

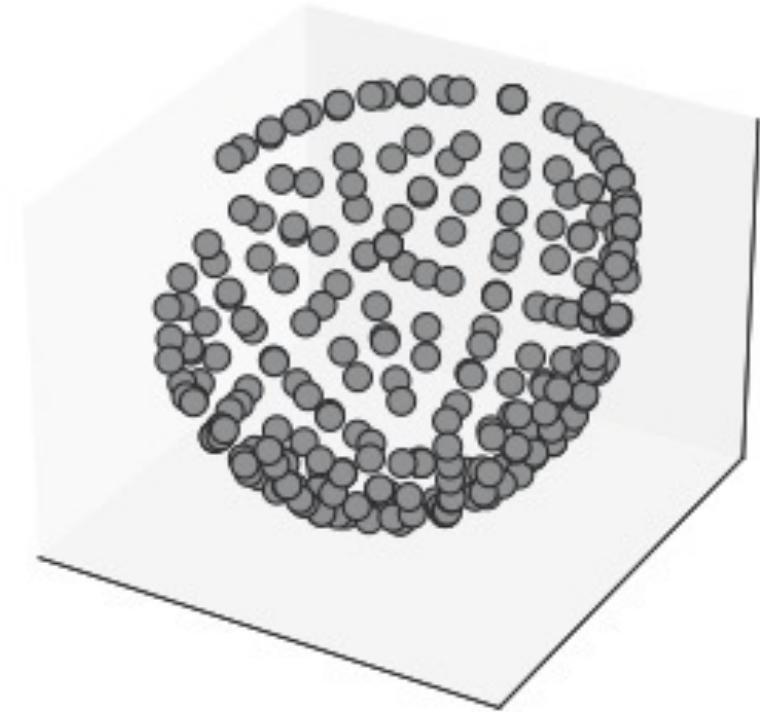
**CS-DSI as an accelerated way to accurately and  
reliably segment white matter tracks and  
examine microstructure**



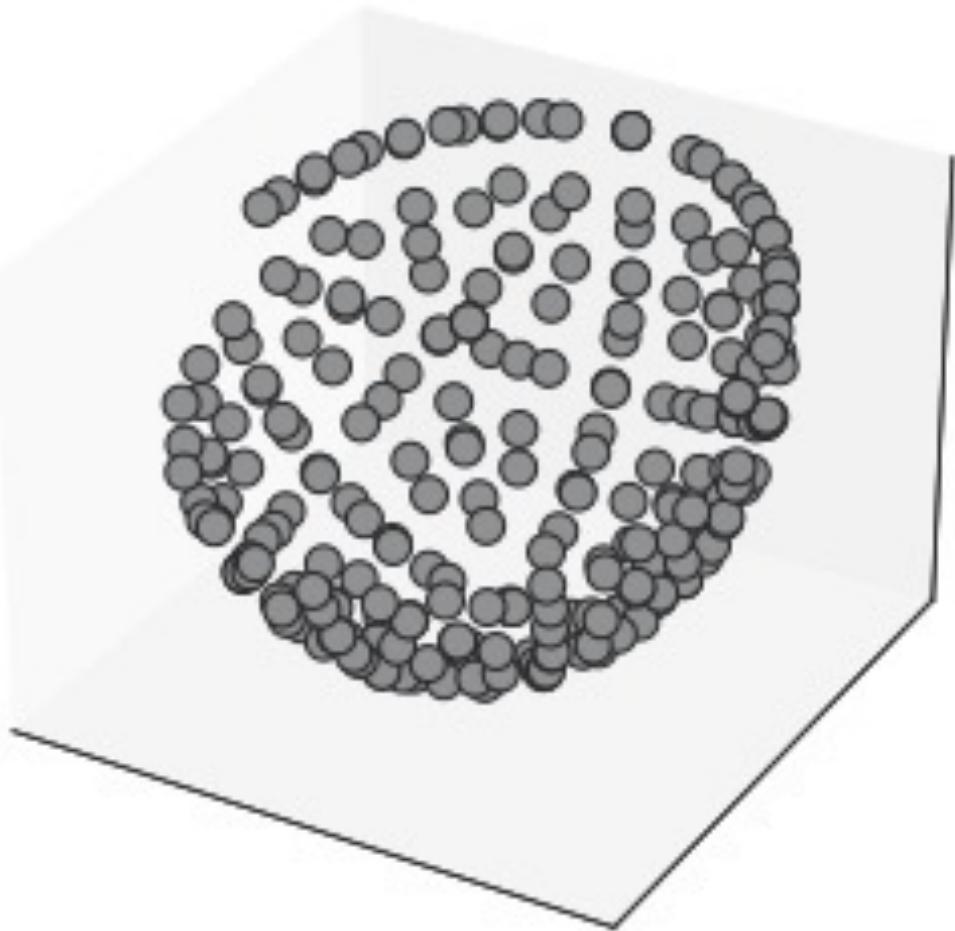
Hamsi Radhakrishnan  
11/01/2022

# Diffusion Spectrum Imaging (DSI)

- Kind of diffusion MRI- allows us to track white matter pathways and examine microstructure!
- Works by densely sampling the *q-space* on a cartesian grid
- Can resolve crossing fibers + may be more specific
- Has a lot of clinical potential



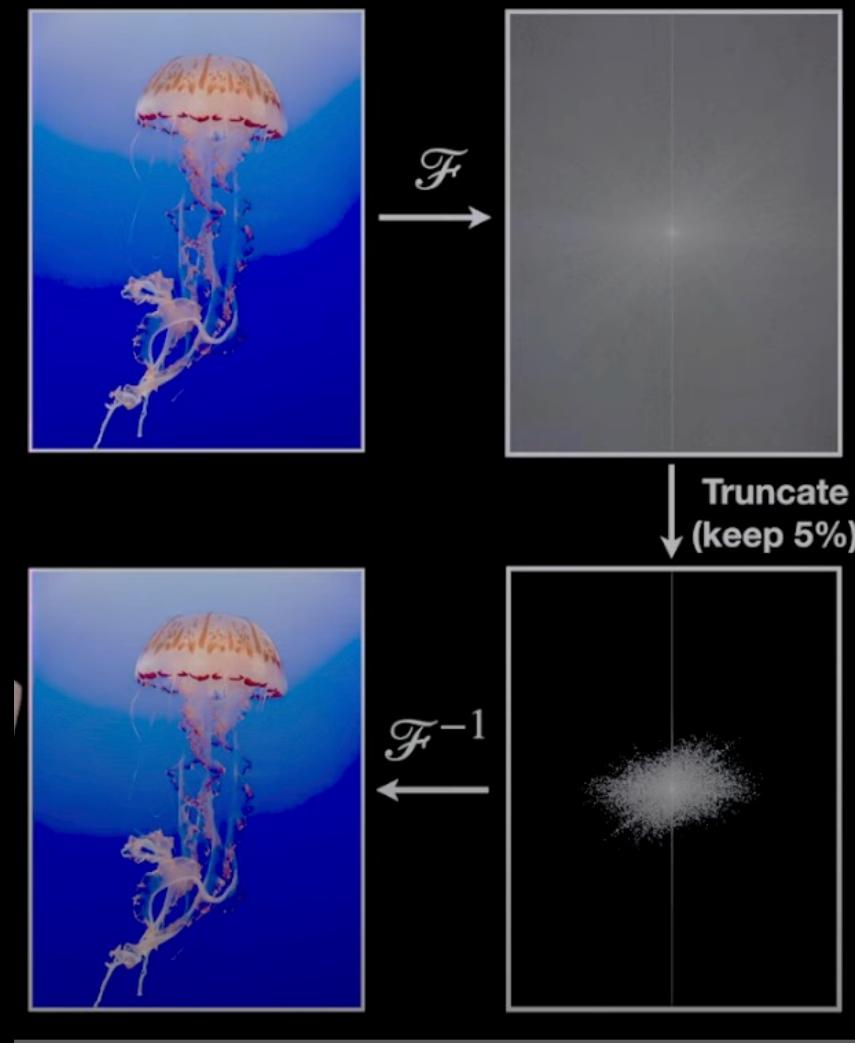
# Very long acquisition time



Each of these dots take about 4.5 seconds to acquire. And when we densely sample—that's an average of 20-25 minutes of scan time!

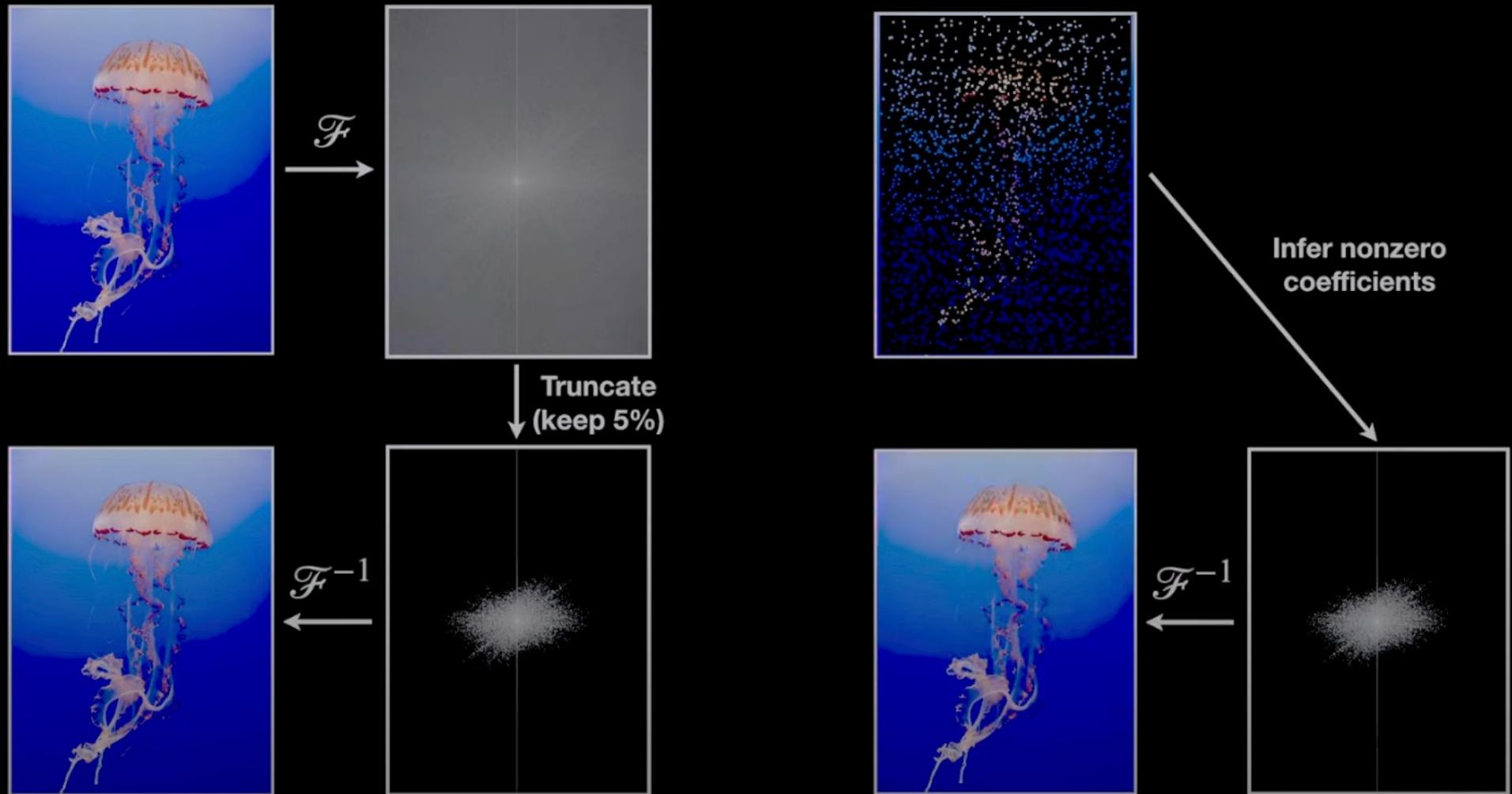
Not very feasible, especially in clinical populations.

# General Compression



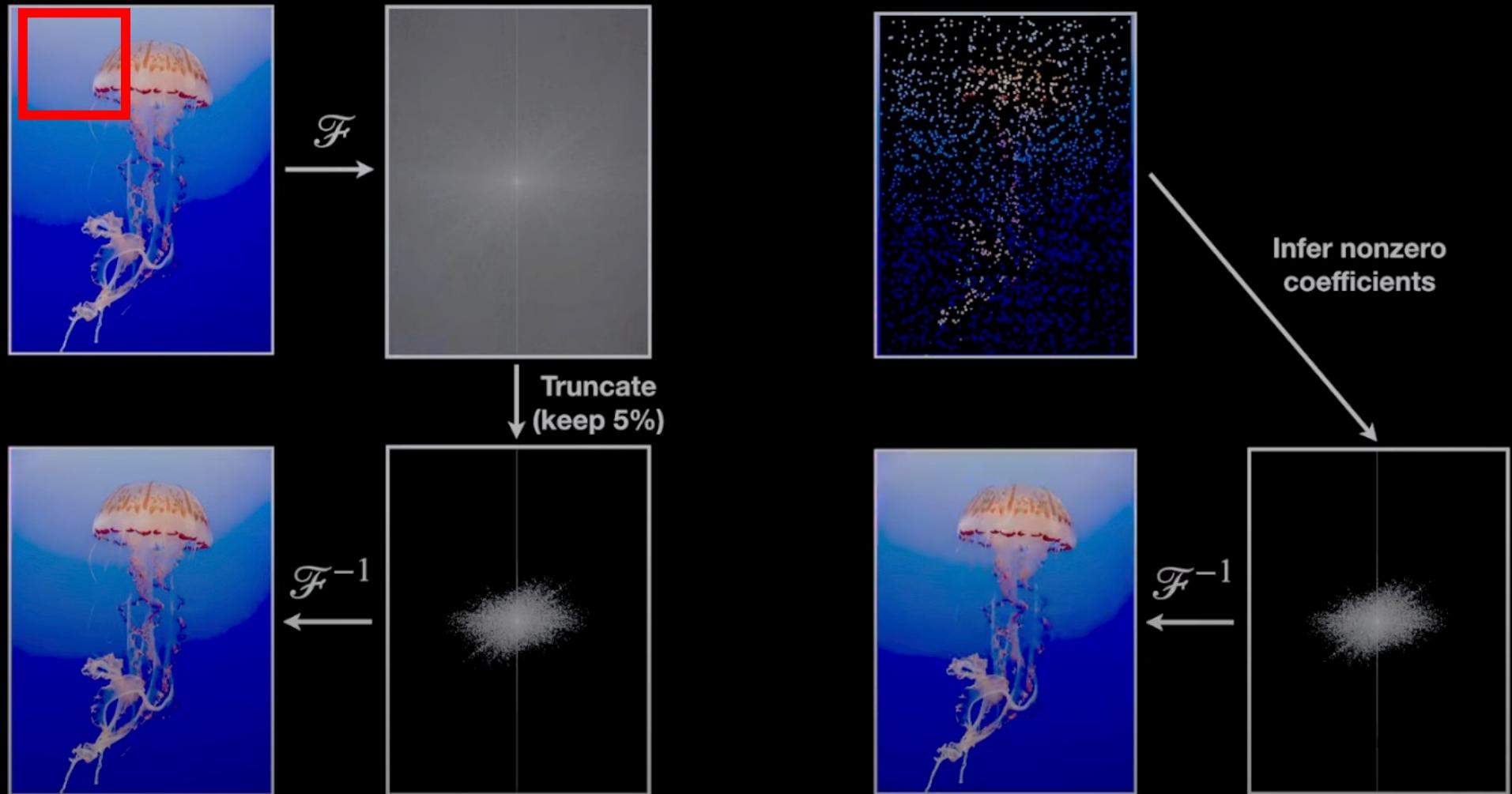
# Compressed Sensing

A method to reconstruct analog signals at a much lower sampling rate.



