HYPERSCANNING
as a tool in social neuroscience

Silke Anders
Universität zu Lübeck
Lausanne, May 15, 2014

Hyperscanning: [...] experiments in which participants can interact with each other while functional MRI is acquired in synchrony with the behavioral interactions.

Montague et al., Neuroimage, 19/11/2002
(Why) do we need *hyperscanning*?
... if one wants to make inroads into the neural basis of social interactions, the plain approach is clear: let humans interact socially while concurrently probing their brain activity.

Montague et al., Neuroimage, 19/11/2002
Challenge I: technical

A. Link brains (sensorimotor)
B. Synchronize data collection

Challenge II: data mining

Molecular Neuroimaging Technology Lab
Yonsei University College of Medicine, Seoul
http://neuroimage.yonsei.ac.kr/
## HYPERSCANNING: A BRIEF HISTORY

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### HYPERSCANNING: A BRIEF HISTORY

#### Study #1: 2002

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**COMMENTARY**

*Hyperscanning: Simultaneous fMRI during Linked Social Interactions*


*Nobel Institute for Neurosciences, Division of Neurosciences, Radiology, University of California, San Diego, CA 92093, USA*  
*Department of Psychology, Yale University, Snell, 240 College Street, New Haven, CT 06520, USA*  
*Department of Psychology, University of Chicago, 5801 South University Avenue, Chicago, IL 60637, USA*  
*Department of Psychology, University of California, Berkeley, 1212 Berkeley Way, Berkeley, CA 94720, USA*  
*Department of Psychology, University of California, San Diego, 9500 Gilman Drive, La Jolla, CA 92037, USA*

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**SCANNERS:** 2 x Philips 1.5 T  
**ANALYSES:** Between-brain cross-spectral coherence of single-brain SVD components
HYPERSCANNING: A BRIEF HISTORY

Study #1: 2002


We explored a novel type of neurofeedback for fMRI signals which allows to scan two subjects simultaneously while they compete in a simple video game (ping pong). Subjects saw the same screen depicting the tennis field, the moving ball and the two rackets. Each subject was instructed to move her racket to the correct position using the BOLD signal. The fMRI measurements were performed on two MRI scanners (Siemens: 1.5 T Sonata and 3 T Trio). For real-time data analysis and synchronized stimulus presentation, we developed a novel brain-computer interface, which allows the experimenter to observe the ongoing brain activity of the two subjects as well as to select the BOLD signal in selected regions-of-interest (ROIs) for neurofeedback. Before running the pong game, each of the participating subjects was trained to modulate regional brain activity to reach specific target levels and to adapt to the hemodynamic response delay. The ROI with the best modulation results was selected in each subject for controlling the racket in the subsequent video game. Subjects succeeded in controlling the up and down movement of the racket by regulating voluntarily the activity in the selected ROIs achieving a hit rate of 60 to 80 %. Subjects reported that playing a game with another subject was highly motivating in contrast to the otherwise effortful brain modulation process. The results revealed that with extensive practice, subjects learned to reach and maintain intermediate levels of brain activity with high accuracy. This study demonstrates that it is possible to simultaneously measure two subjects engaged in joined attention during social interactions and to use subjects brain activity in real-time during these interactions. Our work might inspire further fMRI studies investigating the neural substrate of social cognitive processes.

SCANNERS: 1.5 T Sonata / 3T Trio
ANALYSIS: real-time ROI analysis (?)
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BOX I: GLM-based analysis versus between-brain temporal correlations

hyper: 3 mm spheres at [54 -26 30], scan 6 to 80, FWHM 44s

VARIANTS:

a. ROI/voxel-wise BOLD times series
b. Spatially corresponding / non-corresponding BOLD time series
c. Removal of stimulation
BOX I: GLM-based analysis versus between-brain temporal correlations

VARIANTS:
- ROI/voxel-wise BOLD times series
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- Time lag between BOLD time series of partner 1 and partner 2

HYPERSCANNING: A BRIEF HISTORY

Study #3: 2005

Getting to Know You: Reputation and Trust in a Two-Person Economic Exchange

SCANNERS: 3T Trio (CA) / 3T Allegra (TX)
ANALYSIS: ROI-based between-brain cross-correlation of averaged trial-wise time series
BOX I: GLM-based analysis versus between-brain temporal correlations

Study #3: King-Casas et al., 2005

VARIANTS:
- a. ROI/voxel-wise BOLD times series
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- d. Time lag between BOLD time series of partner 1 and partner 2

HYPERSCANNING: A BRIEF HISTORY

Study #3: 2005
**Study #3: 2005**

### Between-brain correlation analysis:

- **Early rounds**
  - Investor MCC x Trustee ACC
  - Investor MCC x Trustee Caudate

- **Late rounds**
  - correlation coefficient
  - time shift of investor MCC (sec)

