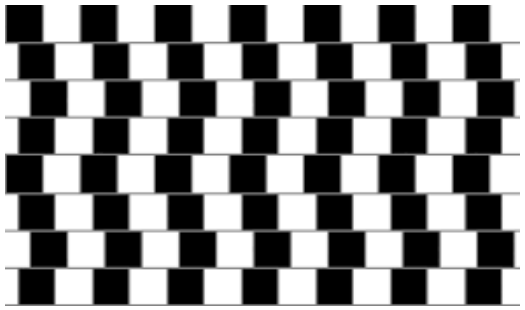
How to study not just the self, but self-consciousness ?

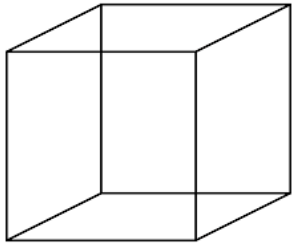
Visual perception/illusions



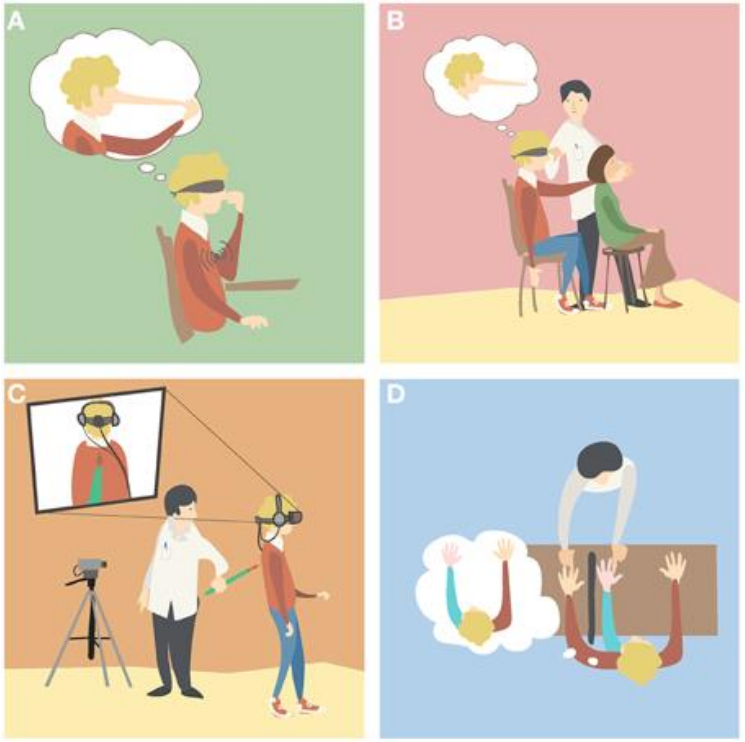








Multisensory body illusions



Illusory own body perceptions allow to study and manipulate self-consciousness

Rubber hand illusion

Full-Body illusion

Subjects are exposed to prolonged multisensory (visuo-tactile-proprioceptive) stimulations, exploiting visual dominance over other sensory cues

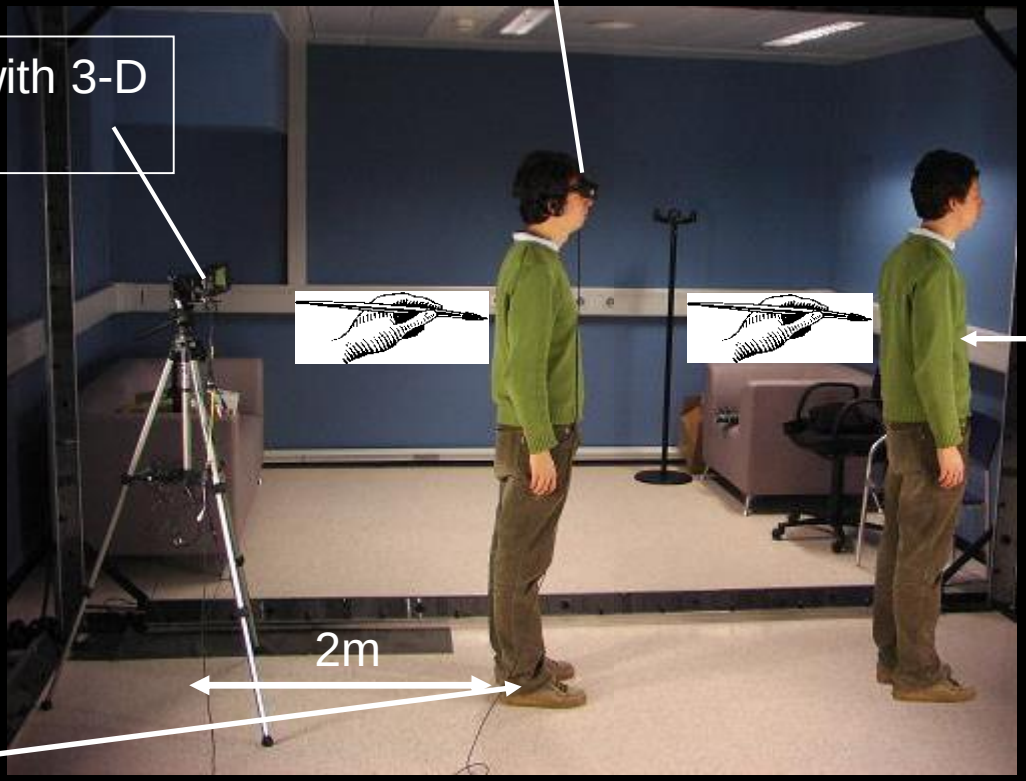
[see also video on youtube: « Virtual rubber hand illusion »; « Virtual Out-of-body experience »]

Full-Body Illusion

Altering bodily self-consciousness using virtual reality

Subject with Head Mounted Display

Video camera with 3-D converter



Virtual body

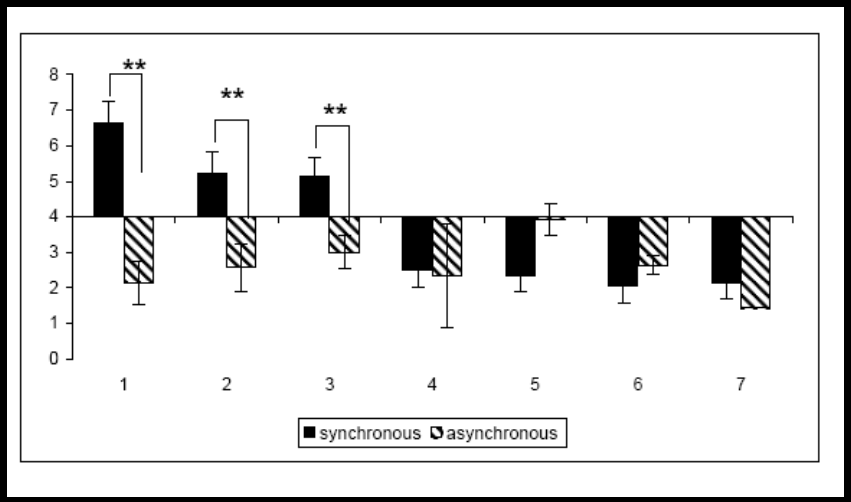
Actual body

[Lenggenhager et al., Video Ergo Sum, Science 2007]

Inducing changes in bodily self-consciousness

A virtual or filmed body feels like my body (self-identification) and "I" am localized at the virtual body's position (self-location)

