

Lectures on

Advanced Machine Learning

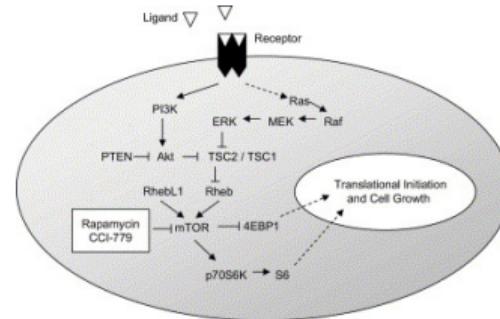
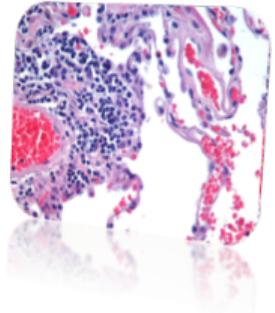
Joachim M. Buhmann

Information Science & Engineering Group
Institute for Machine Learning
D-INFK, ETH Zurich

September 19, 2019

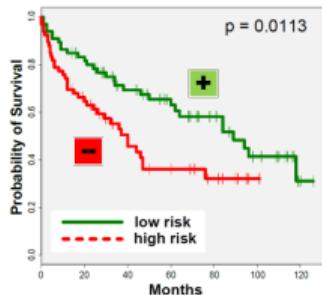
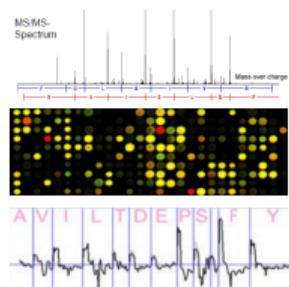
Information Society – the IT Value Chain

Convert data into knowledge to generate value!



Activation of the mTOR Signaling Pathway in Renal Clear Cell Carcinoma. Robb et al., J Urology 177:346 (2007)