**3 Regions of interest (ROIs)**

- **MCC** (within-brain contrast: subject’s decision minus partner’s decision)
- **ACC** (within-brain contrast: partner’s decision minus subject’s decision)
- **CAUDATE** (within-brain contrast: investor’s benevolent decision minus investor’s malevolent decision)

**“Tuning in”**

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**Study #4: 2007**

**Social Comparison Affects Reward-Related Brain Activity in the Human Ventral Striatum**


**SCANNERS:** 1.5T Avanto / 3T Trio

**ANALYSIS:** Single-brain GLM

[...] because both subjects were scanned, they were performing under the same circumstances. Thus, the experimental environment provides no basis or justification for differential payment and is therefore well suited to study the consequences of relative income differences for the same performance under identical conditions.
HYPERSCANNING: A BRIEF HISTORY

Study #6: 2012

Neural responses to advantageous and disadvantageous inequity

Same as 2007, additional participants

SCANNERS: 1.5T Avanto / 3T Trio
ANALYSIS: Single-brain GLM

HYPERSCANNING: A BRIEF HISTORY

Study #5: 2010

“Stay tuned”: inter-individual neural synchronization during mutual gaze and joint attention

SCANNERS: 1.5T Signa Excite / 3T Signa Excite (GE)
ANALYSIS: Voxel-wise between-brain correlation of residual time series
BOX I: GLM-based analysis versus between-brain temporal correlations

Study #5: Saito et al., 2010

![Brain Images](image)

**VARIANTS:**
- a. ROI/voxel-wise BOLD times series
- b. Spatially corresponding / non-corresponding BOLD time series
- c. Removal of stimulation
- d. Time lag between BOLD time series of partner 1 and partner 2

HYPERSCANNING: A BRIEF HISTORY

Study #5: 2010

![Brain Image](image)

Between-brain correlation between partners minus between-brain correlation between non-partners
HYPERSCANNING: A BRIEF HISTORY

Study #8: 2012

Hard to “tune in”: neural mechanisms of live face-to-face interaction with high-functioning autistic spectrum disorder

Between-brain correlation between partners minus between-brain correlation between non-partners

Study #7: 2012

Working Together May Be Better: Activation of Reward Centers during a Cooperative Maze Task

Single-brain GLM

SCANNERS: 1.5T Symphony / 3T Trio
ANALYSIS: Single-brain GLM
HYPERSCANNING: A BRIEF HISTORY

Study #9: 2014

Interindividual synchronization of brain activity during live verbal communication

Kai Spiegelhalder a,1, Sabine Ohlendorf b,1, Wolfram Regen c, Bernd Feige c, Lodger Tebartz van Elst d, Cornelius Weißler d, Jürgen Hennig e, Matthias Berger e, Oliver Tüscher e, f, g

Behavioral Brain Research 258 (2014) 75–79

BOX I: GLM-based analysis versus between-brain temporal correlations

Study #9: Spiegelhalder et al., 2014

VARIANTS:

a. ROI/voxel-wise BOLD times series
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HYPERSCANNING: A BRIEF HISTORY

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HYPERSCANNING

(Why) do we really need hyperscanning?

► To investigate how two (or more) single systems (brains) gradually transform into a unified “hypersystem” (tuning in) = changes over time? = between-brain synchrony?

► To investigate inter-tuple differences in “tuning in”
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### HYPERSCANNING

But…

…there are more to come!
(Why) do we *really* need hyperscanning?

- To investigate how two (or more) single systems (brains) gradually transform into a unified “hypersystem” (‘tuning in’)
  
  = changes over time? = between-brain synchrony?

- To investigate inter-tuple differences in “tuning in”

Pseudohyperscanning
## EXPERIMENTAL SET-UP

**Challenge I: technical**
- Time-lagged between-brain regression

**Challenge II: data mining**
- Between-brain Granger causality
- Between-brain pattern analysis

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HYPERSONCANNING: PSEUDOHYPERSONCANNING

Study #1: 2010

Speaker–listener neural coupling underlies successful communication
Greg J. Stephens\(^{1,3}\), Lauren J. Silbert\(^{1,5}\), and Uri Hasson\(^{1,2}\)
PNAS | August 10, 2010 | vol. 107 | no. 12

**SCANNER:** 3T Allegra, one “speaker”, “several listeners”

**ANALYSIS:** Voxel-wise between-brain time-lagged regression

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BOX I: GLM-based analysis versus between-brain temporal correlations

**Study #1: Stephens et al., 2010**

VARIANTS:
a. ROI/voxel-wise BOLD times series
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d. Time lag between BOLD time series of partner 1 and partner 2

hyper1234, 3 mm sphere at [44–24–32], scan a (Res), scan b (Res), FWHM 14s
Study #1: 2010

**Speaker–listener neural coupling underlies successful communication**

Greg J. Stephens\(^{1,2}\), Lauren J. Silbert\(^1\), and Uri Hasson\(^{1,3}\)