# Compressed Sensing

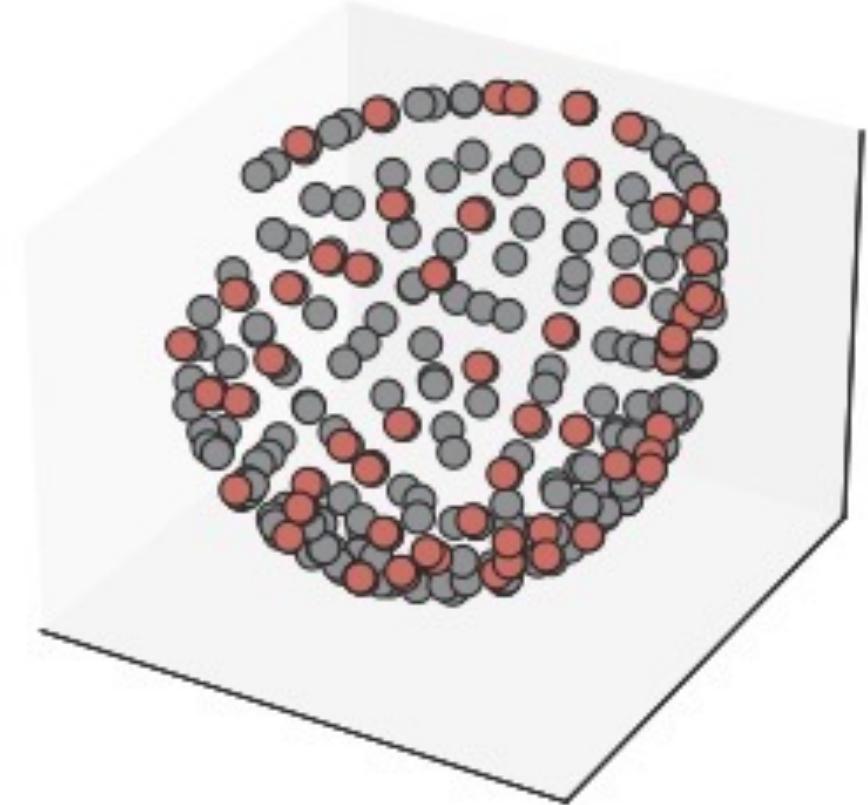
A method to reconstruct analog signals at a much lower sampling rate.



# Compressed Sensing

So instead of densely sampling the q-space, can we sample only a subset of it, and extrapolate what the rest of it is supposed to look like?

Since the acquisition time is directly proportional to number of points sampled, this can significantly bring down acquisition time.



# But biological validity?

- This has been done before- but the focus has been on engineering solutions and optimizing extrapolation methods.
- Most of these studies have also either been on simulated or post-mortem data
- It's currently unclear whether this would actually work in practice, especially in terms of biologically and clinically significant metrics.

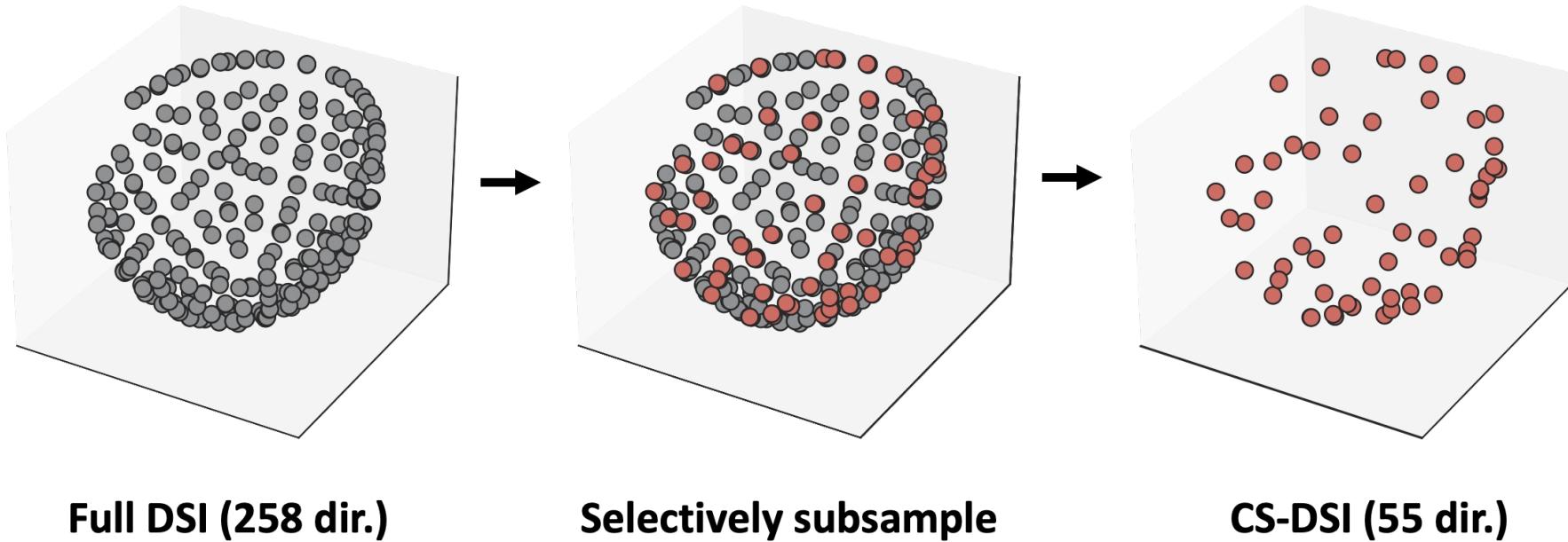
# Our questions:

Can we use these compressed sensing schemes to track white matter pathways or examine localized white matter microstructure?

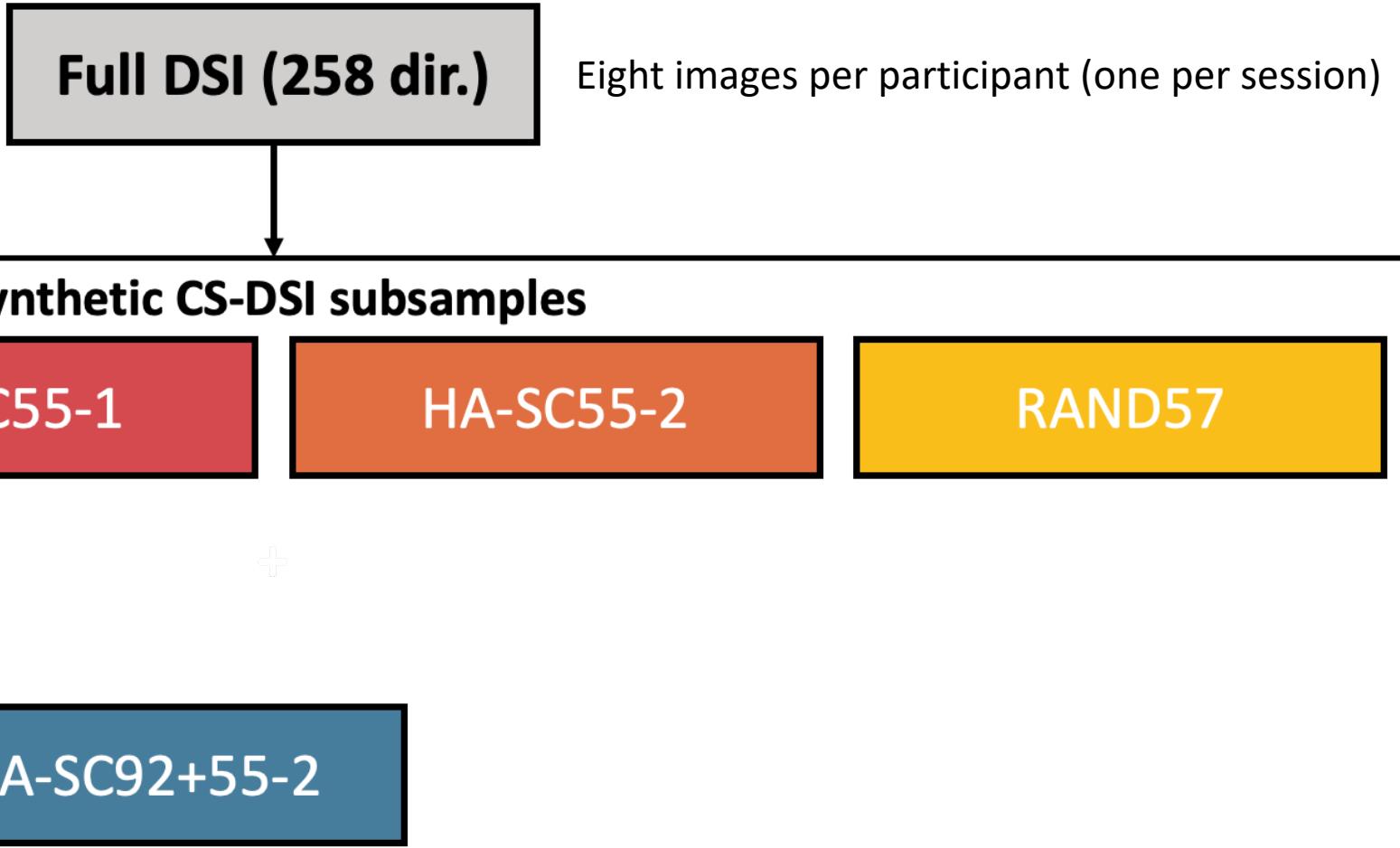
Are the derivatives comparable to those derived by typical full DSI schemes?

# The CRASH dataset

- 26 participants
- **Full DSI acquisitions**
- 8 identical scan sessions (average time between sessions = 14 days)
- CS-DSI schemes are retrospectively acquired.



# Subsampled CS-DSI schemes



# Significantly shorter acquisition times

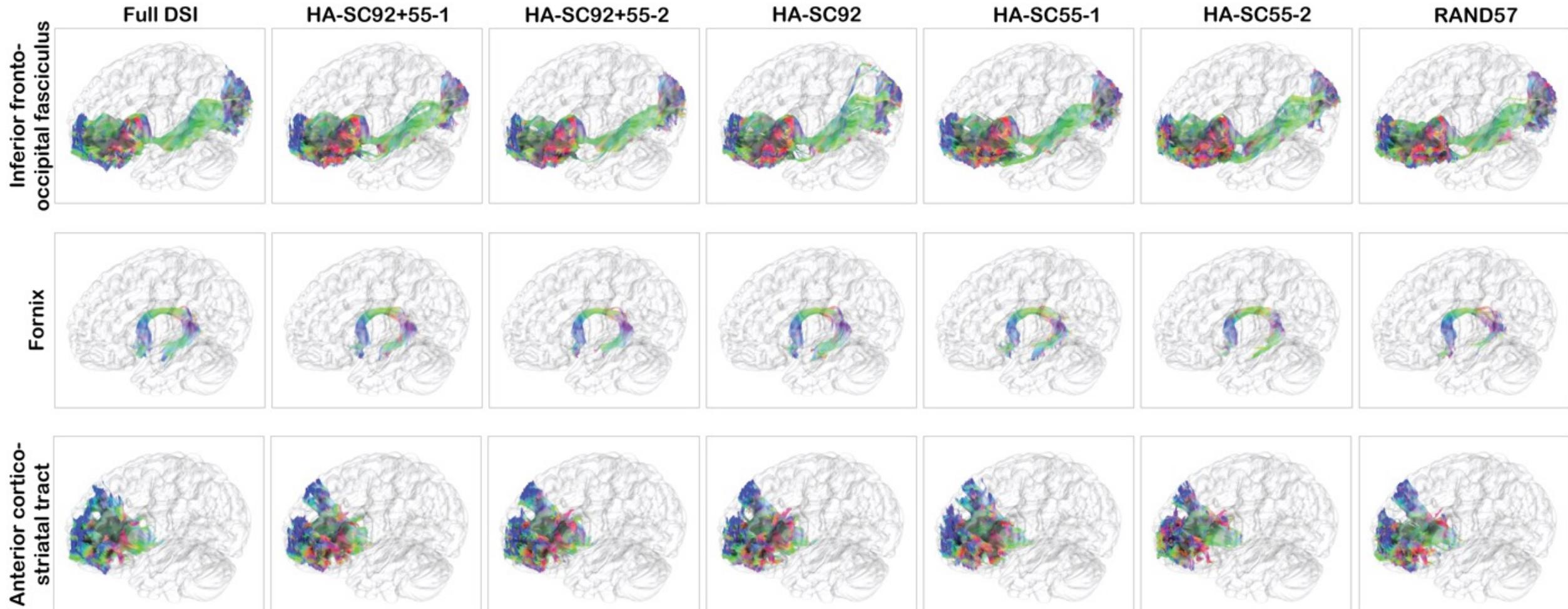
Sequence	Number of directions	Acquisition time (minutes)
Full DSI	258	20
HASC92+55 – 1	147	11.9
HASC92+55 – 2	147	11.8
HASC92	92	7.4
HASC55 – 1	55	4.5
HASC55 – 2	55	4.3
RAND57	57	5.4

# Assessing CS-DSI's ability to:

**Segment white  
matter streamlines**  
[global connectivity]

**Calculate voxel-  
wise scalars**  
[local microstructure]

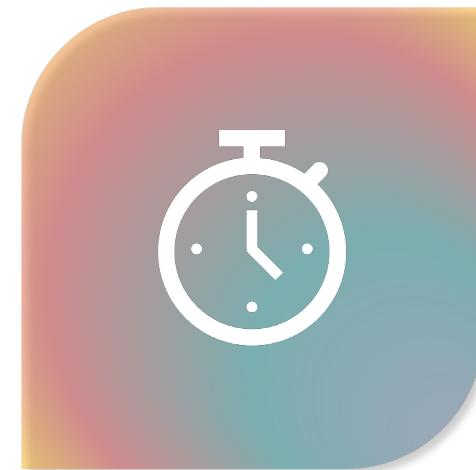
All CS-DSI schemes can reconstruct white matter streamlines of different shapes and lengths successfully.