Self-identification

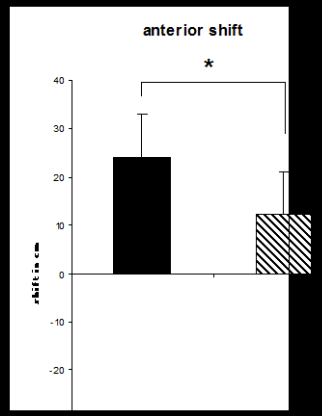


Questionnaire

Multisensory stimulation

1 minute

Self-location



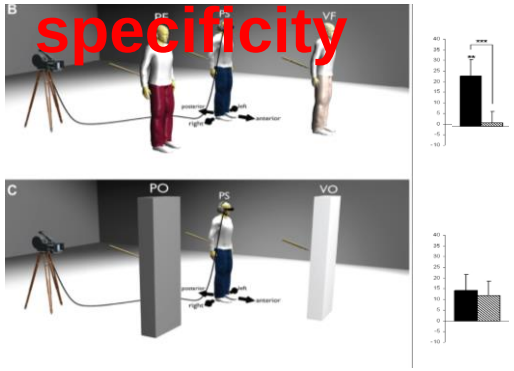
Position Recalibration

[Lenggenhager et al., Science 2007]

[youtube: « Virtual out-of-body experience »

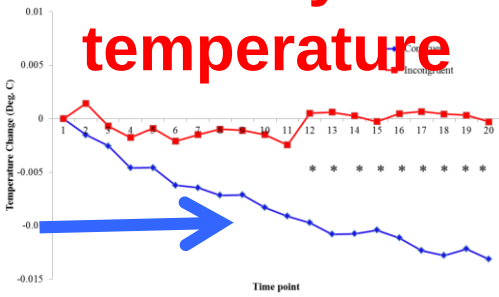
Illusory own body perceptions are associated with changes in tactile perception, body temperature regulation, and analgesia

Body-self-specificity



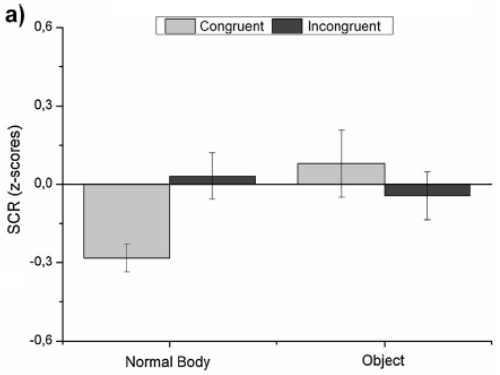
[Palluel et al., J Neurophysiol 2011; Aspell et al., PlosOne]

Decrease in body temperature



[Salomon et al., Frontiers Neuroscience 2013]

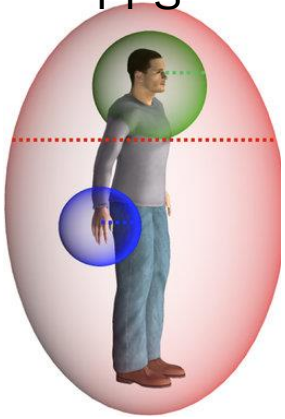
Analgesia



[Hänsel et al., Eur J Pain, 2011; Romano et al., Beh Brain Res, 2014, J Pain, 2015]

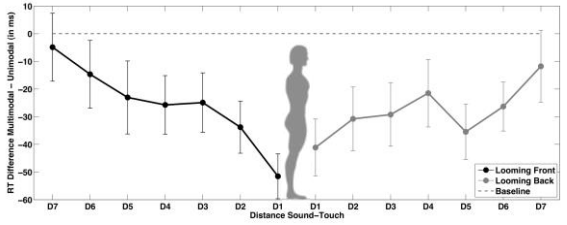
Self-location and peripersonal Space (PPS)

Hand, head, trunk-centered PPS



Illusion induction

PPS dimensions based on speeded RT measurements



Extension of PPS

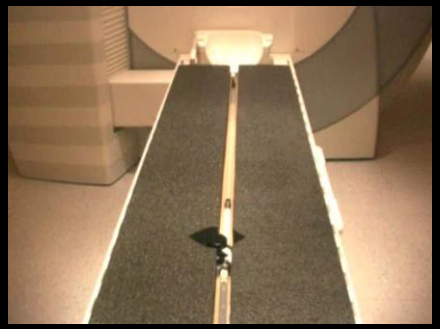
[Serino et al., Scientific Reports 2015; Noel et al., Cognition 2015]

Integrating virtual reality and robotics with fMRI

Subject position

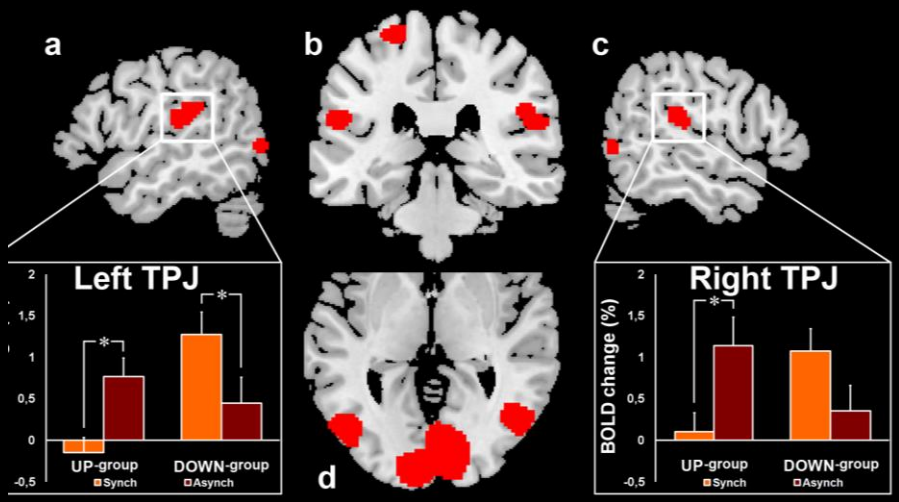
MRI-compatible robot

… in the scanner

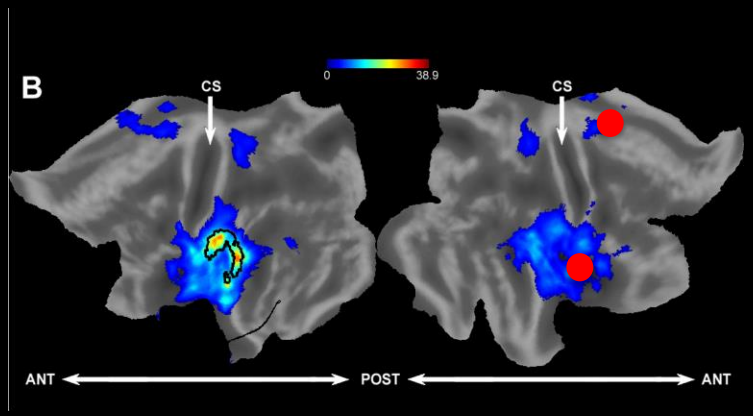


Avatar

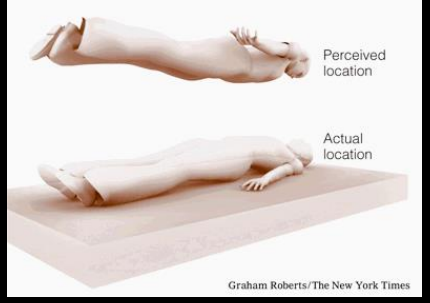
Activation of temporo-parietal junction (SMG, AG, pSTG,) reflects robotically-induced changes in bodily self-consciousness (self-identification and self-location)



[Ionta et al., Neuron 2011]