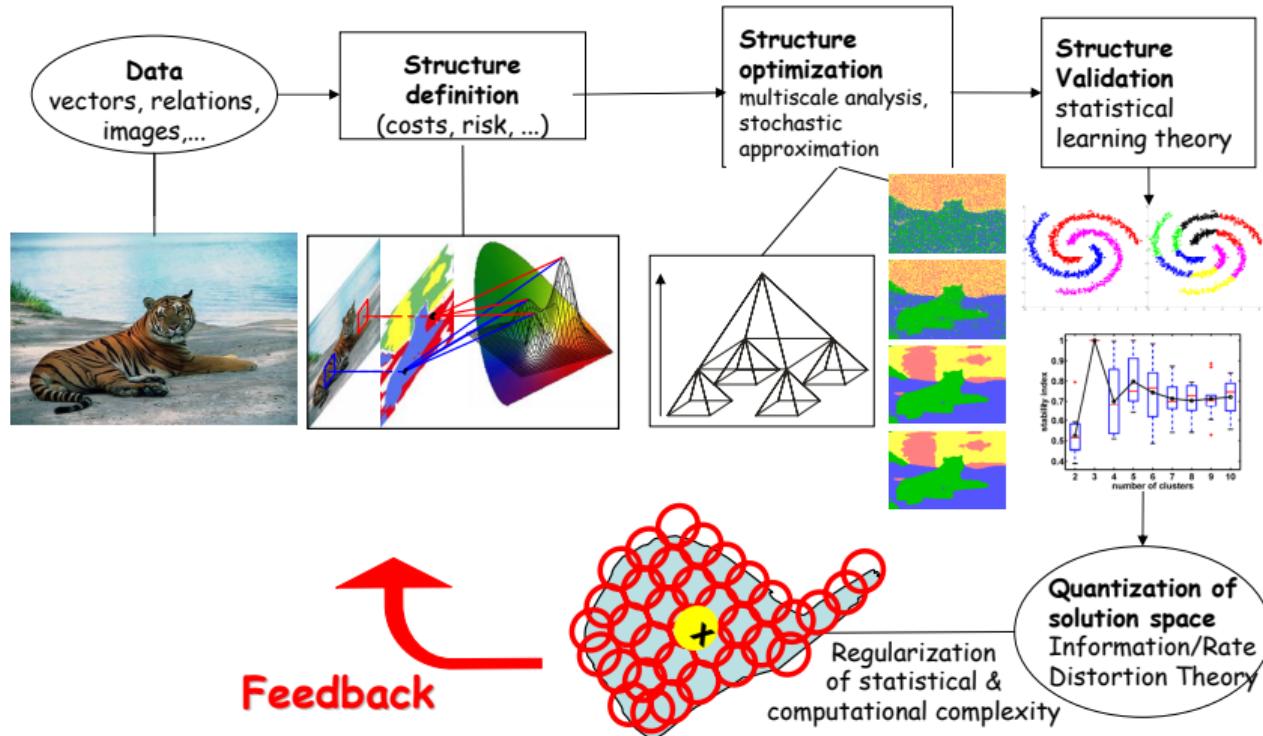
my Data → my Information → my Knowledge



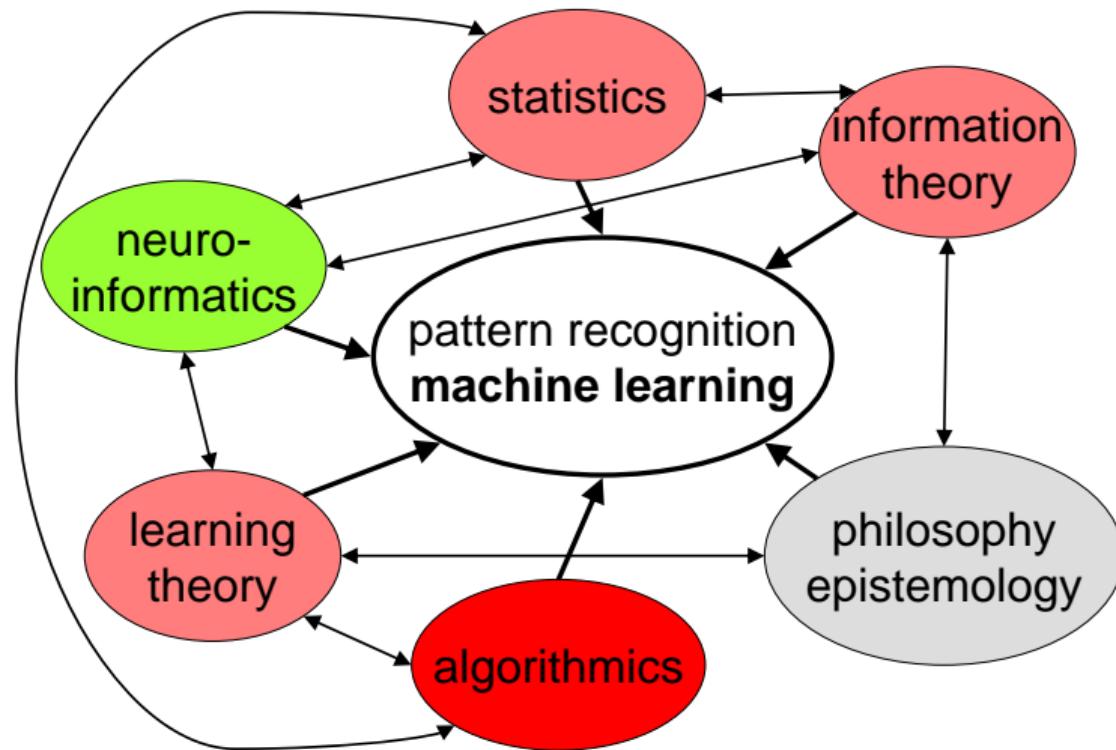
my Value

Machine Learning – What is the Challenge?

Find optimal structure in data and validate it!



How Does “Machine Learning” Relate to Neighboring Scientific Areas



Successes of Machine Learning: Stanley!

Grand Challenge 2005

Welcome to the 2005 DARPA Grand Challenge!



Thank you to the teams, their sponsors, the media, and the spectators for being part of this historic event. The DARPA Grand Challenge is about fresh thinking and new approaches to the tough technical problem of developing a truly autonomous ground vehicle. The competing teams have worked many hours to develop their vehicles, and this event demonstrates their vision, creativity, inspiration, and hard work. I am proud of their effort—someday it will save the lives of U.S. men and women in uniform on the battlefield.