# But how do the streamlines quantitatively compare?



**HOW ACCURATE ARE  
THE STREAMLINES  
SEGMENTED?**



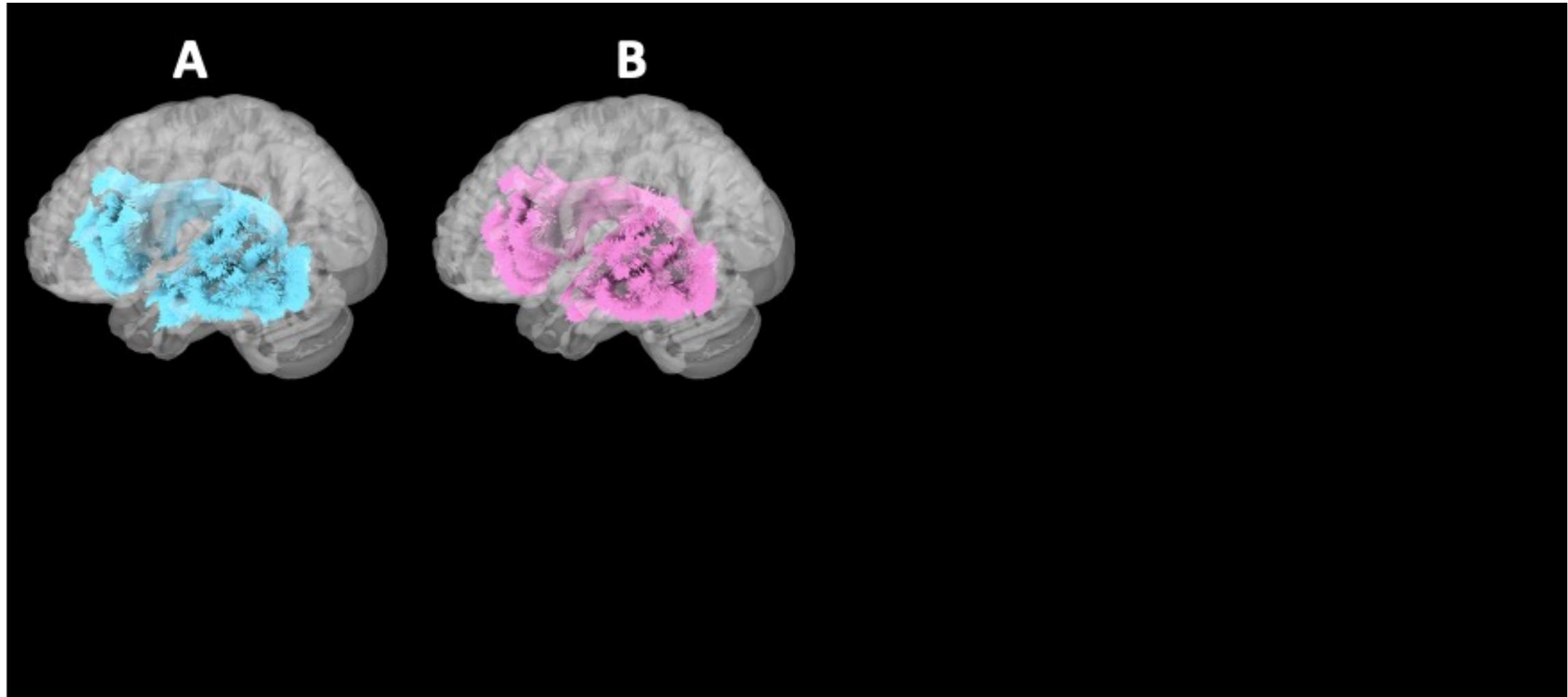
**HOW RELIABLY ARE  
THEY SEGMENTED  
BETWEEN SESSIONS?**

# Within-session accuracy

- Relationship between the streamline generated by a CS-DSI scheme and that generated by the full DSI scheme *within* the same session.
- Calculated per participant. 8 values per participant for a given streamline and acquisition scheme.
- Defined by dice scores for streamlines.

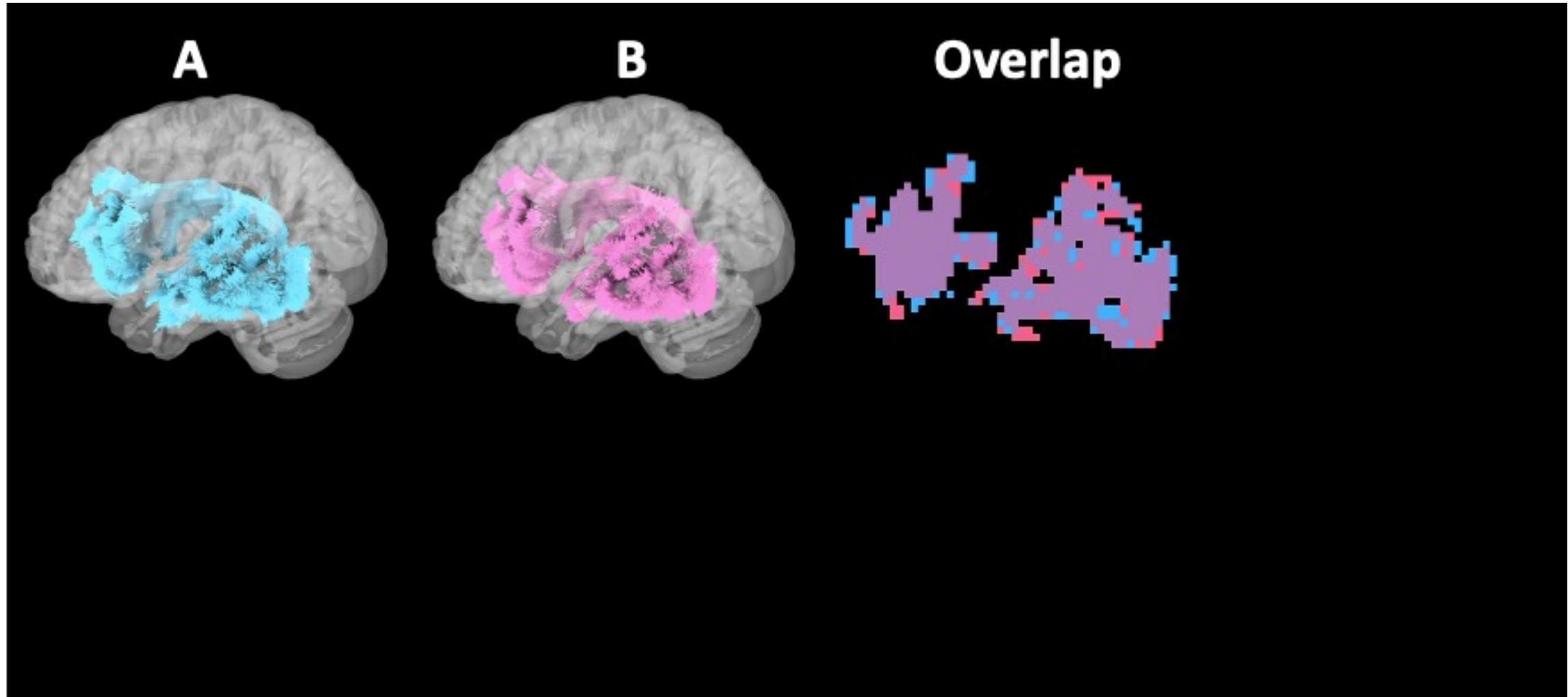
# What is a dice score?

A way to measure the overlap between streamlines.



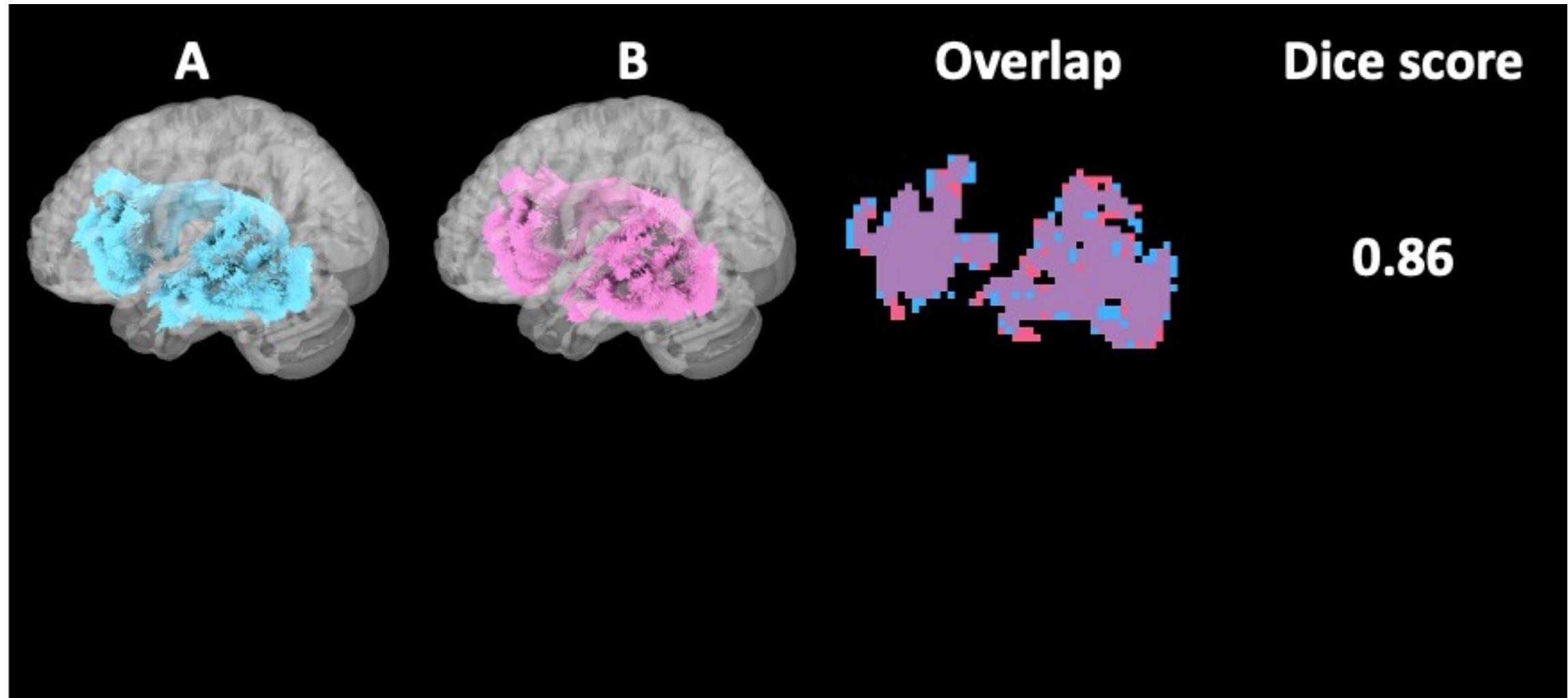
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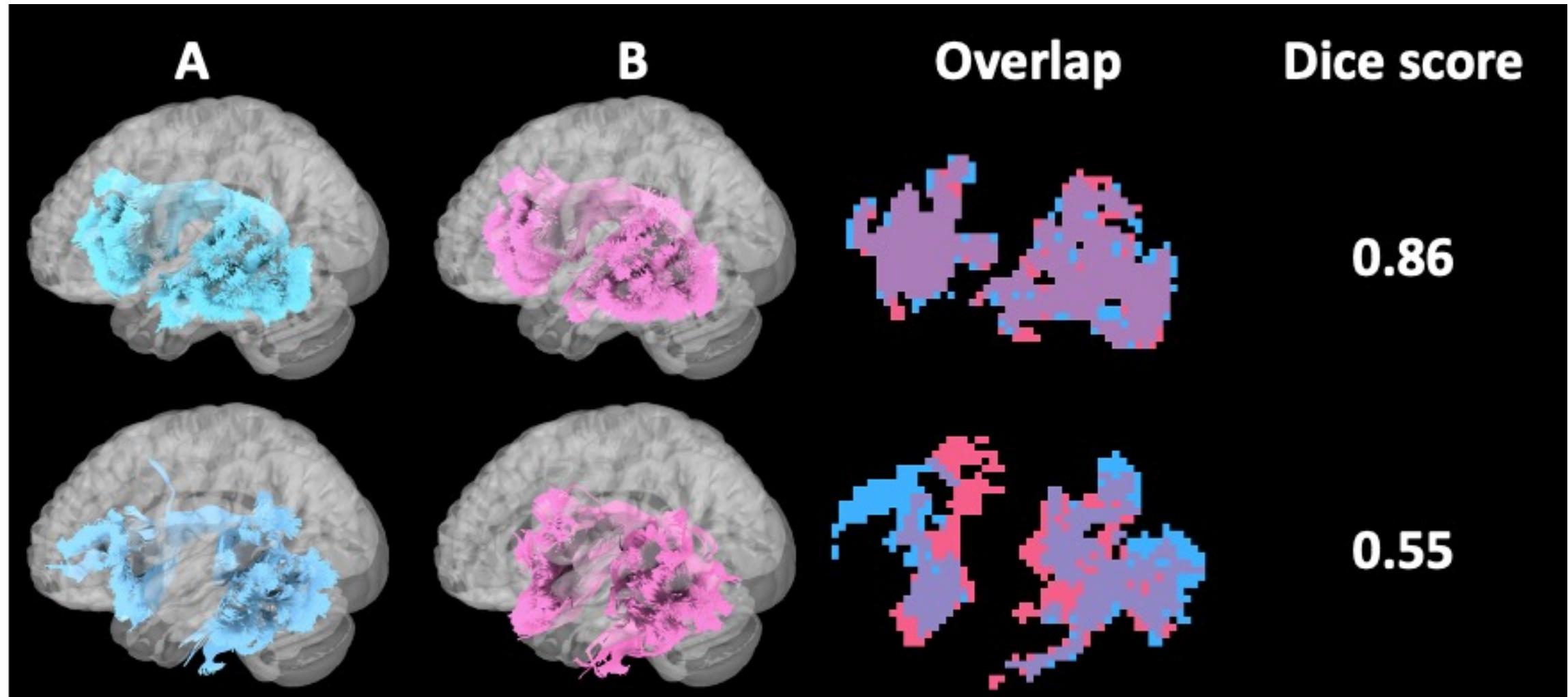
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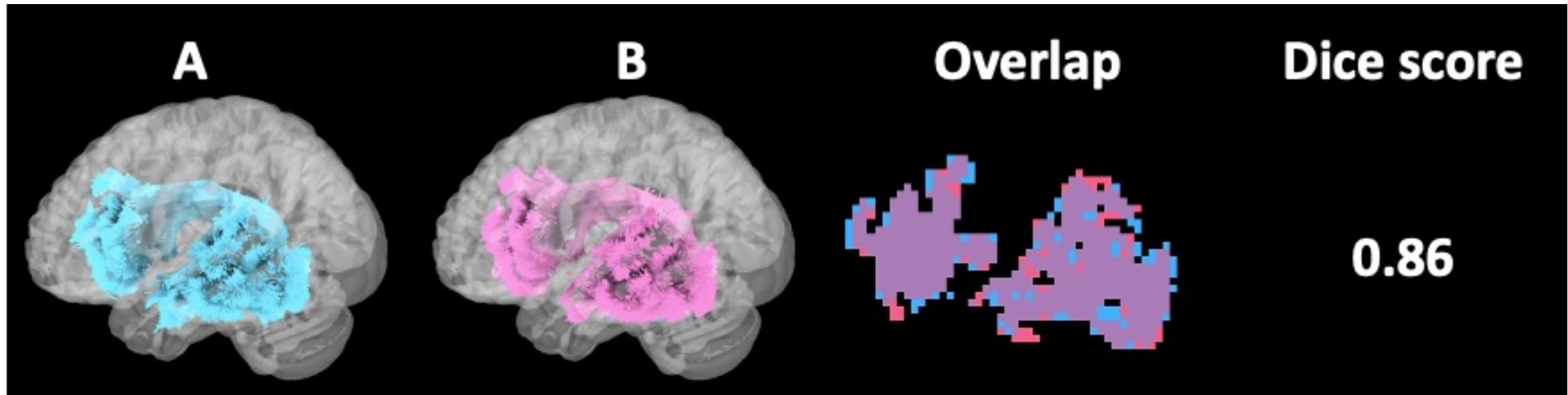
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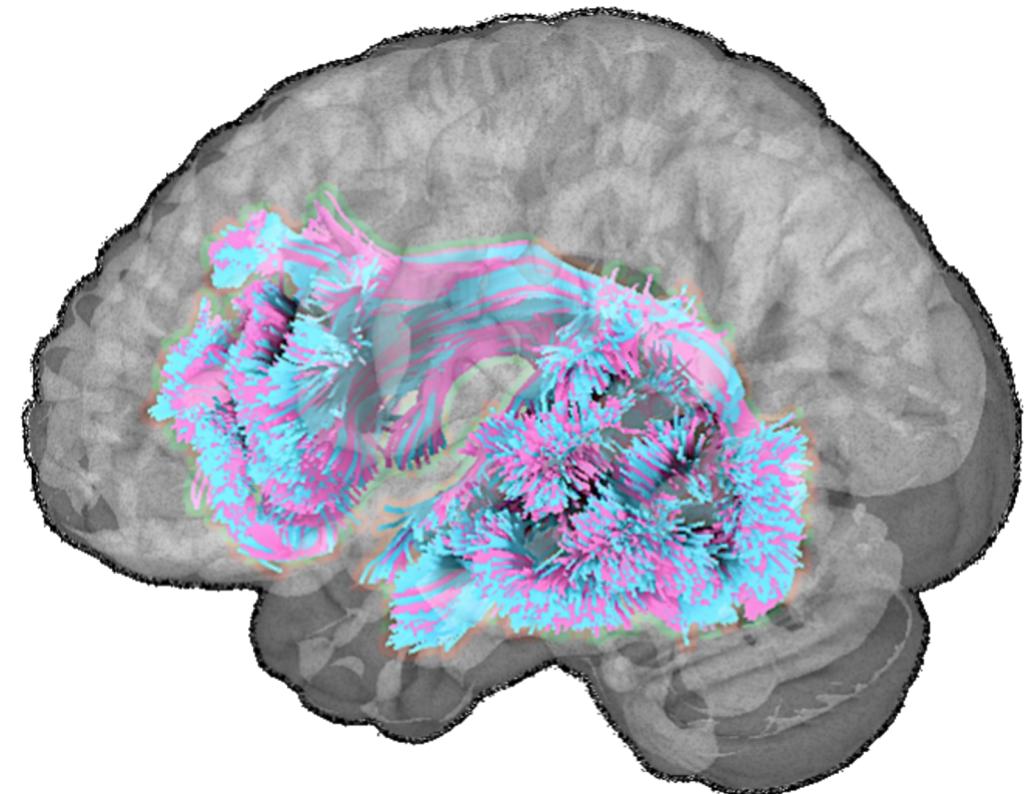
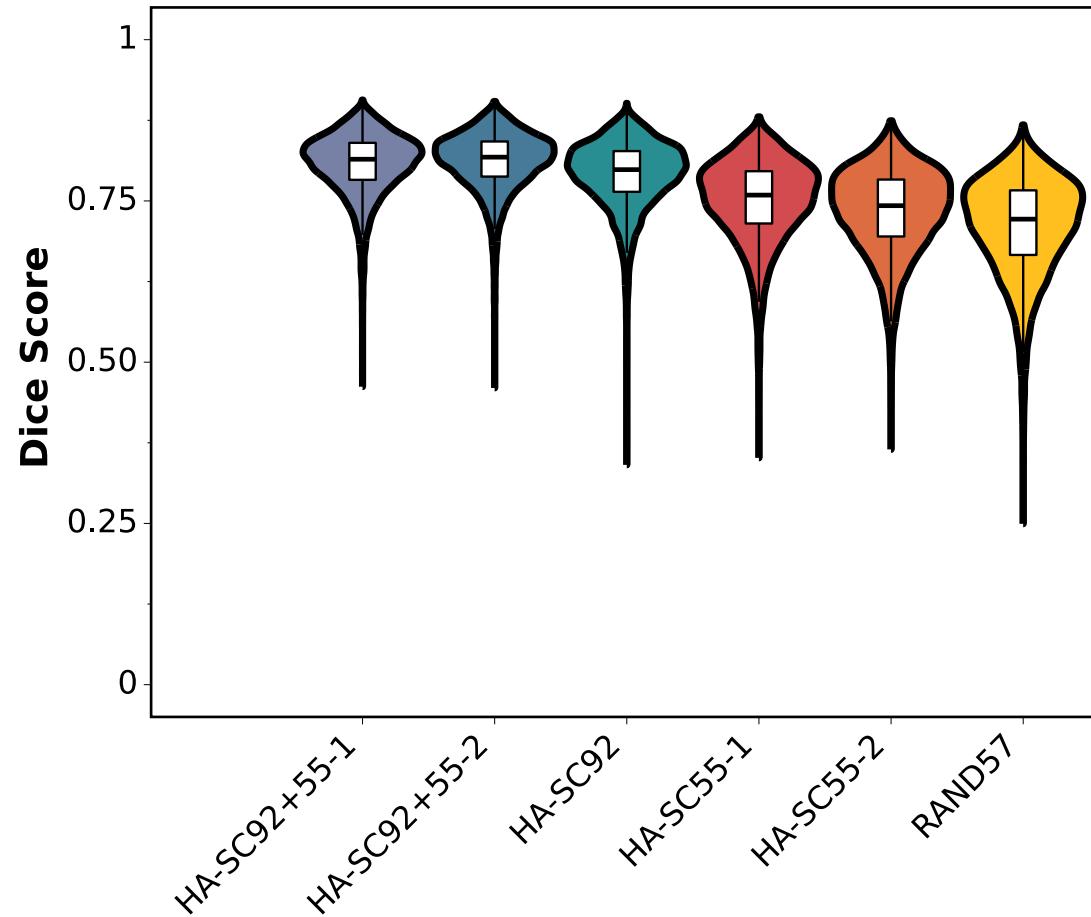