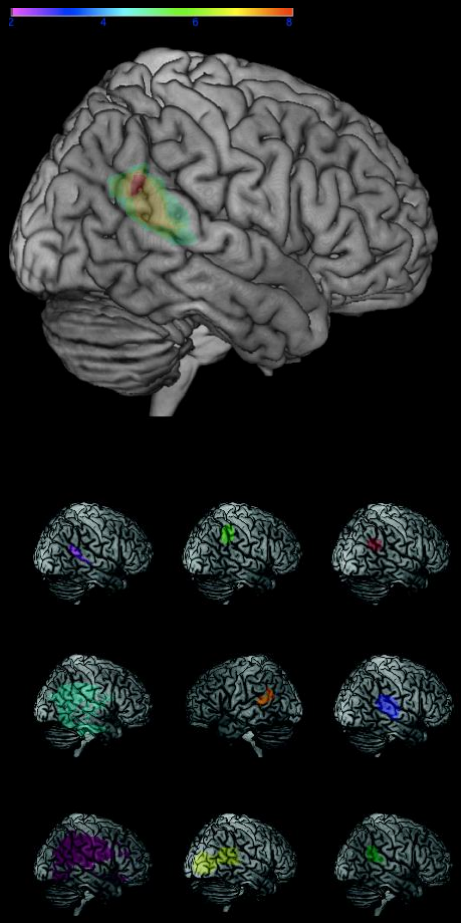


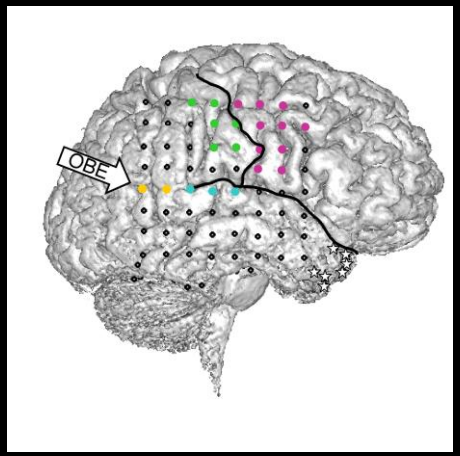
[Ionta et al., Soc Cogn Affect Neurosci 2014 2014]

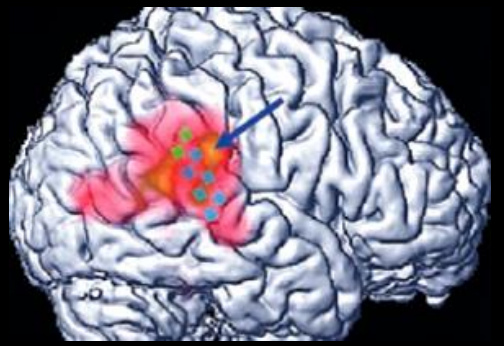


When bodily self-consciousness breaks down

Out-of-body experiences of neurological origin



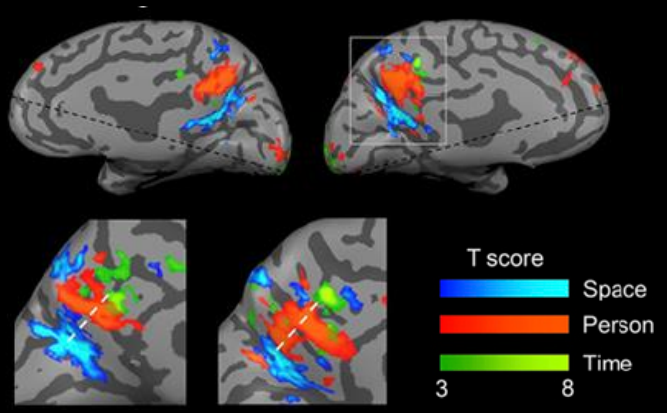




[Blanke et al., Nature 2002; Brain 2004; Ionta et al., Neuron 2011; De Ridder et al., NEJM 2007]

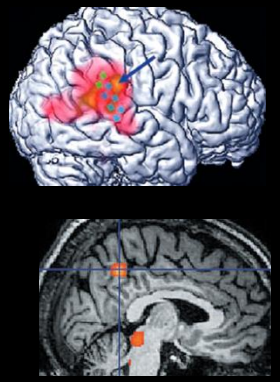
Beyond TPJ –
Precuneus, posterior (superior) parietal cortex, premotor cortex

Self-location/orientation



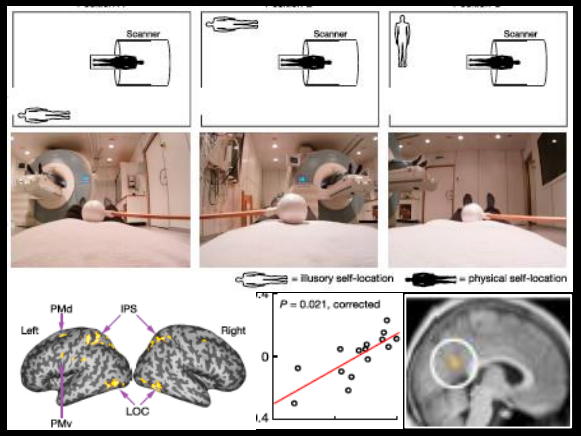
[Peer et al., PNAS 2015]

Out-of-body experiences



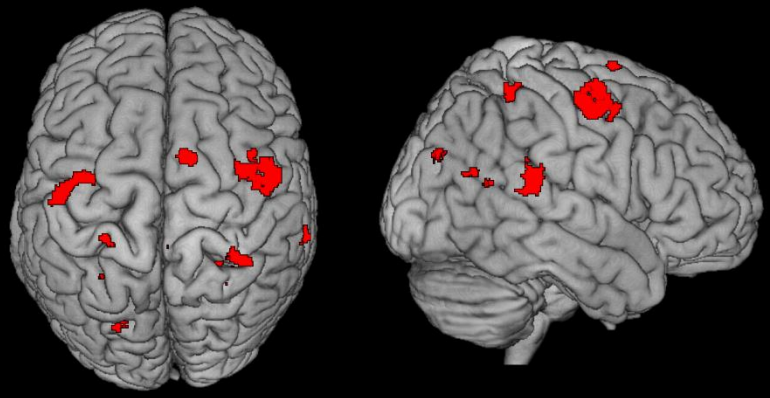
[De Ridder et al., NEJM 2007]

Self-location



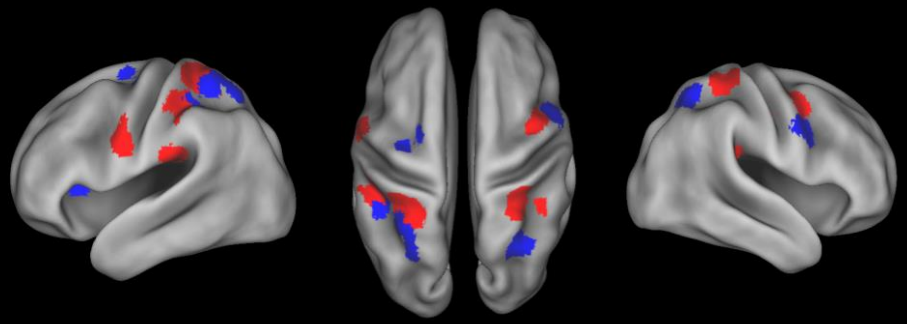
[Guterstam et al., Curr Biol 2015]

Self-location and 7t MRI



Blondiaux et al., Monday P2304

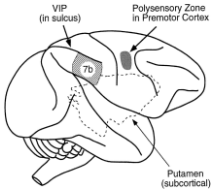
Body ownership & self-identification



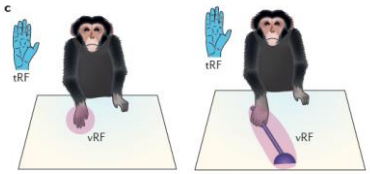
Givraz et al., Tuesday P2255

Neurophysiological basis of bodily self-consciousness: Trimodal neurons in primate posterior parietal cortex