Dr. Anthony J. Tether, DARPA Director

DARPA Grand Challenge

The DARPA Grand Challenge will award a \$2 million cash prize for a technical feat that has never been achieved—an autonomous ground vehicle that successfully travels approximately 150 miles in under 10 hours, across rugged desert roads, using only onboard sensors and navigation equipment to find and follow the route and avoid obstacles. The team whose vehicle finishes the route the fastest under the 10-hour limit wins the \$2 million prize. The route is kept secret until 2 hours prior to start.

DARPA is using the Grand Challenge to accelerate autonomous ground vehicle technology that can be used to save the lives of our men and women in uniform who drive vehicles in dangerous missions today. The route distance and time limit are representative of the capabilities needed for military missions.

Grand Challenge 2005 has been underway since August 2004. DARPA received 105 applications to compete, and the 43 teams at the National Qualification Event (NQE) passed a series of qualification tests and are the top teams. At the NQE, those 43 teams will compete for one of the 20 finalist positions. The finalists will be invited to attempt the Grand Challenge route and have a chance at the \$2 million prize on October 8, 2005.

DARPA

The Defense Advanced Research Projects Agency (DARPA) is the central research and development organization for the Department of Defense (DoD). The Agency manages and directs basic and applied research and development projects for DoD, and pursues research and technology where success may provide dramatic advances for traditional military roles and missions.

DARPA's accomplishments include the Saturn V rocket that enabled the Moon landings, the Arpanet (the first Internet), the Stealth Fighter, and the Predator and Global Hawk unmanned aerial vehicles.



National Qualification Event California Speedway, Fontana

Wednesday, September 28

9:00am Opening ceremony
10:00am Vehicle inspections begin
1:30pm–8:00pm Track operations

Thursday, September 29–Saturday, October 1

7:00am–2:00pm Track operations
12:00pm–1:30pm Lunch
1:30pm–8:00pm Track operations

Sunday, October 2

7:00am–12:00pm Track operations
12:00pm–1:30pm Lunch
1:30pm–4:00pm Track operations

Monday, October 3–Tuesday, October 4

7:00am–2:00pm Track operations
12:00pm–1:30pm Lunch
1:30pm–8:00pm Track operations

Wednesday, October 5

7:00am–8:30am Track operations
8:30am Closing ceremony
Announcement of the Grand Challenge finalists will be made at the closing ceremony after all runs are finished.

Thursday, October 6

Travel day to Grand Challenge start area in Primm, Nevada
12:00pm–7:00pm Teams arrive

Grand Challenge Primm, Nevada

Friday, October 7

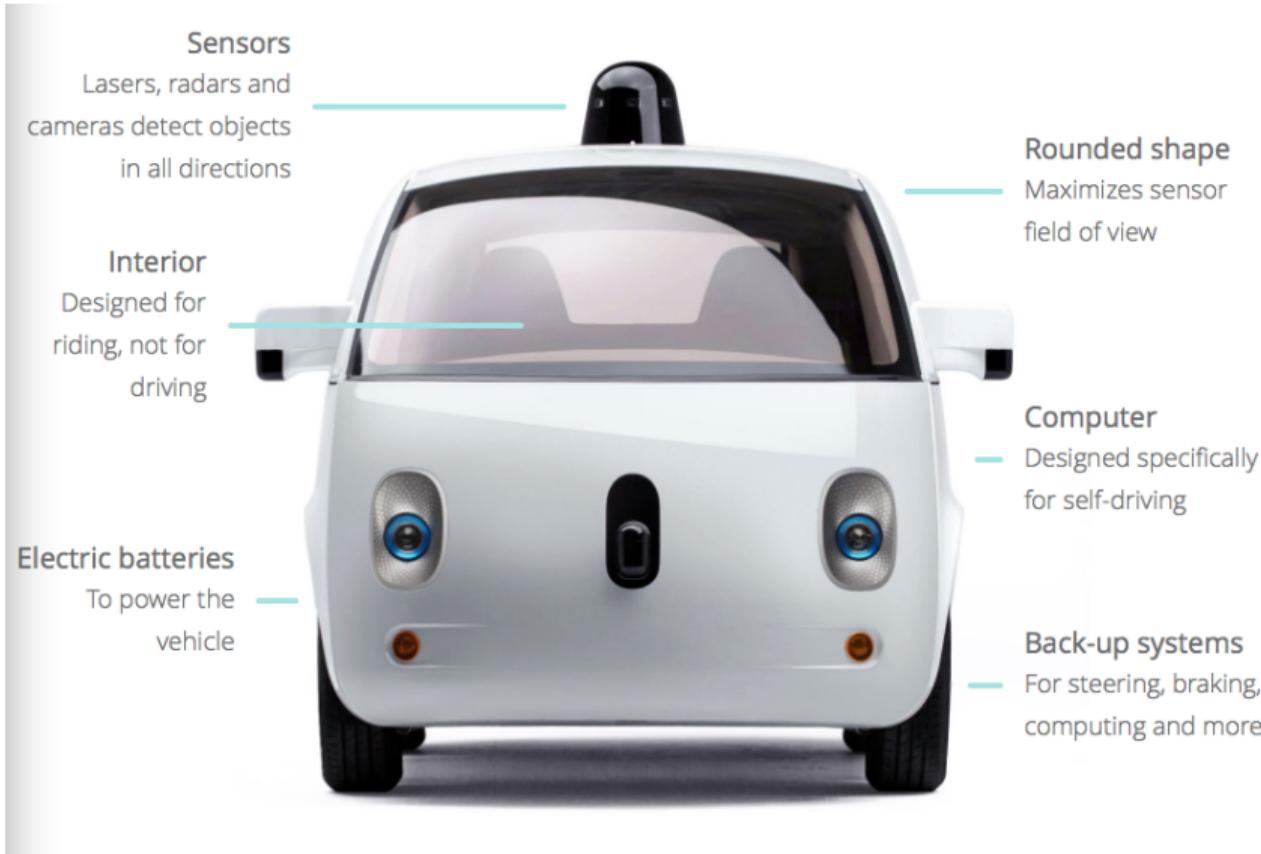
4:00pm–7:00pm Kickoff BBQ*
**Tickets will be available on a limited basis.*