CS-DSI session 1 vs. Full DSI session 1 for participant X

**Within-session accuracy** is the dice score between the streamline produced by a CS-DSI acquisition scheme and that produced by the full DSI acquisition scheme *within* a single session.

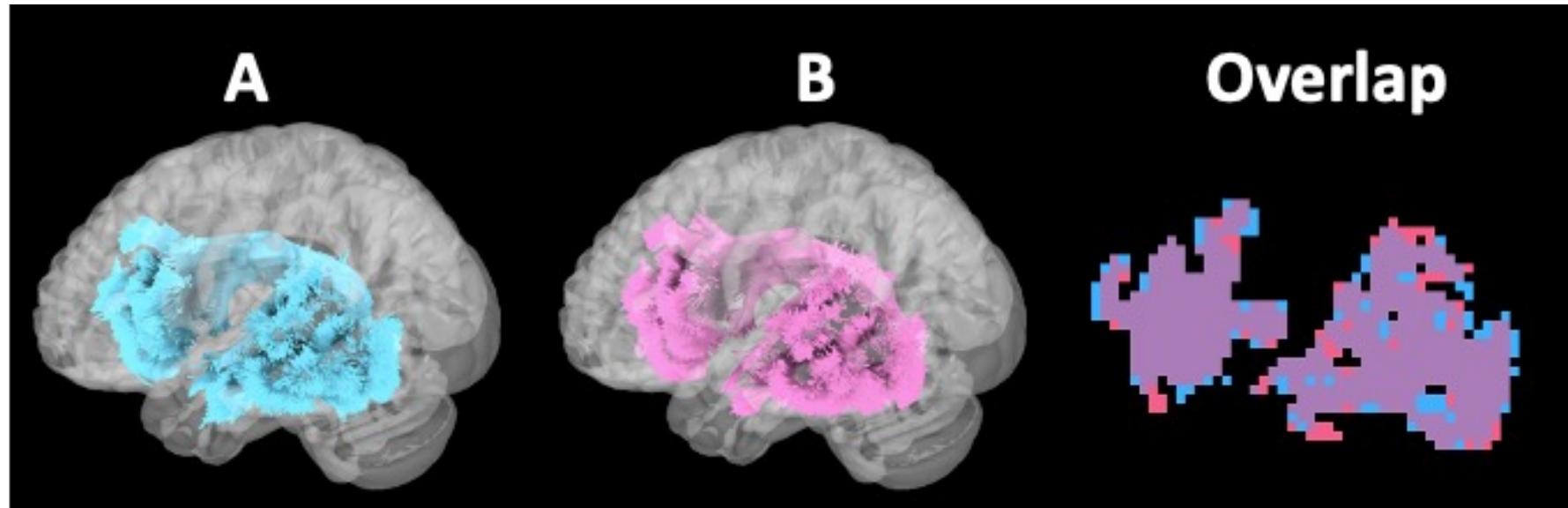
# Within-session accuracies of all CS-DSI schemes are very high!!!

**Distribution across all streamlines**



# Need a standard to compare against

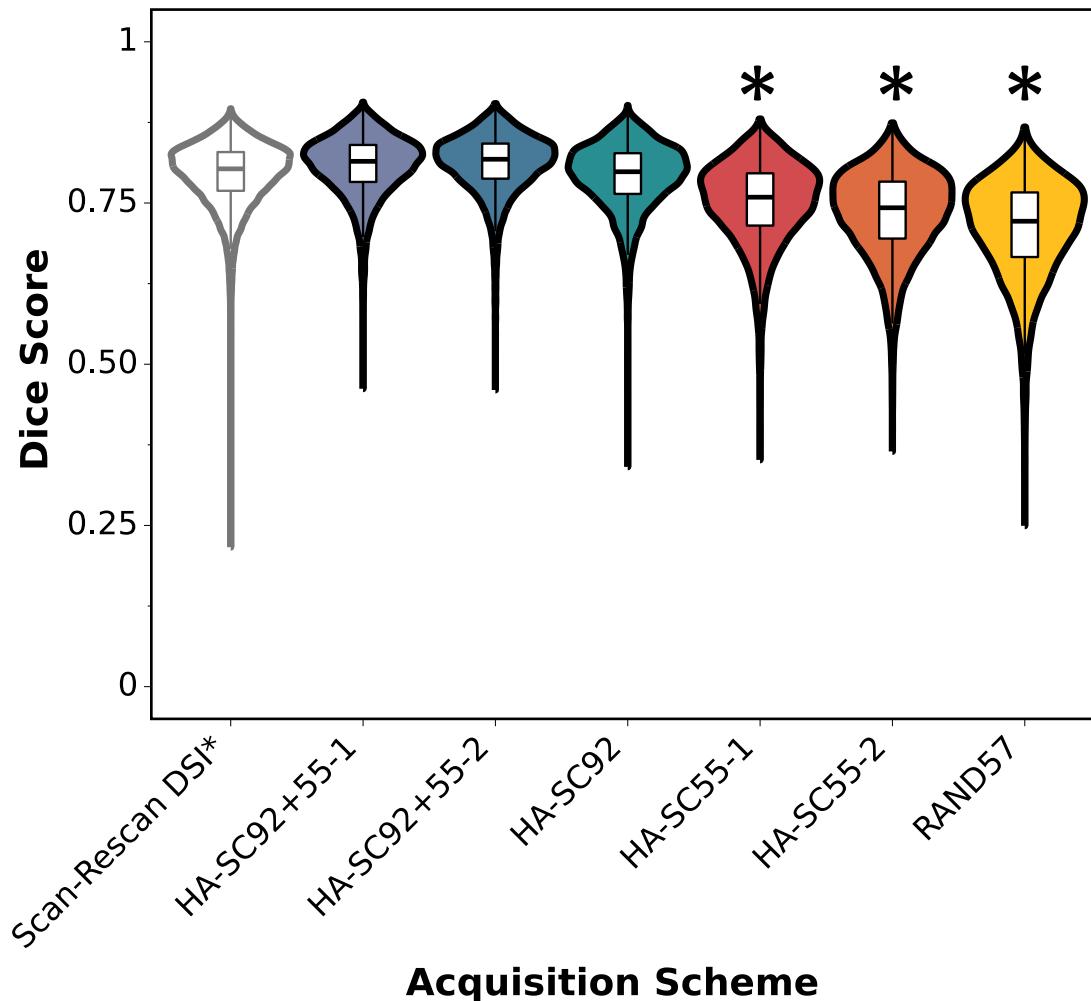
Scan-rescan dice score of the full DSI (between-session reliability)



Full DSI session 1 vs. Full DSI session 2 for participant X

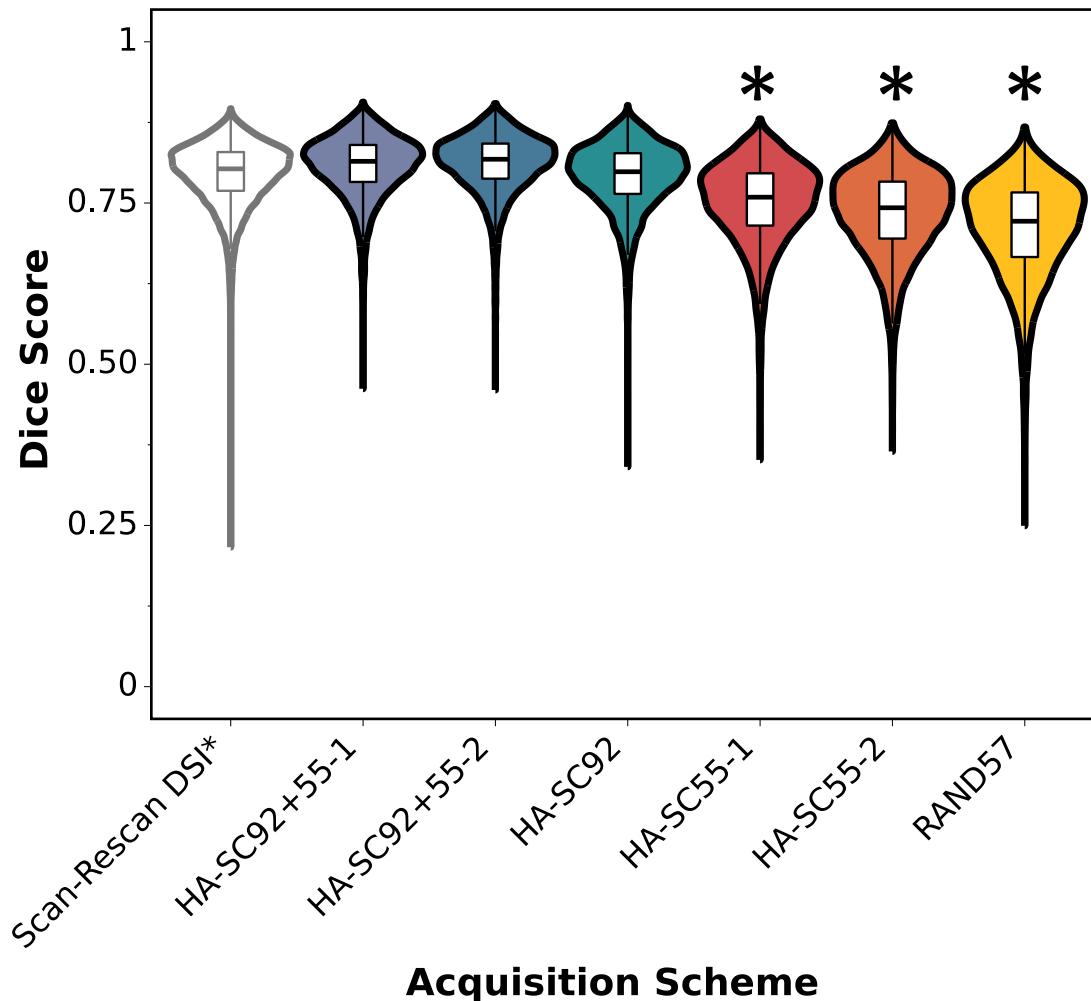
**Difference between scan sessions of the full DSI. Sequence.**