Monkey data

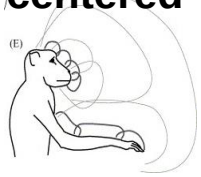


Arm-centered



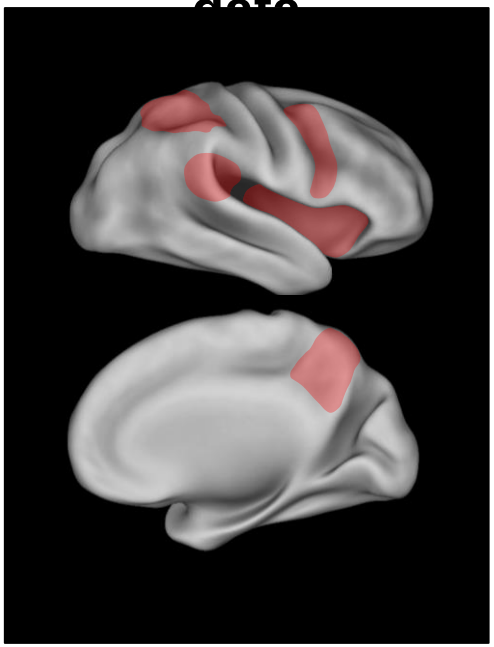
before **after**

Trunk-centered



Multisensory neurons (visual-tactile, proprioceptive) in posterior parietal and premotor cortex

Human data



Visual receptive fields (peripersonal space)

before

Enlarged visual receptive fields (peripersonal space)

after

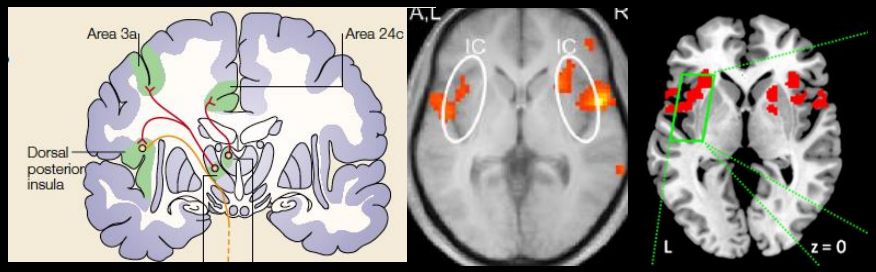
4 neural constraints of bodily self-consciousness, especially trunk-centered global processing

[Iriki et al., 1996, 2001; Graziano et al., Science 2000; Maravita and Iriki, 2004]

[Serino et al., Sci Reports 2015; Blanke Nature Rev Neurosci 2012; Blanke et al., Neuron 2015]

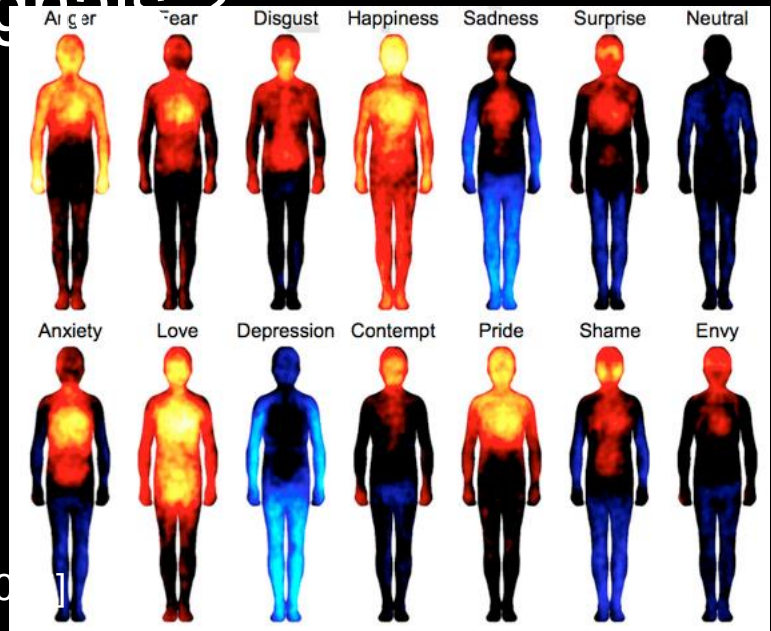
Previous models about self-consciousness have highlighted the importance of interoceptive/visceral signals and the insula (i.e. **A. Damasio, B. Craig, …)**

Do interoceptive signals impact bodily self-consciousness ? Are they integrated with exteroceptive multisensory signals ?

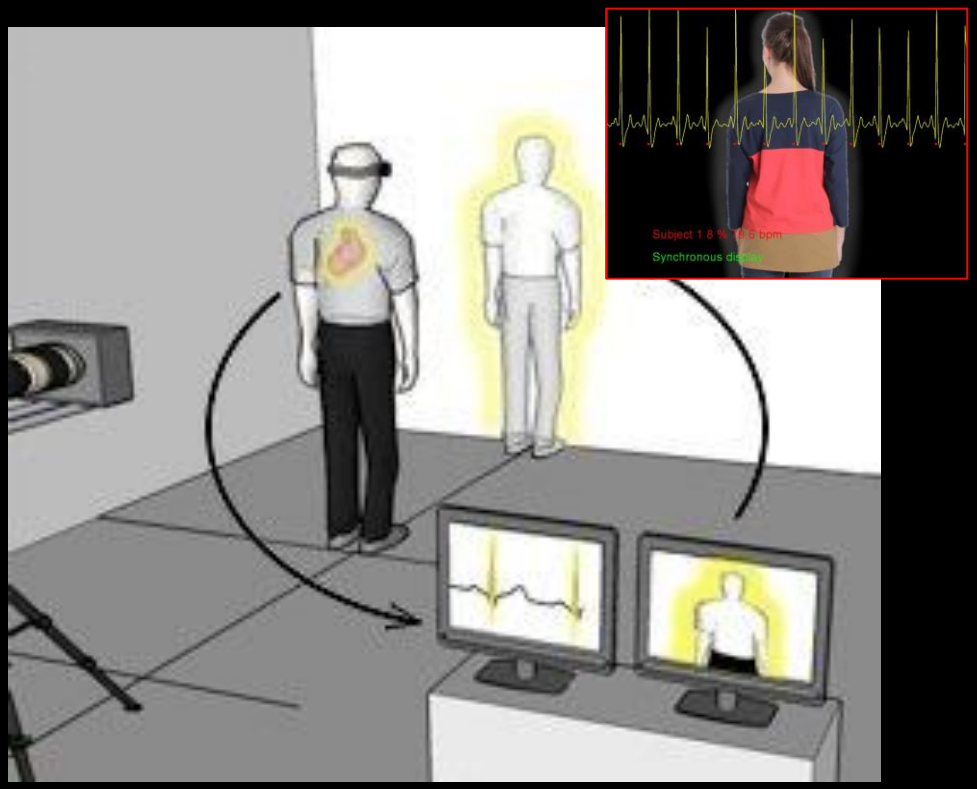


[Critchley, 2013; Wiebking et al., 2013; Gray et al., 2009; Craig, 2002, 2009; von Leupoldt et al., 2009; Park & Tallon-Baudry, 20]

[Nummenmaa et al., PNAS 2013]



Virtual reality and cardio-visual stimulation (online detection of the heartbeat to illuminate an avatar's body) leads to controlled changes in bodily self-consciousness