Saturday, October 8

4:00am (approx.) Teams receive the route
6:00am Opening ceremony
6:30am First vehicle launched
9:00am–8:00pm Concessions open
7:00pm Closing ceremony



Google self-driving cars (2016)



ML-Successes: TD-Gammon!

Neurogammon wins Computer Olympiad

Neural Computation 1, (1989), 321-323

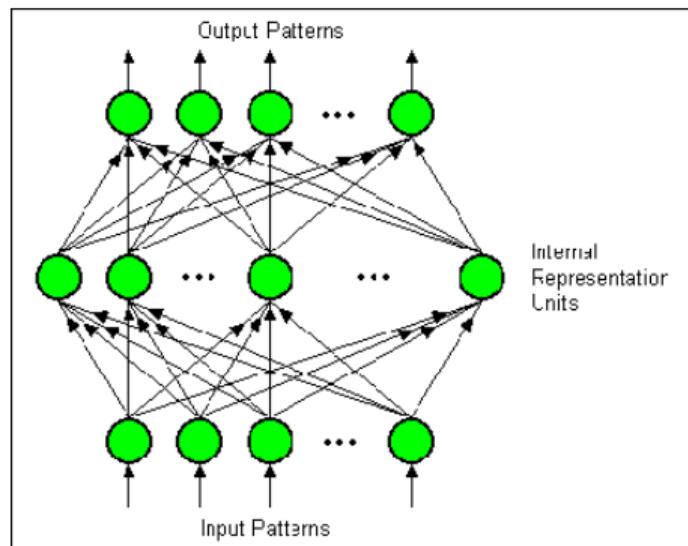


Figure 1. An illustration of the multilayer perceptron architecture used in TD-Gammon's neural network. This architecture is also used in the popular backpropagation learning algorithm.