PNAS | August 10, 2010 | vol. 107 | no. 12

**Scanner:** Philips, "gesturer"-"guesser" dyads, partners switch roles

**Analysis:** ROI-based between-brain Granger causality

---

Study #2: 2010

**Mapping the information flow from one brain to another during gestural communication**

Marleen B. Schippers\(^1\), Aald Rodbro\(^1\), Ronco Renken\(^1\), Luca Noneth\(^1\), and Christian Keysers\(^1,2\)

PNAS | May 18, 2010 | vol. 107 | no. 20

**Scanner:** 3T Philips, "gesturer"-"guesser" dyads, partners switch roles

**Analysis:** ROI-based between-brain Granger causality
BOX I: GLM-based analysis versus between-brain temporal correlations

Study #2: Schippers et al., 2010

VARIANTS:
- ROI/voxel-wise BOLD times series
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HYPERSONCANNING: PSEUDOHYPERSCANNNING

Study #2: 2010

Mapping the information flow from one brain to another during gestural communication

Marleen B. Schippers², Aldo Roebroeks³, Remco Renken⁴, Luca Noneth⁵, and Christian Keysers²⁶

PNAS | May 18, 2010 | vol. 107 | no. 20 |

GRANGER CAUSALITY

\[ X_t = \sum_{i=1}^{3} \alpha_i X_{t-i} + \epsilon_t \quad \text{Regression on guesser’s own past} \]

\[ X_t = \sum_{i=1}^{3} \alpha_i' X_{t-i} + \sum_{i=1}^{3} \beta_i Y_{t-i} + \epsilon_t \quad \text{Regression on guesser’s own past and gesturer’s past} \]
Study #2: 2010

Mapping the information flow from one brain to another during gestural communication

Marleen B. Schippers*, Allard Roebroek*, Remco Renken*, Luca Nonetto*, and Christian Keysers*#1

PNAS | May 18, 2010 | vol. 107 | no. 20 |

Seed ROIs (gesturer’s brain)

Target voxels (guesser’s brain)

Between brains Granger: gesturer to guesser

TR = 1.33s
HYPERSCANNING: PSEUDOHYPERSCANNING

Study #2: 2010

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Marleen B. Schippers, Allard Roebroek, Remco Renken, Luca Nenetti, and Christian Keysers
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Seed ROIs
Target voxels
(gesturer’s brain)
(guesser’s brain)

T-test: gesturer to guesser versus gesturer to corresponding word of random guesser
TR = 1.33s

HYPERSCANNING: PSEUDOHYPERSCANNING

Study #3: 2011

Flow of affective information between communicating brains
Silke Anders, Jakob Heinze, Nikolaus Weiskopf, Thomas Eterolf, John-Dylan Haynes
Neurolmage 54 (2011) 459-466

SCANNER: 1.5T Avanto, “sender”-“observer” dyads, no switching
ANALYSIS: Between-brain pattern analysis
Is emotion-specific information encoded in similar ways in the brain of the sender and the perceiver?

DECODER
(learns how to distinguish emotions in the sender’s brain)

Sender

Perceiver

BOX II: Between-brain pattern analysis (univariate)

Fear
Joy
Disgust
Anger
Sadness

“TRAINING”

“TEST”

Classification accuracy

Map of voxel-wise classification accuracies
HYPERSONSCANNING: PSEUDOHYPERSONSCANNING

Study #3: 2011

Flow of affective information between communicating brains
Silke Anders a,b,c, Jakob Heinze a, Nikolaus Weiskopf b, Thomas Etherer a,b,c, John-Dylan Haynes b,c,1

NeuroImage 54 (2011) 439–446

BOX III: Between-brain pattern analysis (multivariate)
HYPERSCANNING: PSEUDOHYPERSCANNING

Study #3: 2011

Flow of affective information between communicating brains
Silke Anders a,b,c, Jakob Heinze b, Nikolaus Weiskopf b, Thomas Etheoer b,c, John-Dylan Haynes b,c

NeuroImage 54 (2011) 435-445

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- To investigate how two (or more) single systems (brains) gradually transform into a unified “hypersystem” (“tuning in”) = changes over time? = between-brain synchrony?
- To investigate inter-tuple differences in “tuning in”
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  - = changes over time? = between-brain synchrony?
- To investigate inter-tuple differences in “tuning in”
Is flow of neural information increased in partners with a strong **social bond**?
BOX IV: BETWEEN-BRAIN SPATIAL CORRELATION

HYPERSCANNING: PSEUDOHYPERSCANNING
Future directions

DUAL-BRAIN SCANNER

Decoupled Circular-Polarized Dual-Head Volume Coil Pair for Studying Two Interacting Human Brains with Dyadic fMRI

Ray F. Lee,* W. Dai, and J. Jones
HYPERSCANNING: FUTURE DIRECTIONS
silke.anders@neuro.uni-luebeck.de

HYPERSCANNING

Take home message