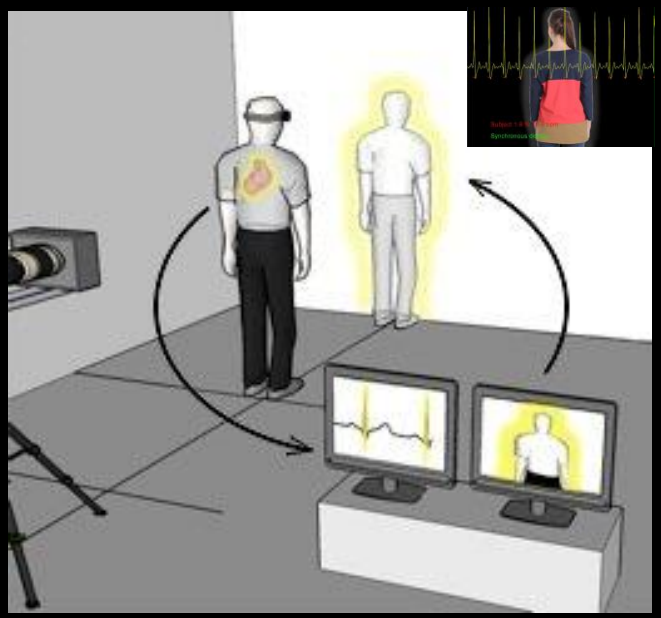


Video as shown on head-mounted video

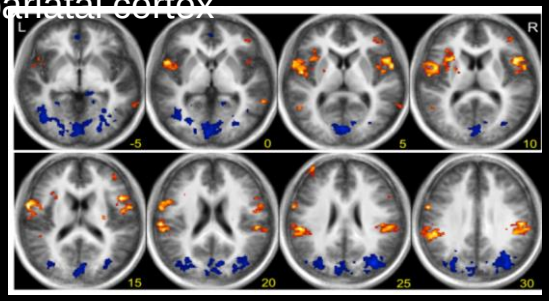
Cardio-visual illumination of the avatar was used to create a flashing silhouette around the avatar that was either sync or asnyc with respect to the participant's heartbeat

[Aspell et al., Psychological Science 201

Cardio-visual stimulation leads to changes in self-location and self-identification

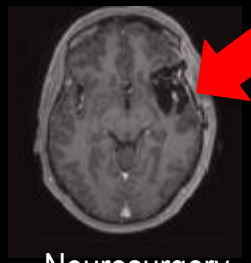


Cardio-visual signals that mediate self-consciousness are processed by the insula and temporo-parietal cortex

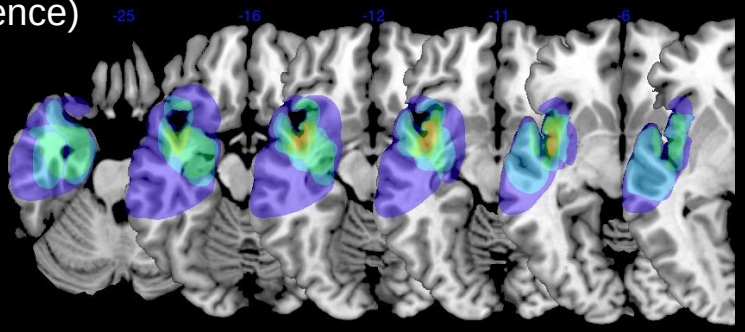


fMRI (healthy subjects)

Insula damage impairs integration of cardio-visual signals and alters bodily self-consciousness (doppelgänger experience)

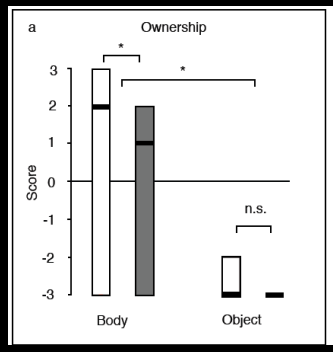


Neurosurgery



Lesion overlap analysis (n=11)

Self-identifcation



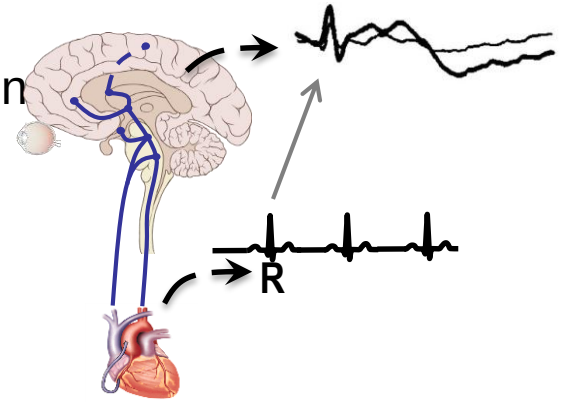
Questionnaire

Self-location

Position Recalibration

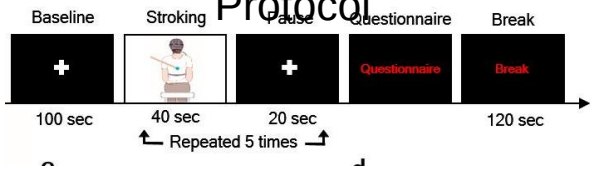
Aspell et al. Psychological Science 2013; Suzuki et al. Neuropsychologia 2014
Ronchi et al. Neuropsychologia 2015; Heydrich and Blanke Brain 2014
Blefari et al., submitted; Park et al. Nature Neurosci 2014;

The heartbeat evoked potential (online measuremen of insula activation) and reflects changes in bodily self-consciousness and visual consciousness (not shown)



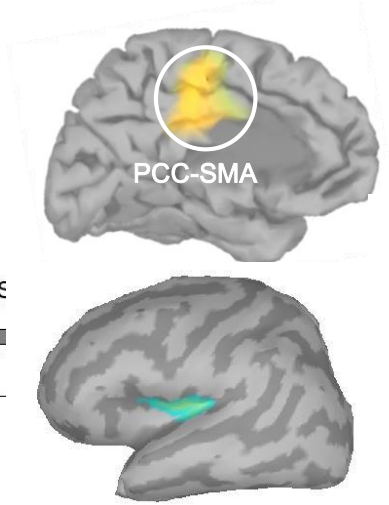
Illusion

Experimental Protocol

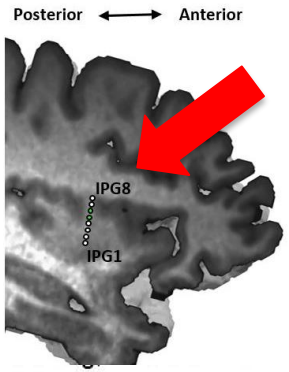


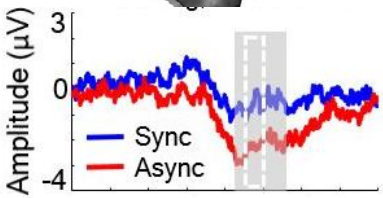
Schandry et al. Biol. Psychol. 1996

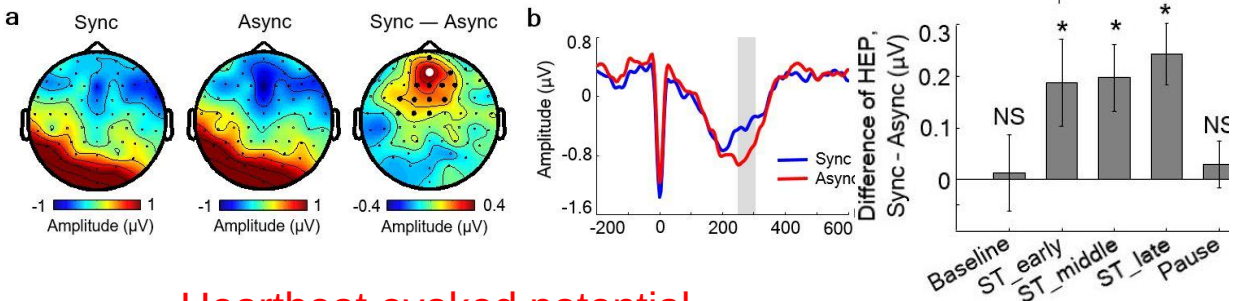
Insula and PCC



ECoG (Insula)