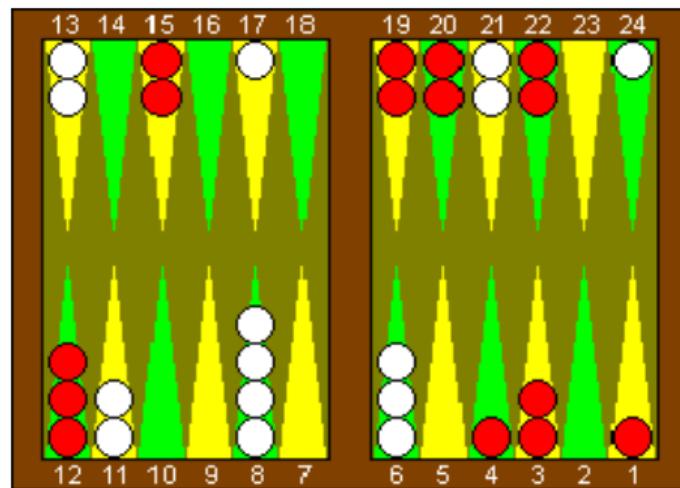


Figure 3. A complex situation where TD-Gammon's positional judgment is apparently superior to traditional expert thinking. White is to play 4-4. The Obvious human play is 8-4, 8-4, 11-7, 11-7. (The asterisk denotes that the opponent checker has been hit.) However, TD-Gammon's choice is the surprising 8-4*, 8-4, 21-17, 21-17!

ML-Success 2016: Google DeepMind's AlphaGo ...

... wins against the champion Go player Lee Sedol

Nature, 529 (7587): 484-489



“Mastering the game of Go without human knowledge”

AlphaGo Zero: Nature 550 (7676): 354-359

AlphaGo Zero learns to play Go exclusively by playing against itself. Neither human heuristics nor data from human games are used to achieve this performance level. TensorFlow is employed to train AlphaGo Zero's neural network. (Google DeepMind)



ML-Successes: Zipcode Recognition!

[Back to Yann's Home Publications](#)

[LeNet-5 Demos](#)

[Unusual Patterns](#)
[unusual styles](#)
[weirdos](#)

[Invariance](#)
[translation \(anim\)](#)
[scale \(anim\)](#)
[rotation \(anim\)](#)
[squeezing \(anim\)](#)
[stroke width](#)

LeNet-5, convolutional neural networks

Convolutional Neural Networks are a special kind of multi-layer neural networks. Like almost every other neural networks they are trained with a version of the back-propagation algorithm. Where they differ is in the architecture.

Convolutional Neural Networks are designed to recognize visual patterns directly from pixel images with minimal preprocessing.

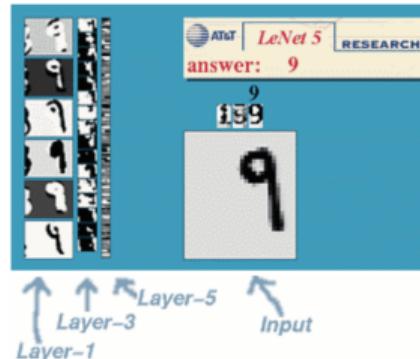
They can recognize patterns with extreme variability (such as handwritten characters), and with robustness to distortions and simple geometric transformations.

Noise Resistance
[noisy_3 and 6](#)
[noisy_2 \(anim\)](#)
[noisy_4 \(anim\)](#)

Multiple Character
[various stills](#)
[dancing_00 \(anim\)](#)
[dancing_384 \(anim\)](#)