# CS-DSI within-session accuracies are comparable with full DSI reliability!



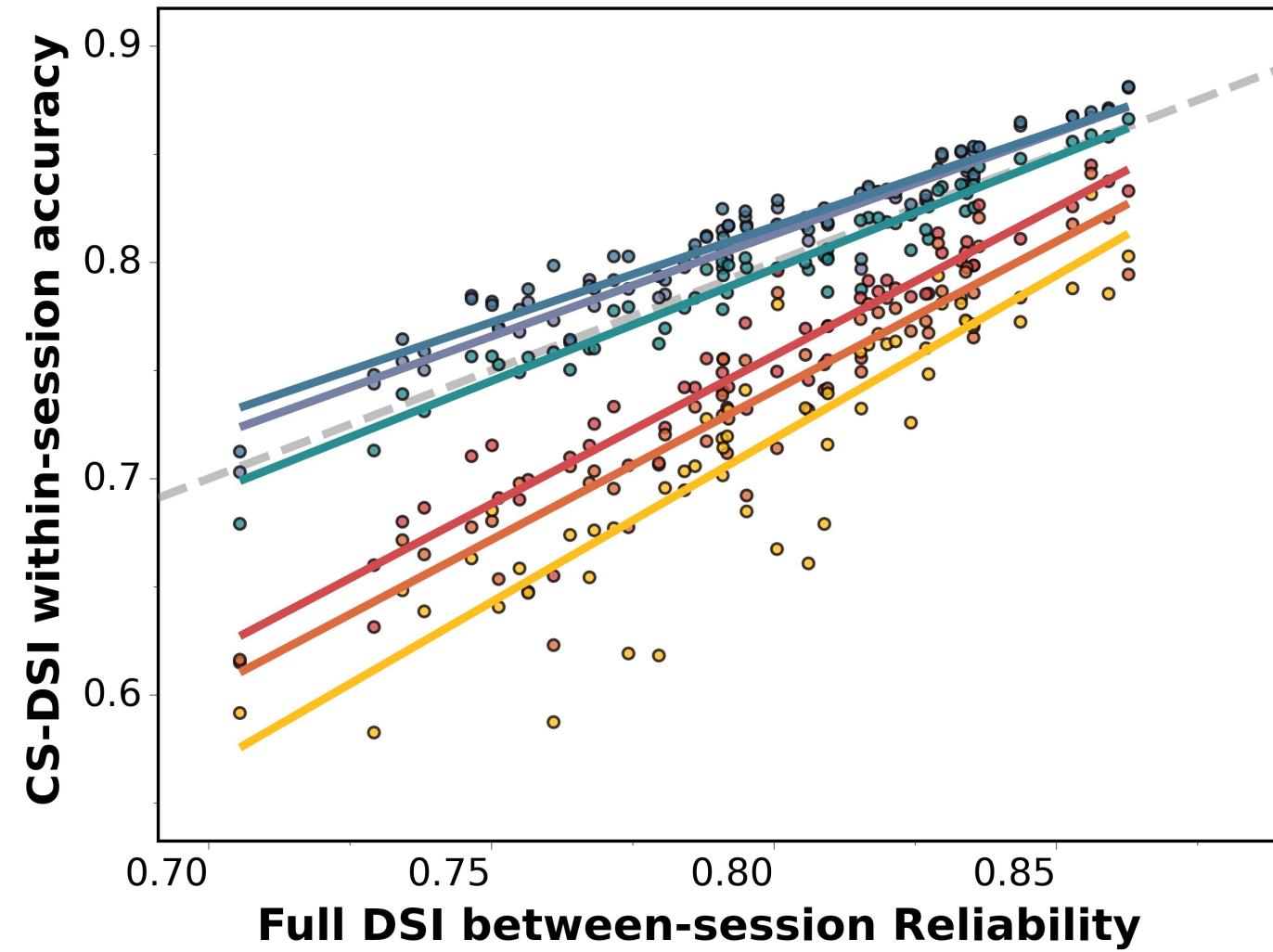
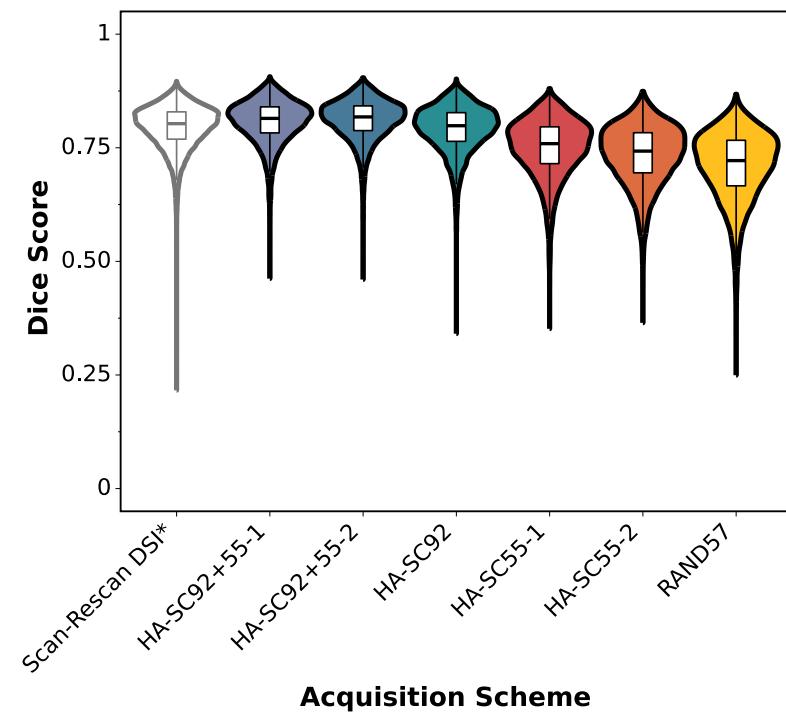
**Scan-rescan DSI:**  
Dice score between  
streamline reconstructed  
by full DSI in different  
sessions (pair-wise)

# CS-DSI within-session accuracies are comparable with full DSI reliability!

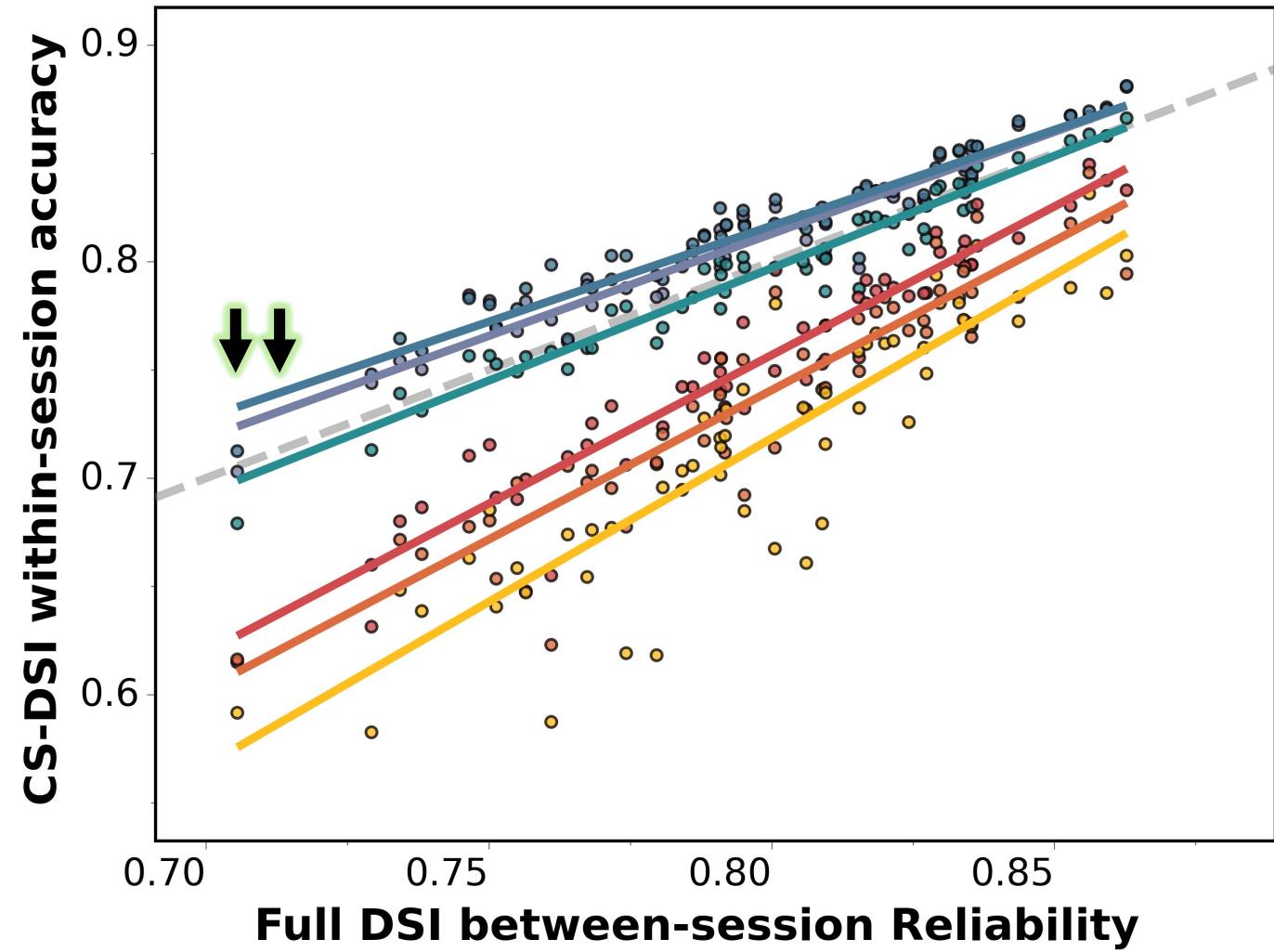
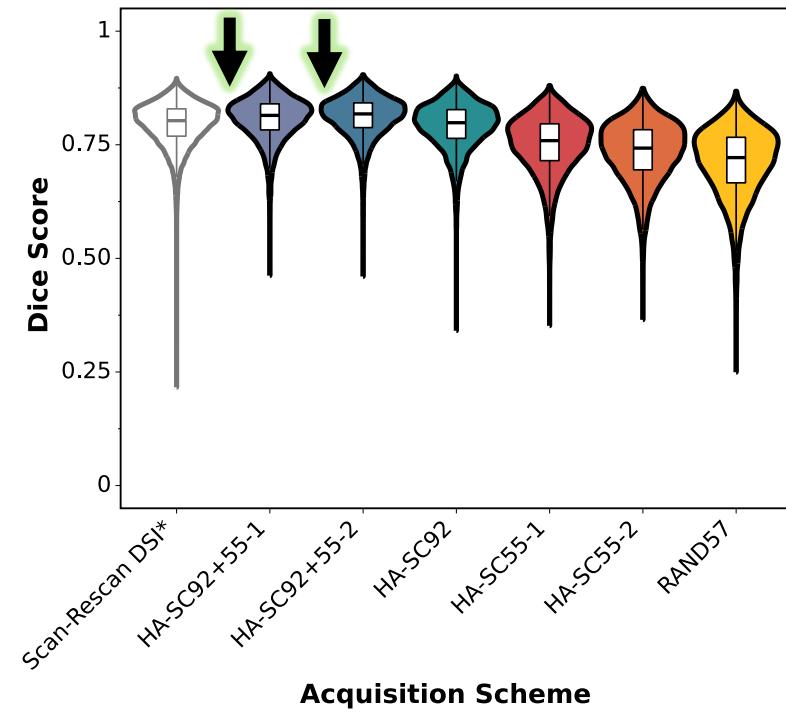


**Scan-rescan DSI:**  
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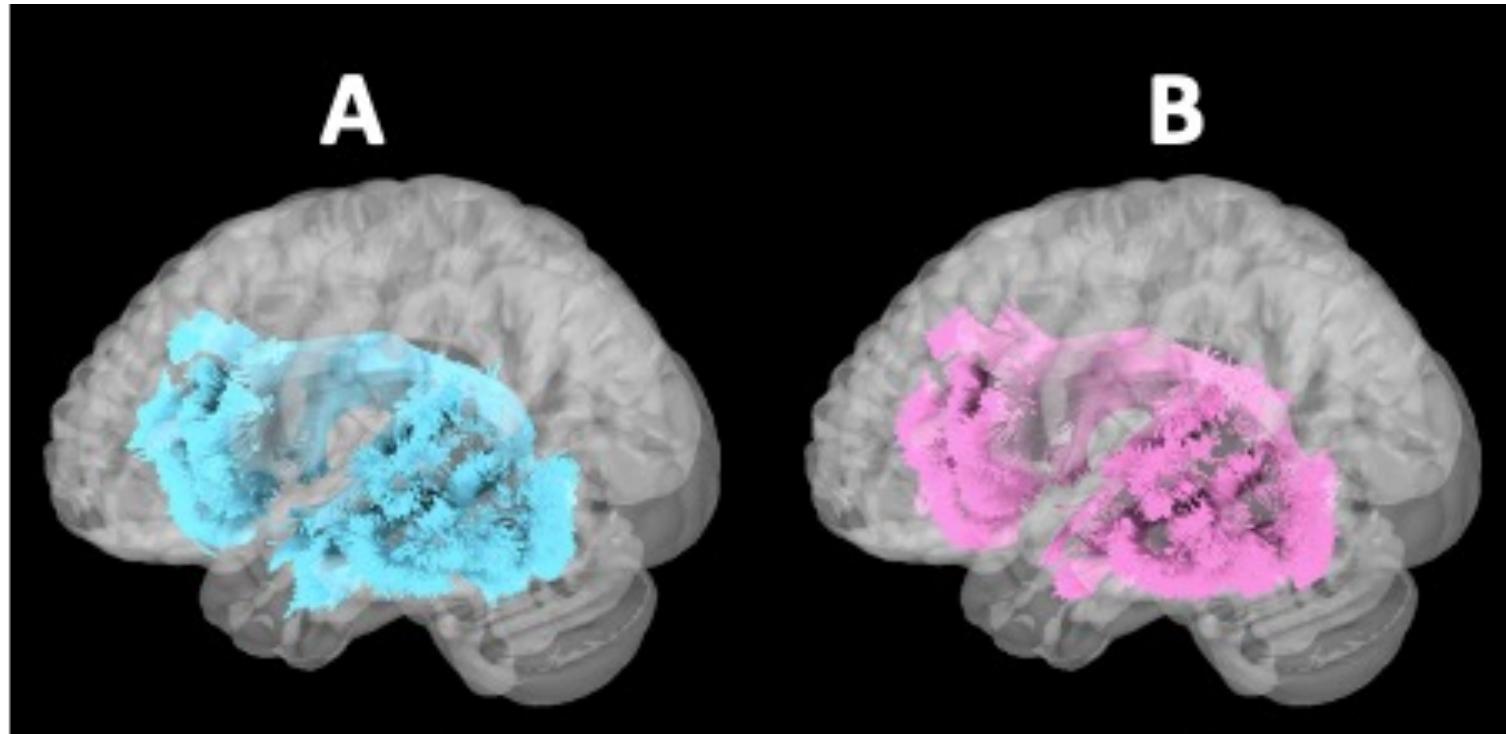
# CS-DSI within-session accuracies are correlated with full DSI reliability!