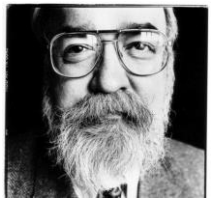




Heartbeat evoked potential

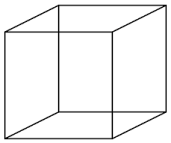
Park et al., Nature Neurosci 2014; J Neurosci 2016 → Poster 4327 Thursday

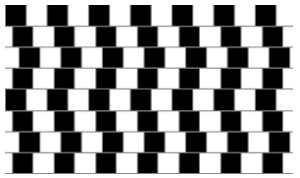
Neuroscience of self-consciousness



Autobiographical Memory, Thought-Language, Visual Mirror Recognition, Social, conceptual, language, …

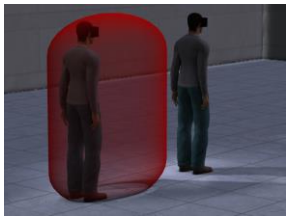
Bodily self-consciousness





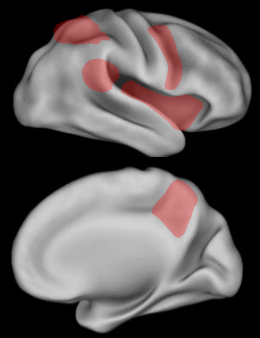
Self-consciousness is based on multisensory integration of bodily signals.

Such bodily self-consciousness is a low-level account of self-consciousness (multisensory-motor-interoceptive brain mechanisms).



Global/full body representations are the most crucial system for self-consciousness in particular trunk-centered processing.

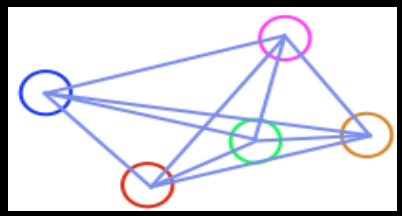
[Blanke & Metzinger, Trends Cogn Sci 2009; Blanke et al., Neuron 2015

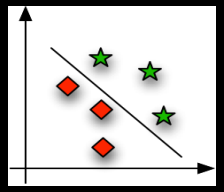


Bodily self-consciousness

Functional networks

Network modeling





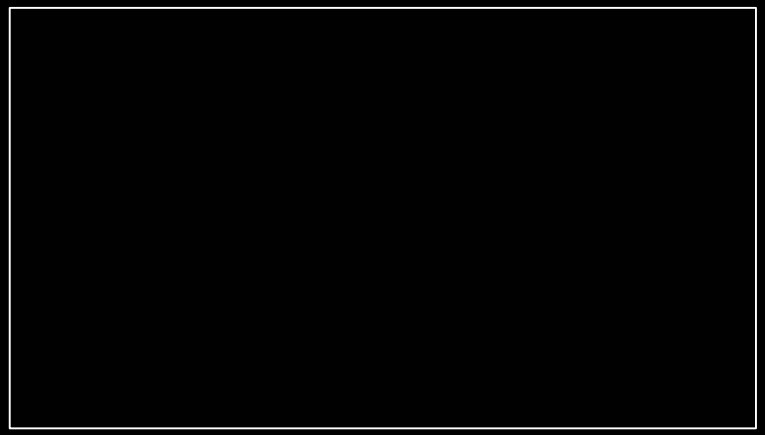
Machine learning

Joint work with group of Dimitri Van de Ville (i.e. Karahanuglu, Nature Communications 2015; Leonardi et al., HBM

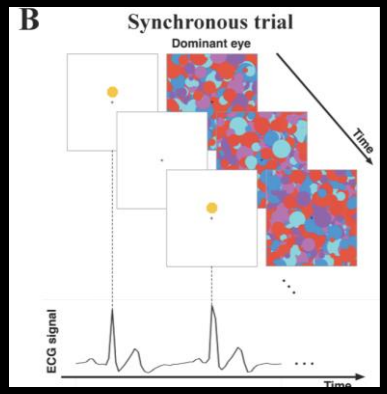
Multisensory bodily processing is not just relevant for self-consciousness, but also impacts visual consciousness

Heartbeat timing modulates binocular rivalry

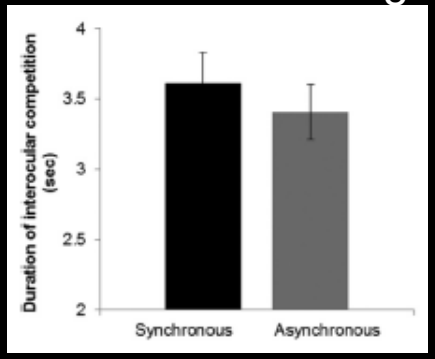
new Continuous flash supression
(dot flash is linked to heartbeat)



How flashes were linked to heartbeat

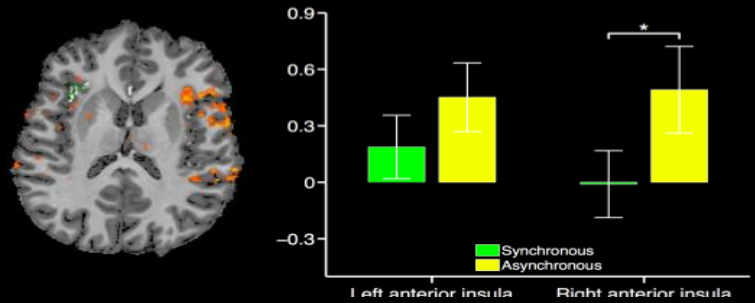


Visual consciousness depends on cardio-visual timing



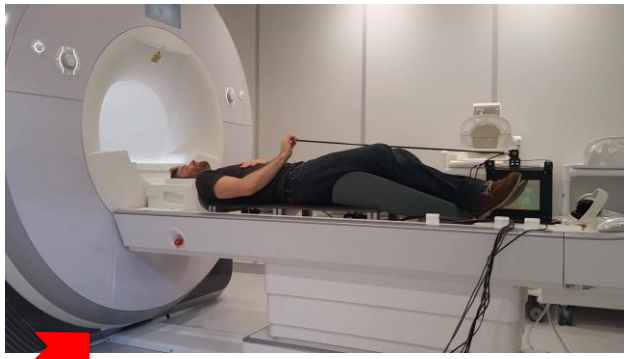
Time/flashes needed to break CFS

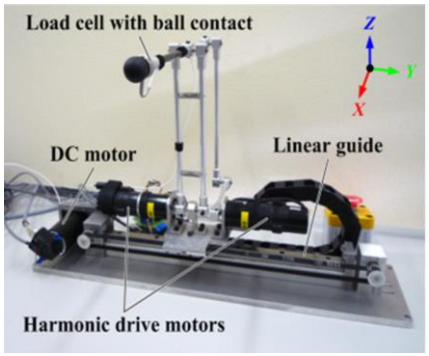
Insula activity reflects supression

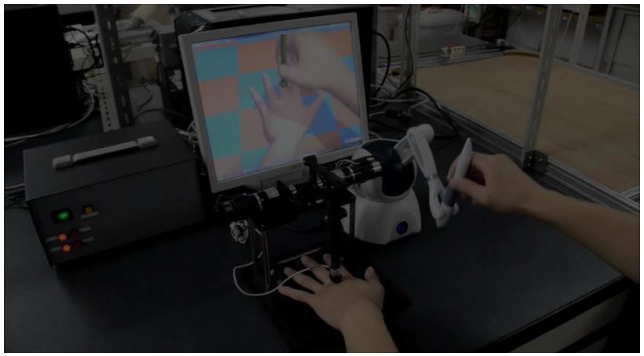


Salomon et al. Neuropsychologia 2015, J Neurosci 2016

Virtual reality & augmented reality and robotics & haptics as tools for human neuroscience (including motor signals)