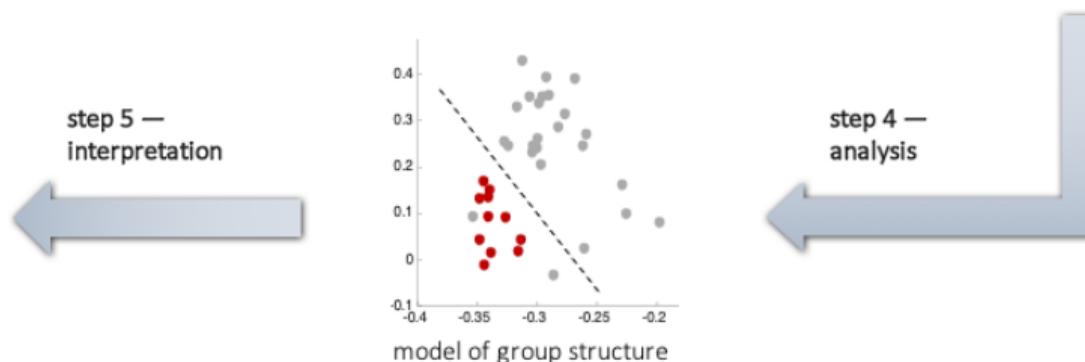
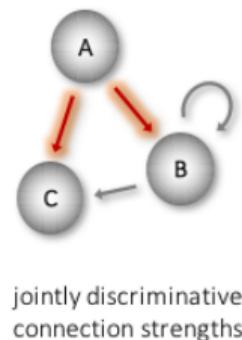
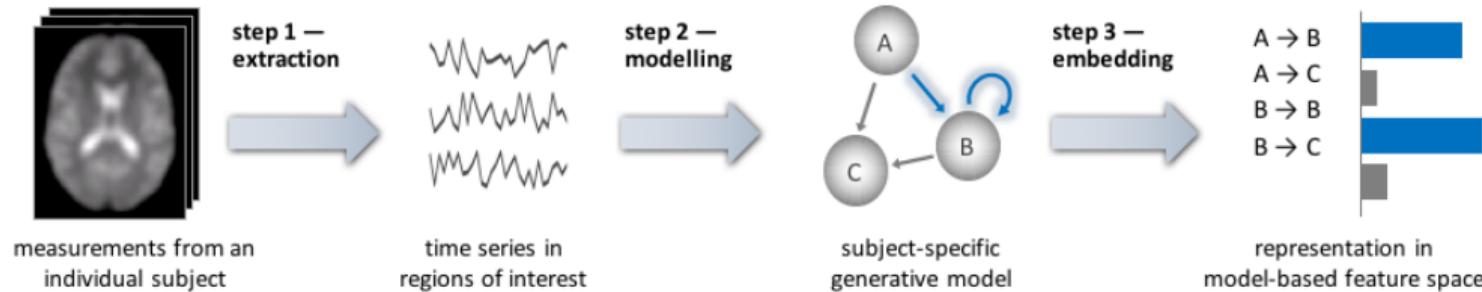
Complex cases
(anim)
[35 -> 53](#)
[12 -> 4-> 21](#)
[23 -> 32](#)
[30 + noise](#)
[31-51-57-61](#)

LeNet-5 is our latest convolutional network designed for handwritten and machine-printed character recognition. Here is an example of LeNet-5 in action.



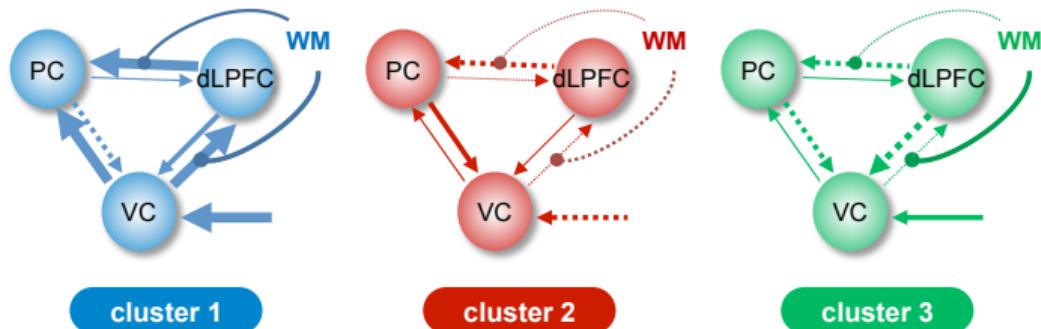
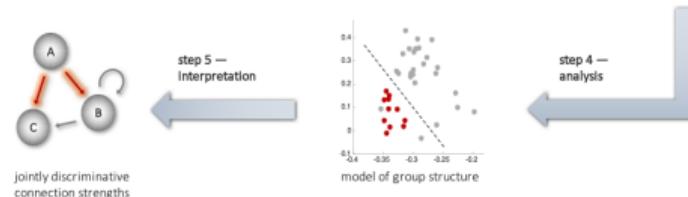
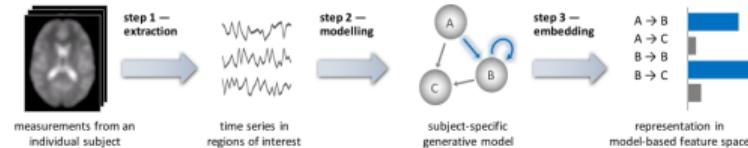
Many more examples are available in the column on the left:

Functional Magnetic Resonance Imaging to understand Schizophrenia



Discover subtypes of mental diseases

Schizophrenia is a spectrum disease with (possibly) different causes.



WM: working memory
dLPFC: dorsolateral prefrontal cortex
PC: parietal cortex
VC: visual cortex

Kay Brodersen (2012)