# CS-DSI within-session accuracies are correlated with full DSI reliability!



# Between session accuracy



CS-DSI session 1

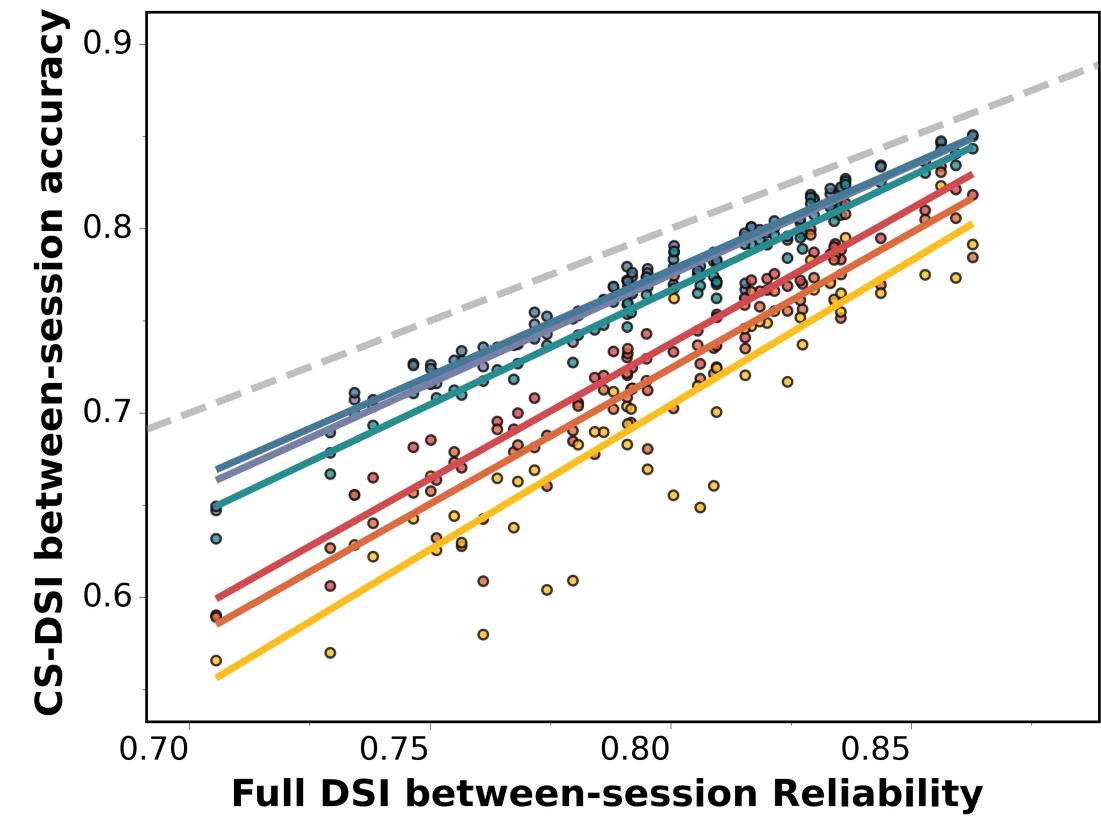
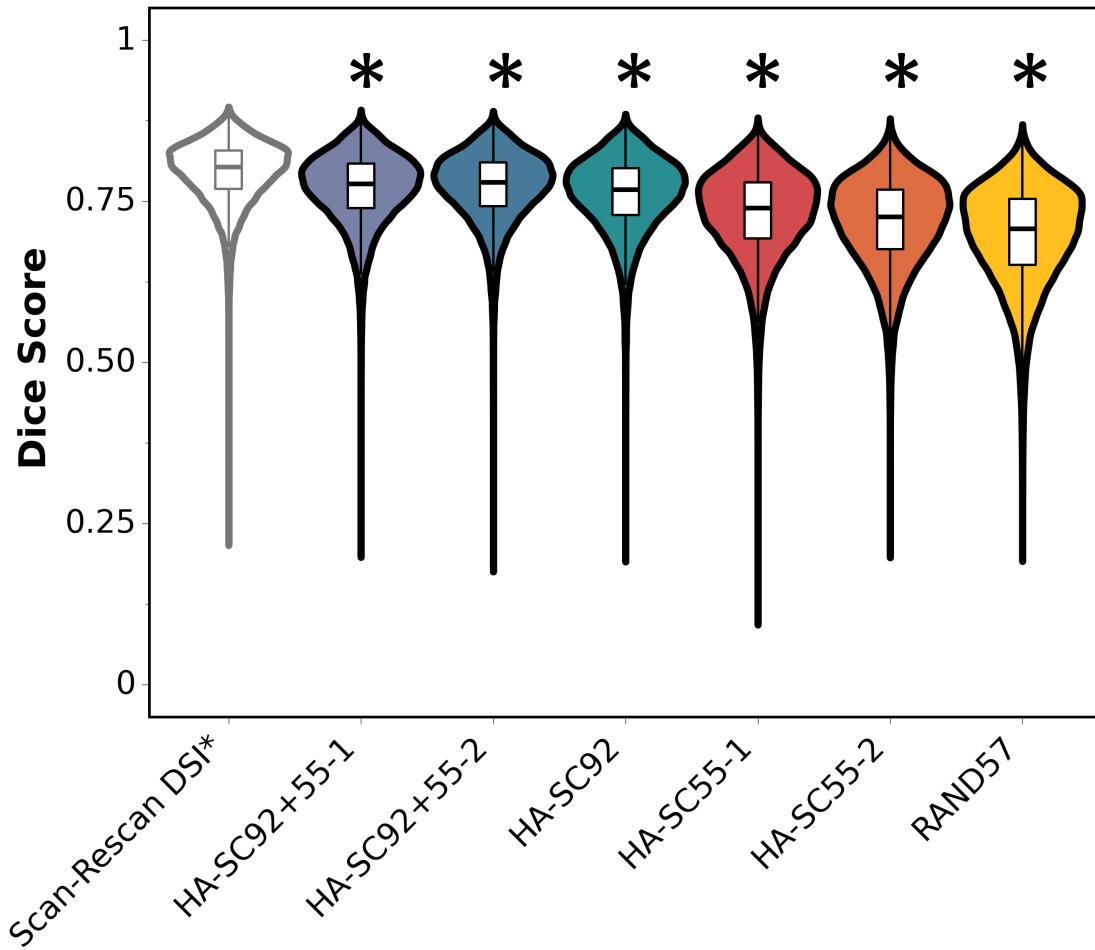
vs.

Full DSI session 2

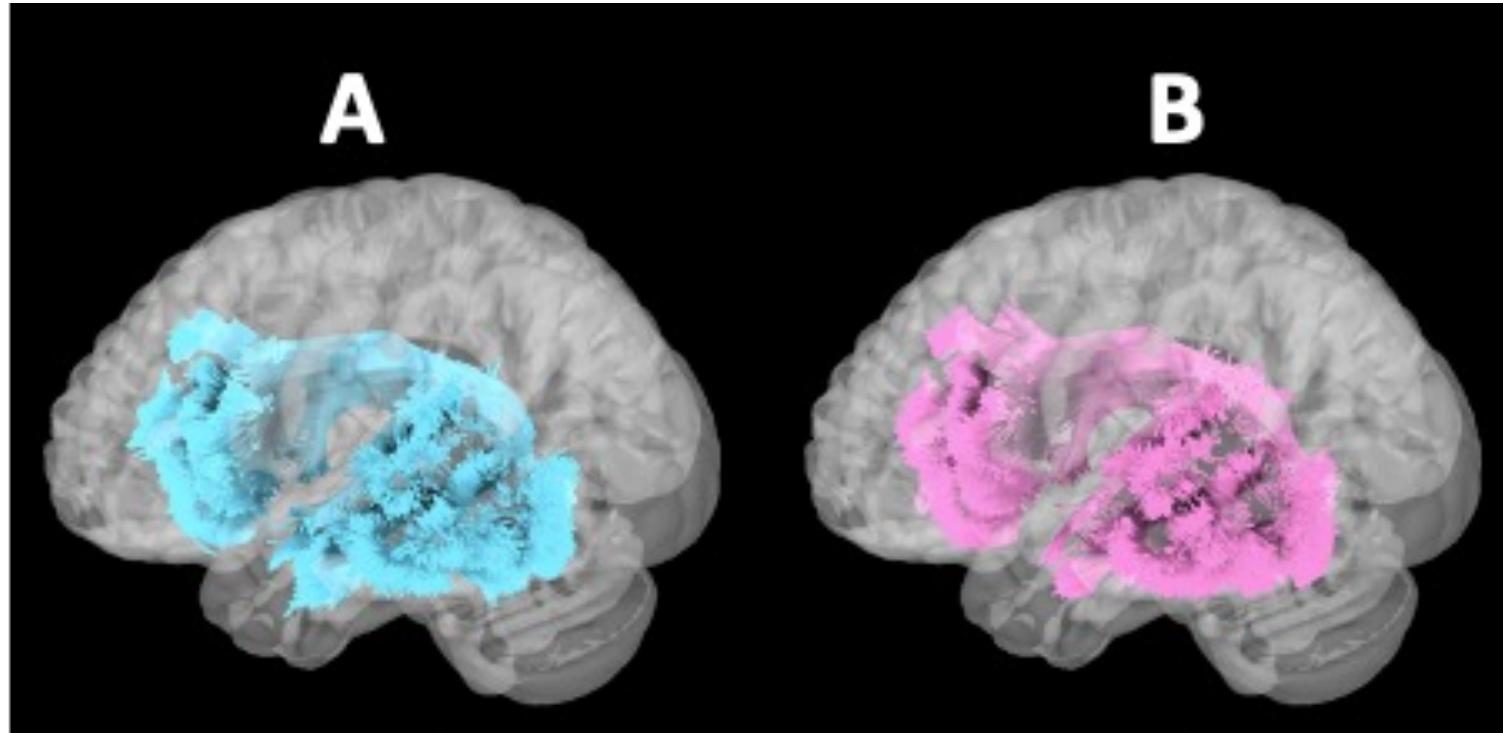
for participant X

Dice score  
between  
streamlines  
generated by CS-  
DSI in a session  
and full DSI in a  
*different* session  
(set of 28 pairwise  
dice scores for  
each sub).

*CS-DSI between-session* accuracy is also comparable and correlated with full DSI reliability!



# Between session reliability



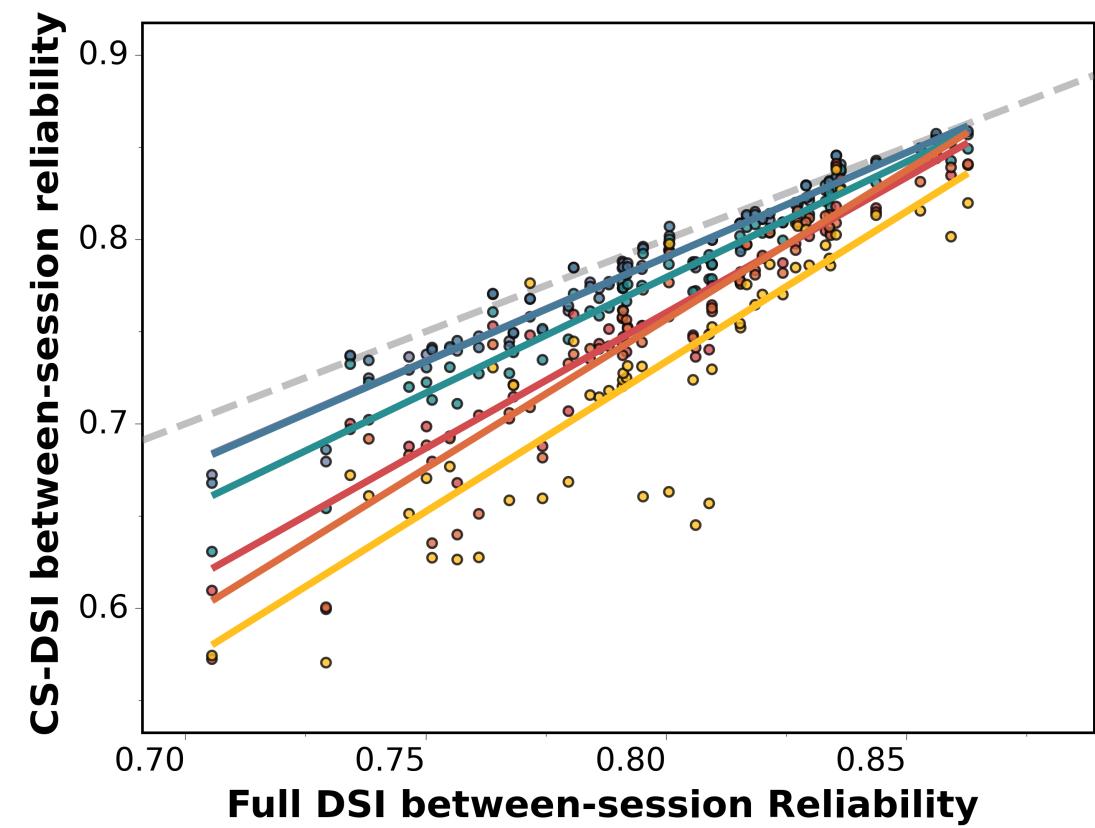
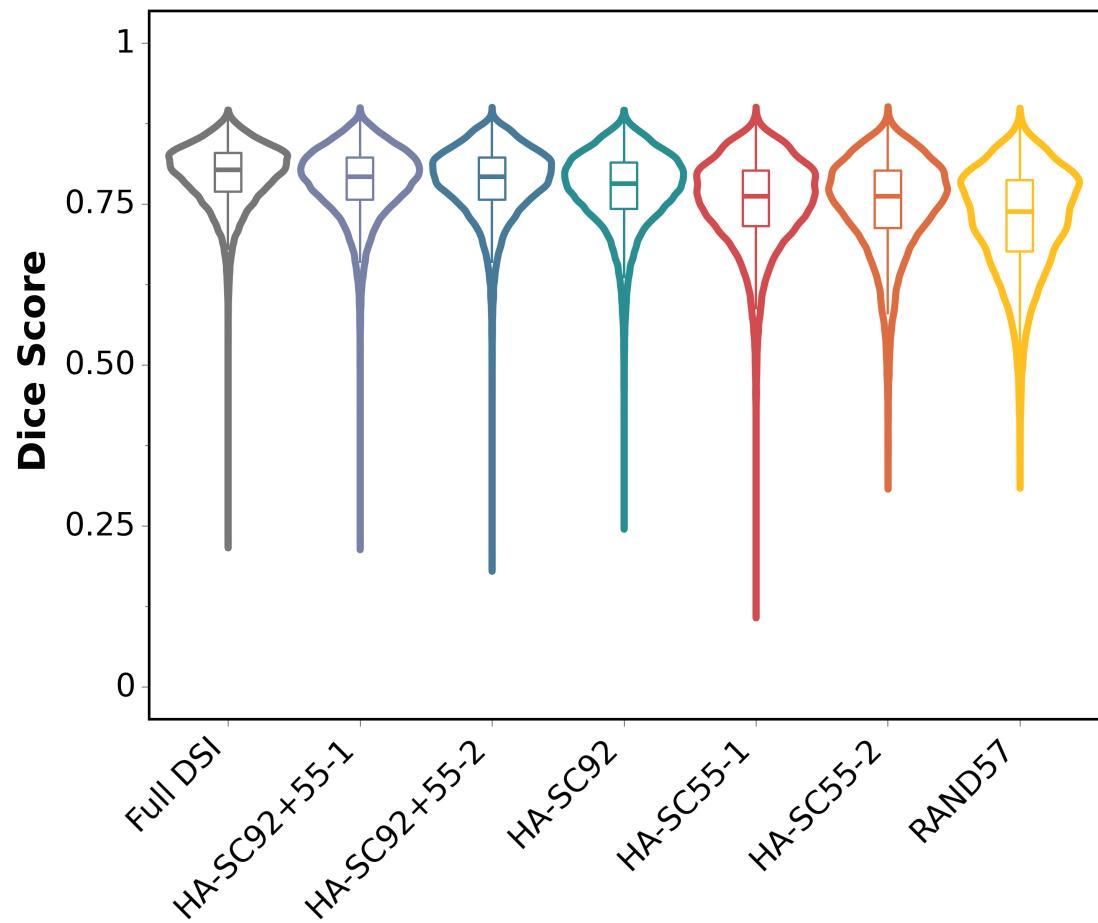
CS-DSI session 1

vs.