Clinical applications:
Psychiatry/Schizophrenia – Positive symptoms/Hallucinations/Delusions
Chronic pain

[Rognini & Blanke, Trends Cogn Sci 2016; Hara et al., J Neurosci Methods 2011, 2014; Blanke et al., Current Biolog

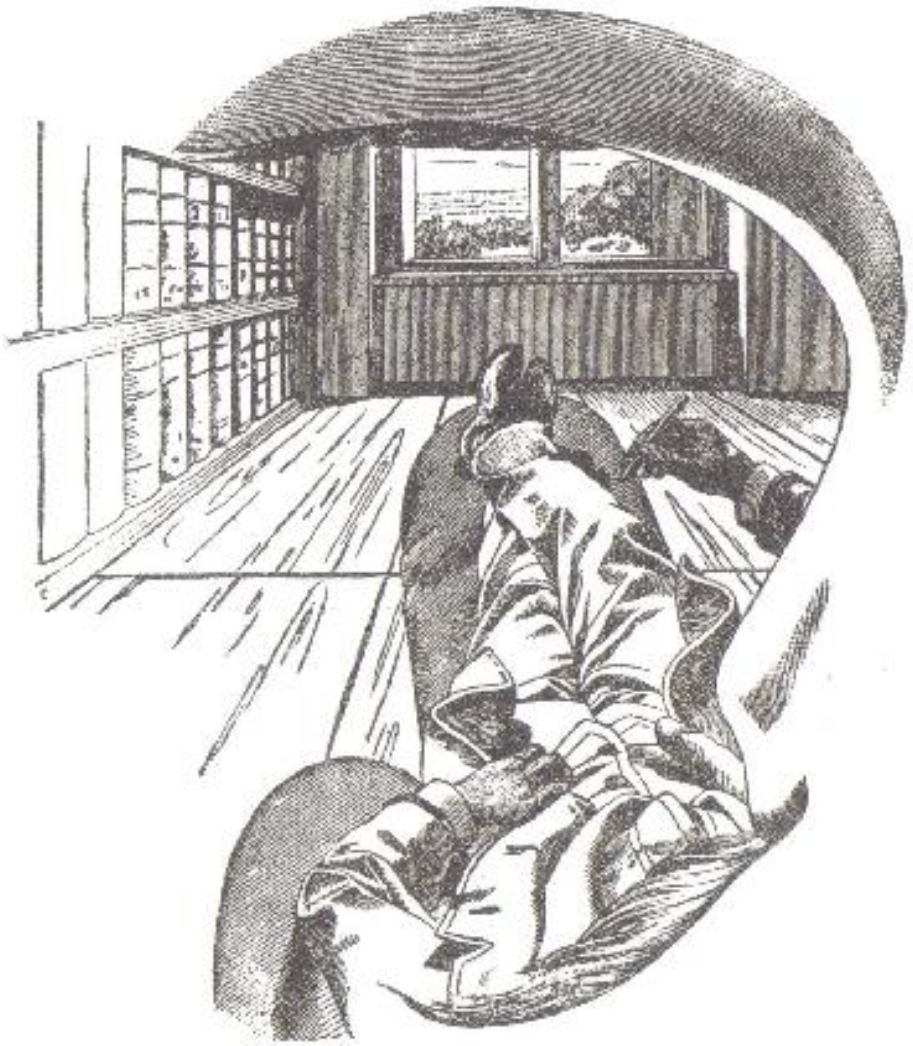
Thank you !

Swiss National Science Foundation
Bertarelli Foundation
European Science Foundation
Spoelberch foundation
IRP foundation

2 open imaging positions (postdoc)

olaf.blanke@epfl.ch

Laboratory of Cognitive Neuroscience
Center for Neuroprosthetics



Phenomenology, bodily self-consciousness and the 1st person perspective (in OBEs)

OBI and experimentally induced changes in bodily self-consciousness

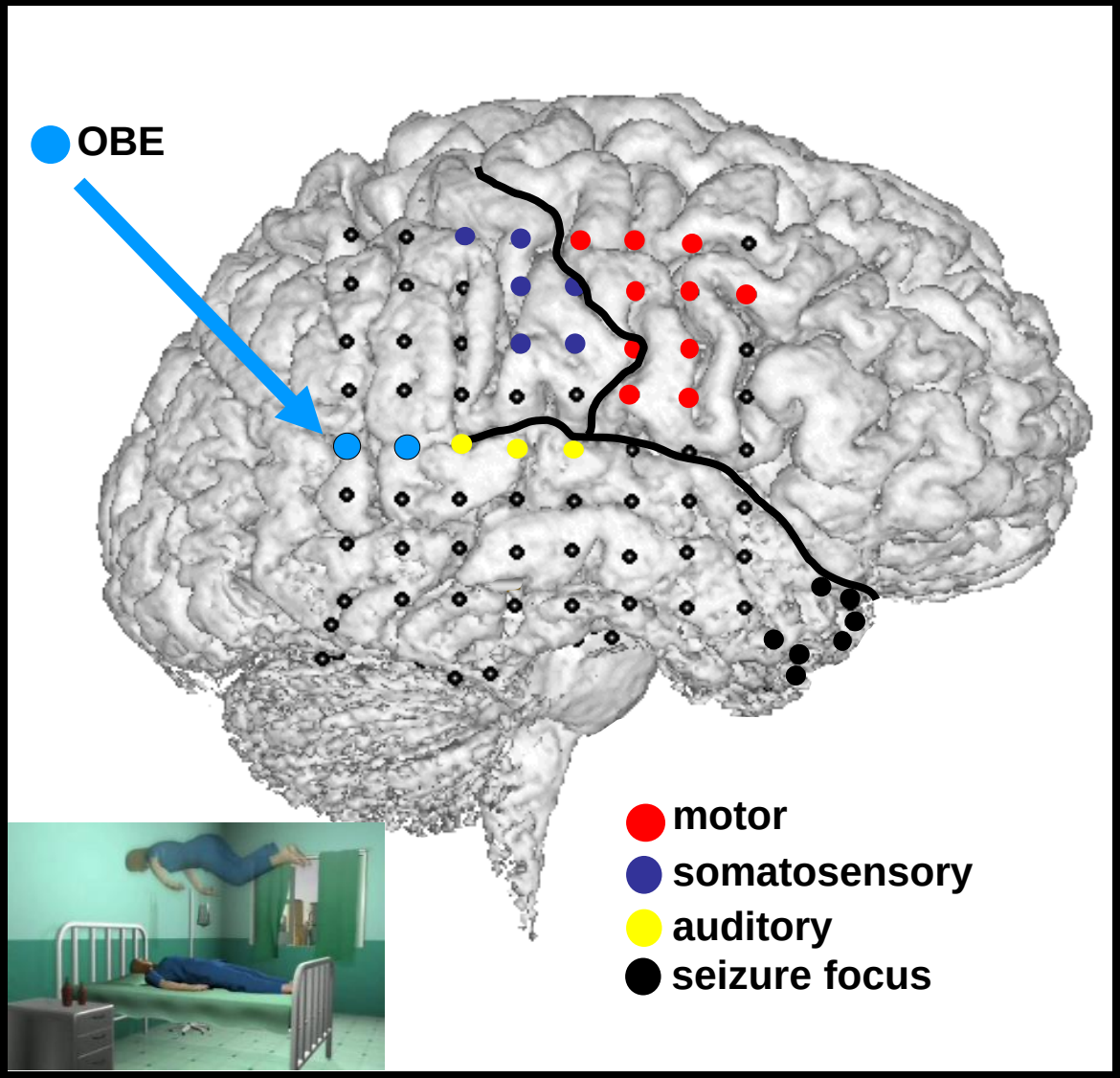
The peripersonal space is the multisensory volume/space of the self

Bodily self-consciousness (self-identification, self-location, 1st person perspective is mediated by network of TPJ, insula, precuneus, EBA, IPS, PMC)

Interoceptive signals and integrated with exteroceptive

Cortical stimulation induces out-of-body experience

with abnormal self-location, perspective, self-identification



Falling/vestibular (2.5-3.0 mA)

OBE (3.5 mA)

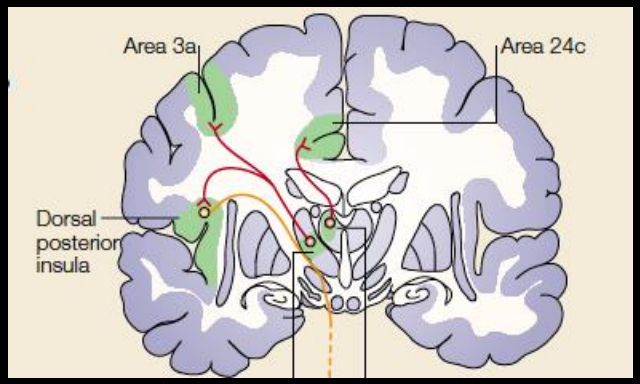
Visual body part illusions (3.5-5 mA)

Kinesthetic illusions (3.5-5 mA)

[Blanke et al., Nature 2002]

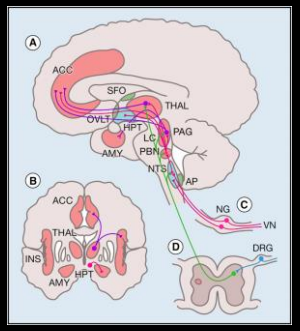
Insula (and anterior cingulate cortex) process and control cardiac and other interoceptive signals

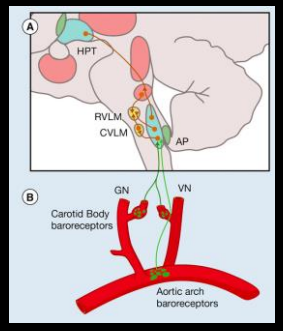
Visceral perception, insula, and self-awareness



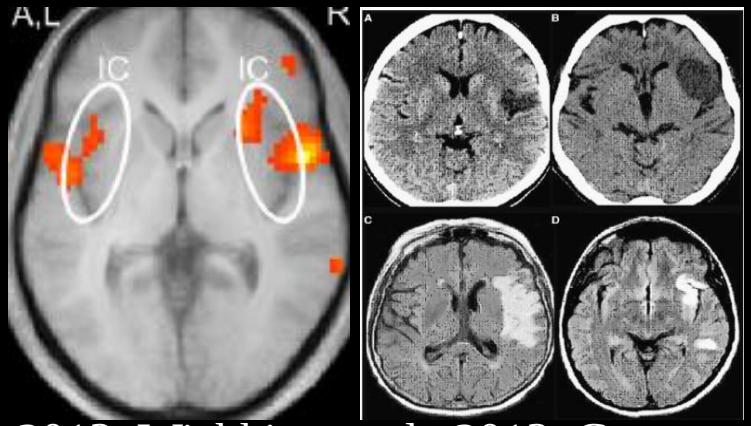
[Craig, Nat Neurosci Rev 2002, 2009]

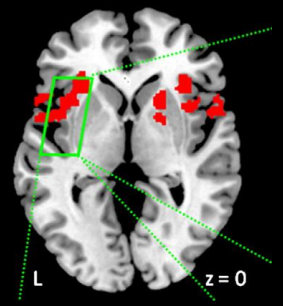
Cardiac frequency, baroreflex, heartbeat awareness …





Breathing Dyspnea

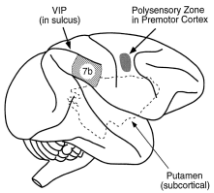


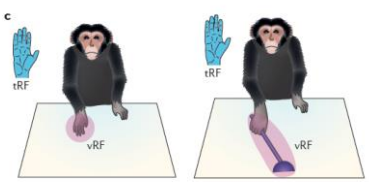


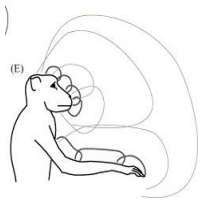
[Critchley, Neuron 2013; Wiebking et al., 2013; Gray et al., 2009; von Leupoldt et al., 2009]

Neurophysiological basis of bodily self-consciousness: Trimodal neurons in primate posterior parietal cortex

Monkey data

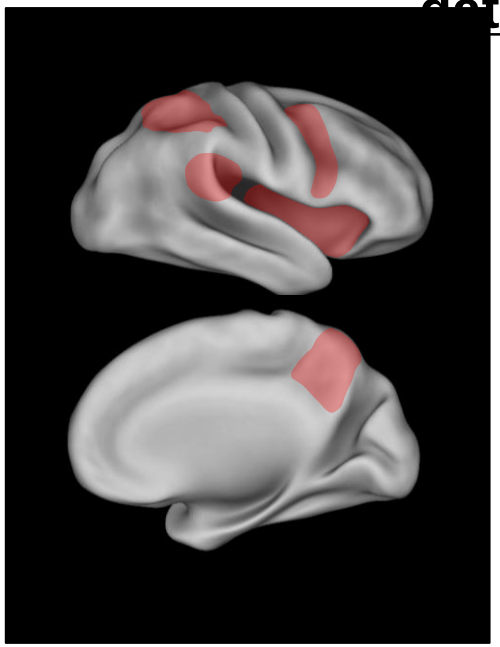






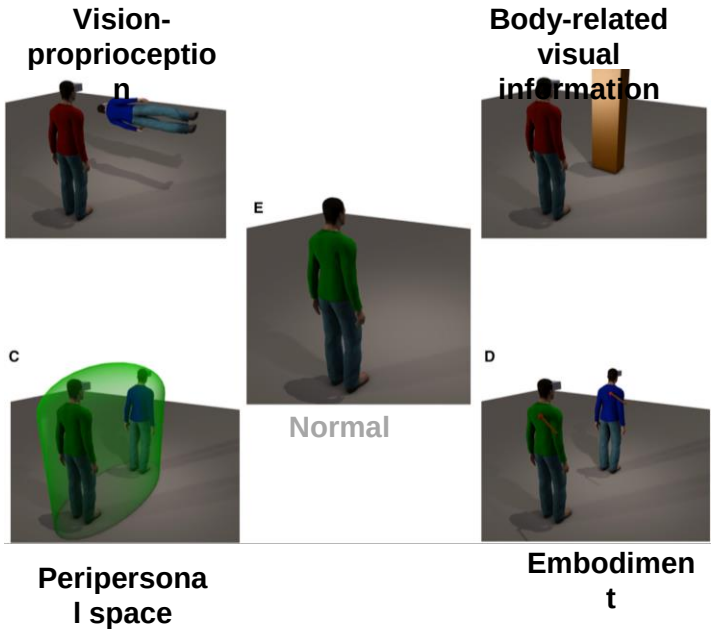
Multisensory neurons (visual-tactile, proprioceptive) in posterior parietal and premotor cortex

Human data



[Iriki et al., 1996, 2001;
Graziano et al., Science 2000;
Maravita and Iriki, 2004]

4 neural constraints of (bodily) self-consciousness



[Blanke Nature Rev Neurosci 2012;
Blanke et al., Neuron 2015]