CS-DSI session 2

for participant X

*CS-DSI reliability is comparable and correlated with full DSI reliability!*

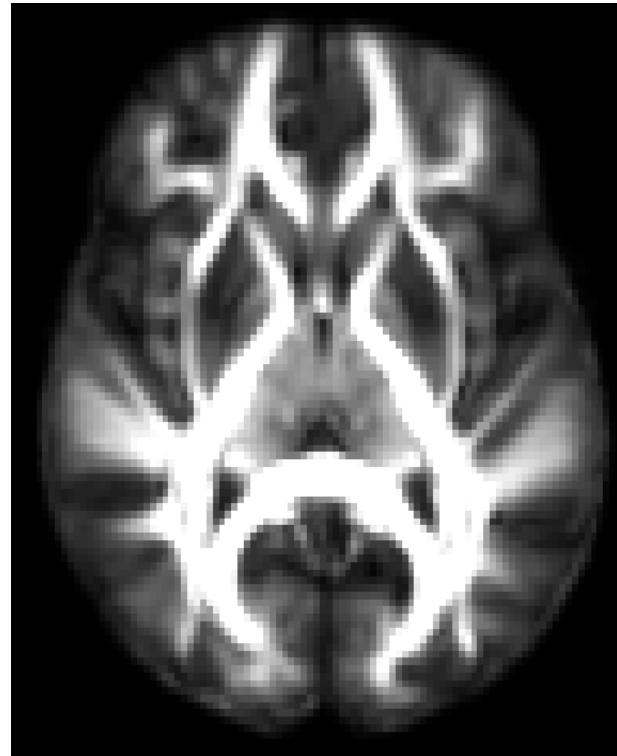
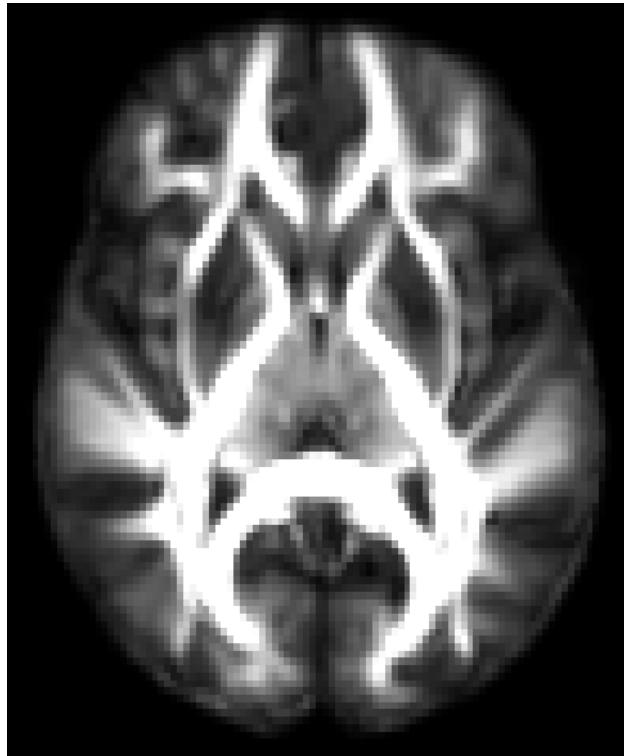


CS-DSI can **accurately** and **reliably** reconstruct streamlines, comparable with those reconstructed by full DSI, at a fraction of the acquisition time.



What about more localized metrics of microstructure like voxel-wise scalars?

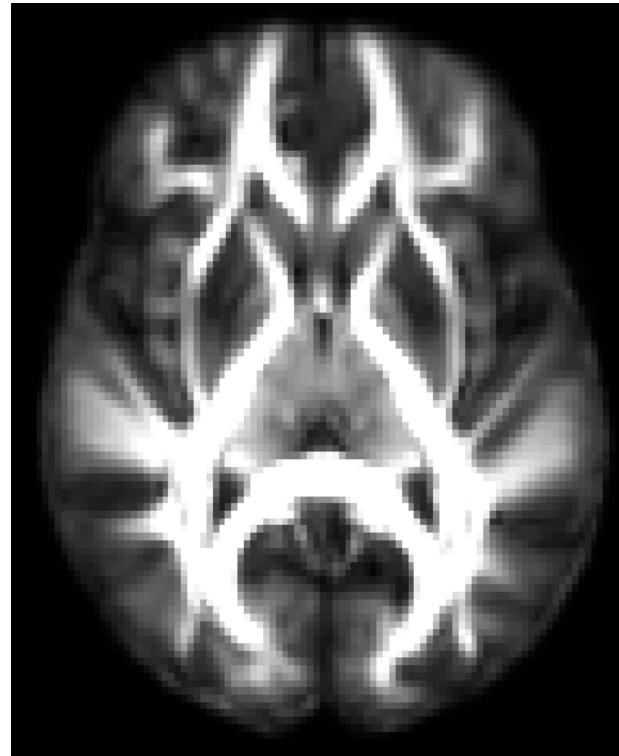
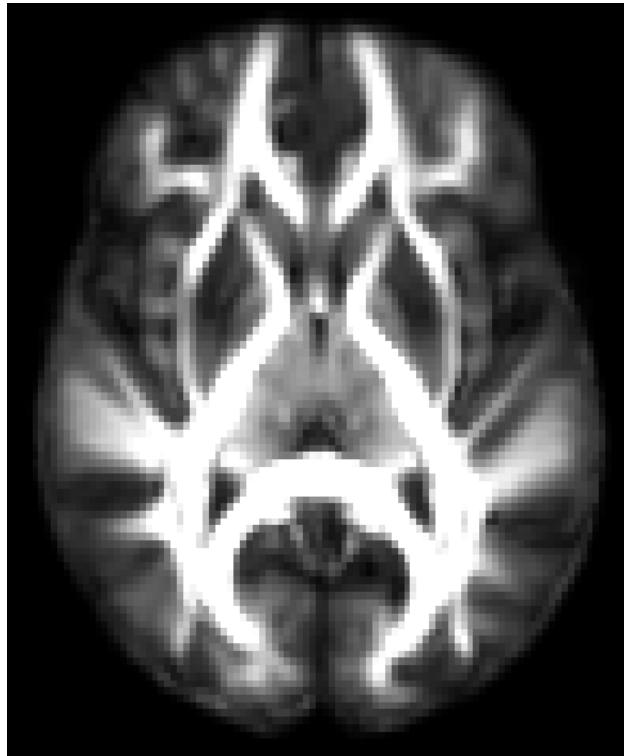
Using the same metrics to evaluate CS-DSI scalars, but with Pearson R to quantify relationships, instead of dice scores.



**NQA as the exemplar scalar:**

- Normalized Quantitative Anisotropy
- Maximum peak of the ODF
- Similar to FA
- Can be thought of as a measure of integrity

Using the same metrics to evaluate CS-DSI scalars, but with Pearson R to quantify relationships, instead of dice scores.



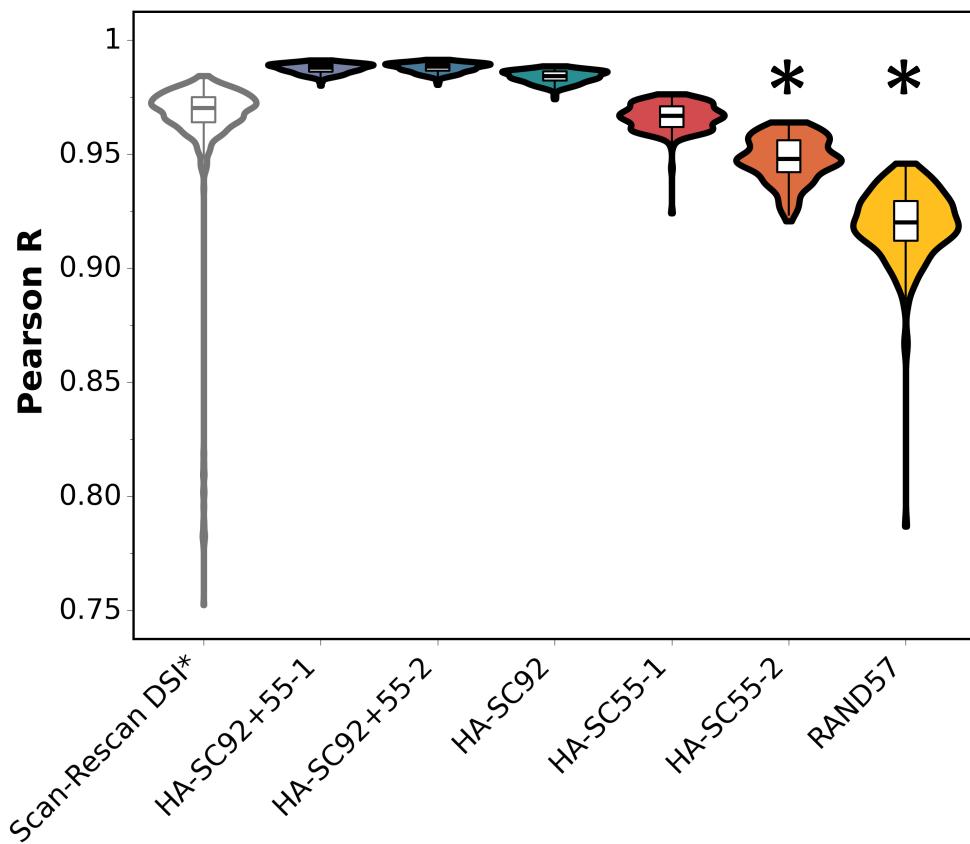
**Within Session Accuracy:**  
CS-DSI vs Full DSI, same session

**Between Session Accuracy:**  
CS-DSI vs Full DSI, different sessions

**Between Session Reliability:**  
CS-DSI vs CS-DSI, different sessions.

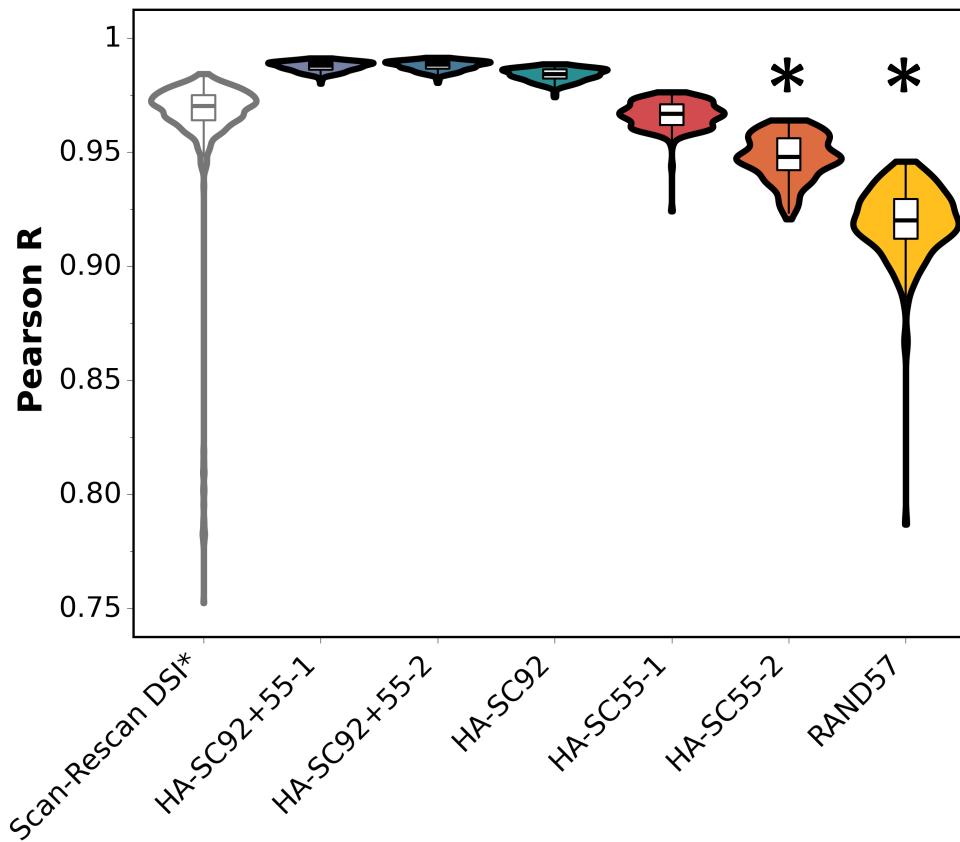
# NQA is also accurately estimated by CS-DSI!

## Within-session accuracy

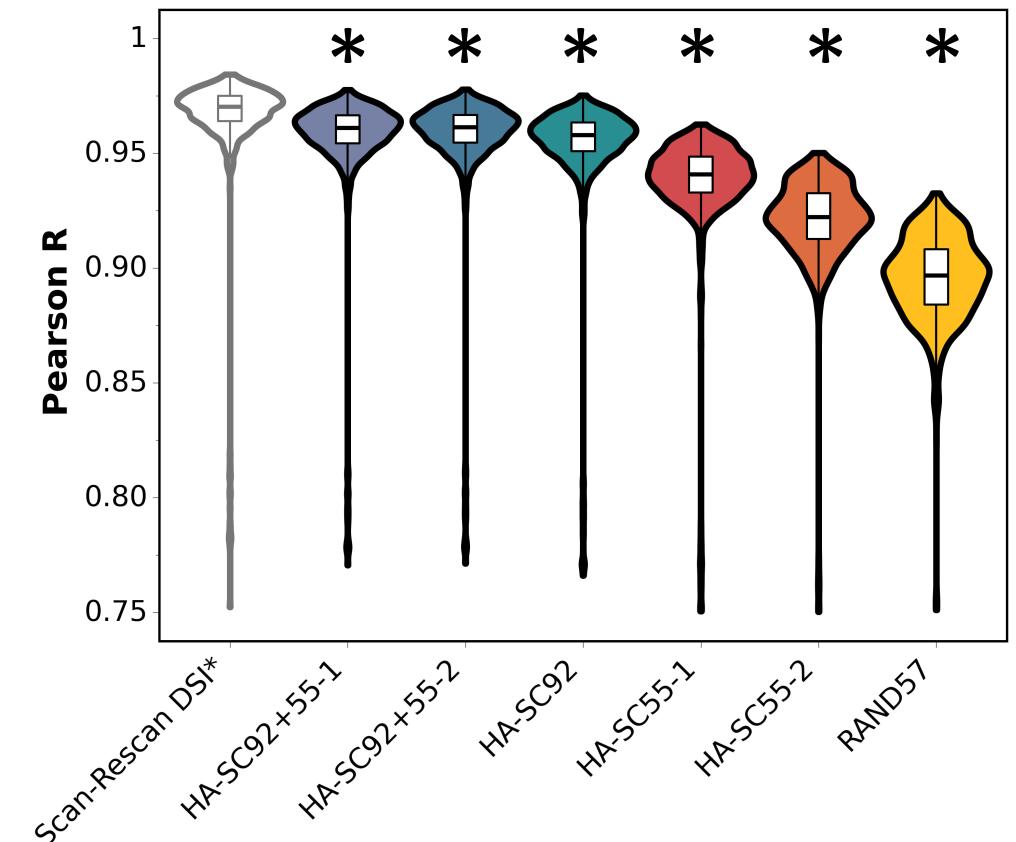


# NQA is also accurately estimated by CS-DSI!

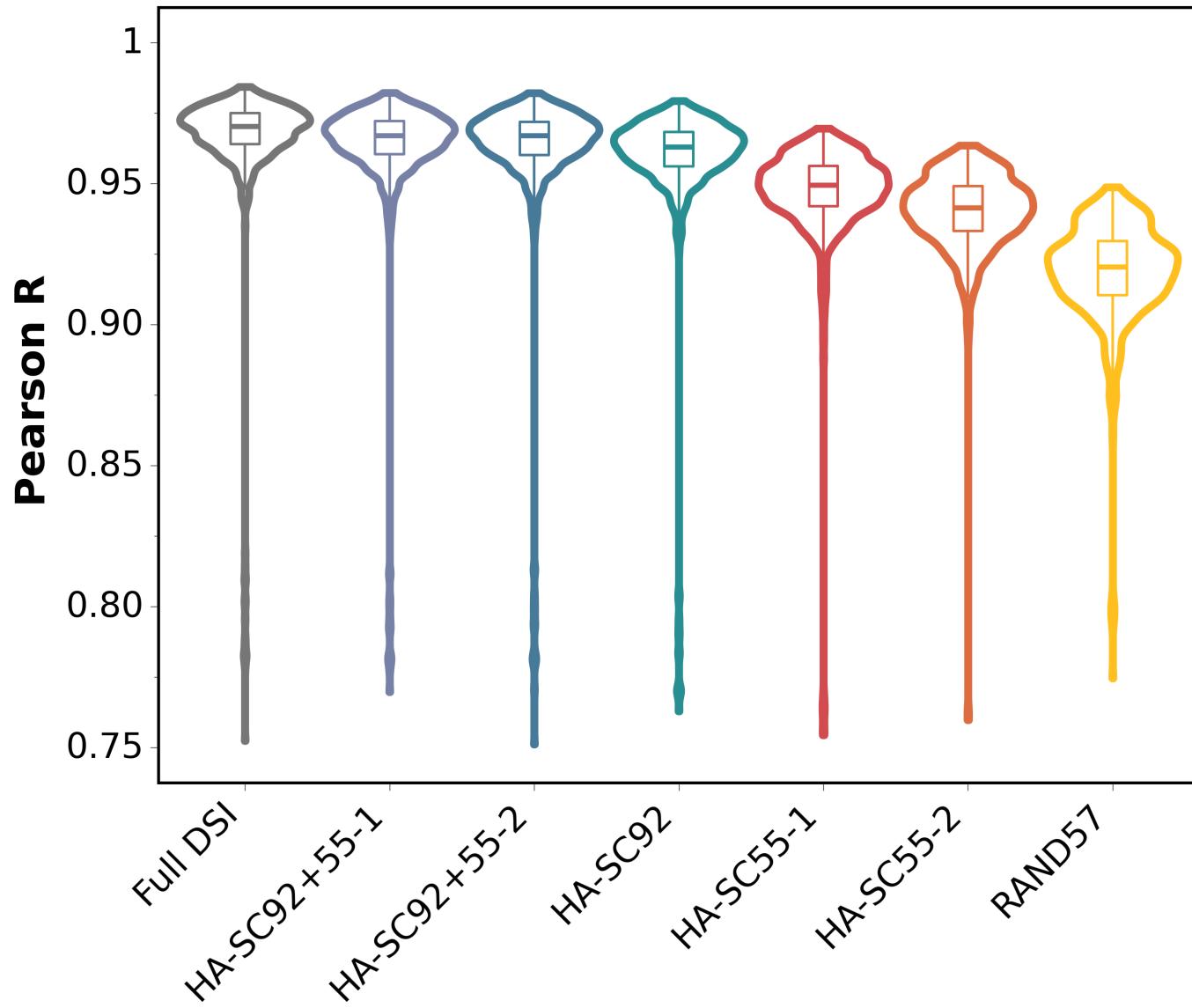
## Within-session accuracy



## Between-session accuracy



# NQA is reliably estimated by CS-DSI!



## CS-DSI can:

- Accurately and reliably reconstruct streamlines
- Accurately and reliably estimate scalar metrics
- All in up to 20% of the scan time!

## CS-DSI can:

- Accurately and reliably reconstruct streamlines
- Accurately and reliably estimate scalar metrics
- All with upto an 80% reduction in scan time!

But all of these results were shown in synthetically subsampled data.  
Can we get similar outcomes from directly acquired CS-DSI data?

# Prospective dataset

20 participants, 1 session only (can only evaluate accuracy).

**Acquired:**

HA-SC92

HA-SC55-1

HA-SC55-2

RAND57

**Combined:**

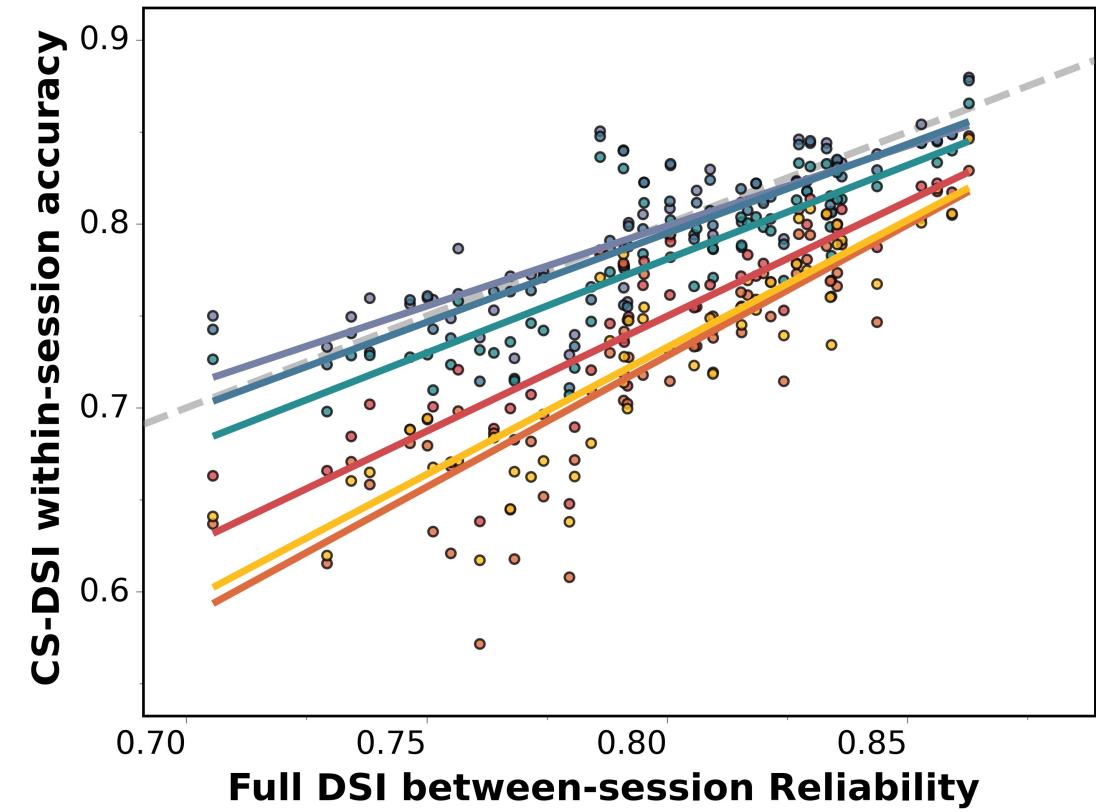
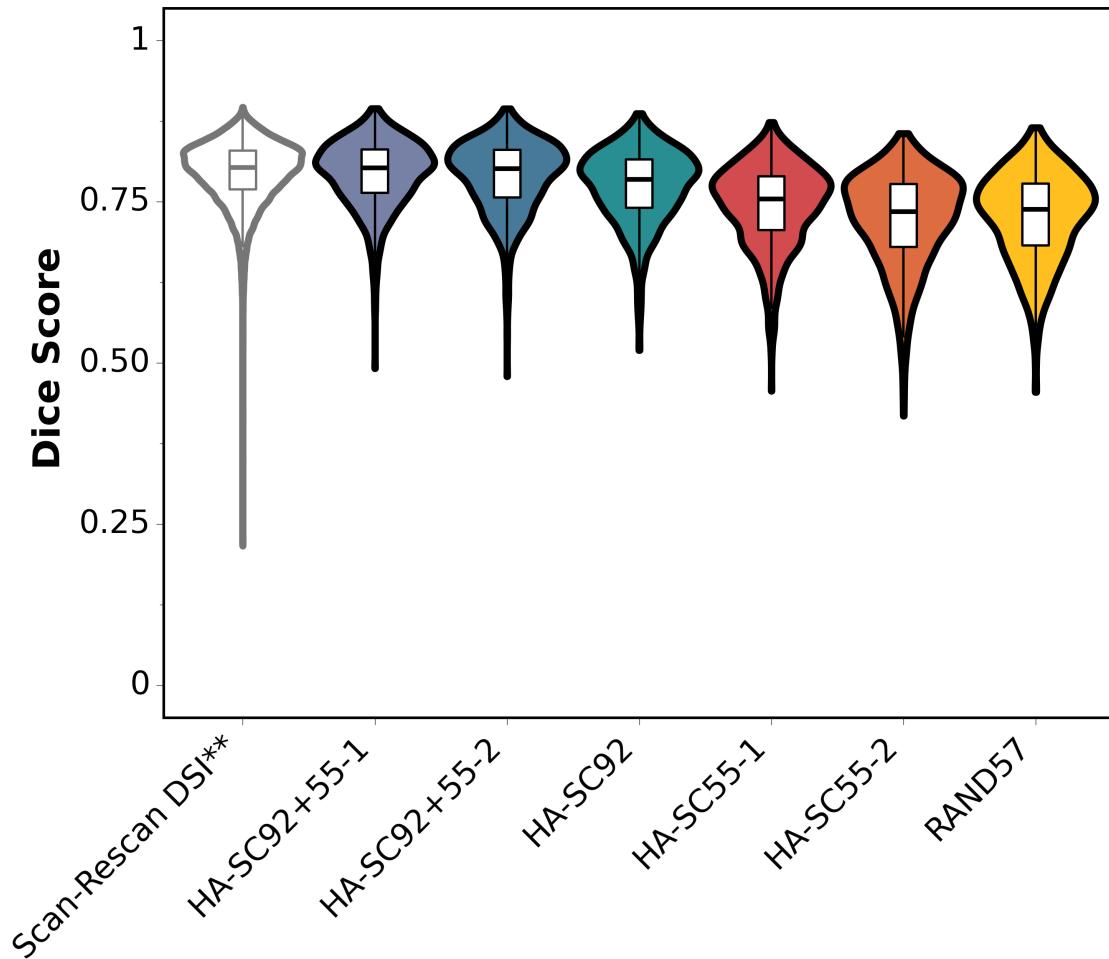
**Full DSI (258 dir.)**

HA-SC92+55-1

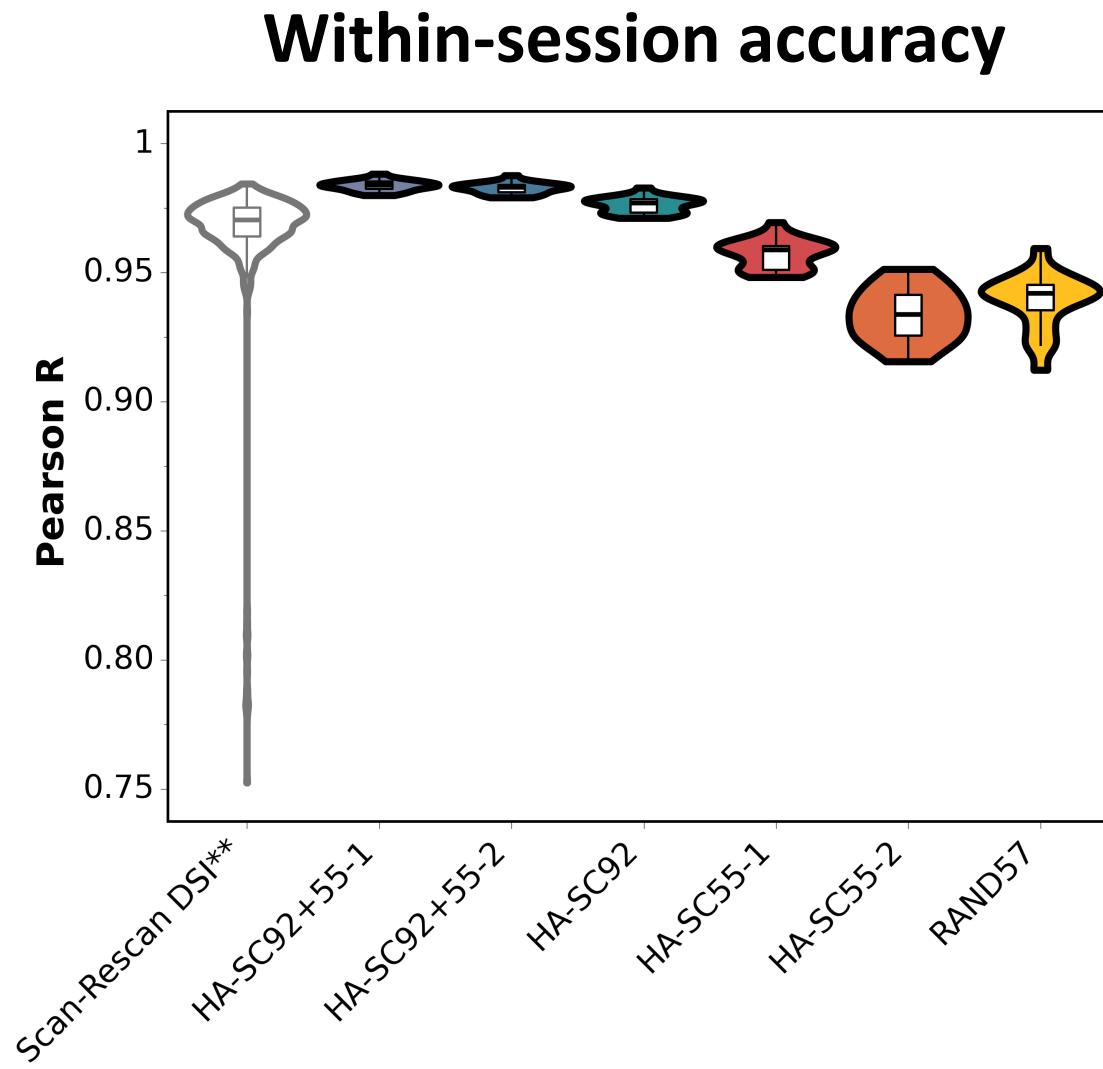
HA-SC92+55-2

Prospectively acquired CS-DSI can accurately segment streamlines.

### Within-session accuracy



Prospectively acquired CS-DSI can also accurately NQA.



# Summary, based on stats



Sequence	Acquisition time (minutes)	Streamlines	Scalars
Full DSI	20		
HASC92+55 – 1	11.9		
HASC92+55 – 2	11.8		
HASC92	7.4		
HASC55 – 1	4.5	96%	
HASC55 – 2	4.3	94%	95%
RAND57	5.4	93%	95%