# Accurate Prediction of Individual Brain Function Maps From Structural Imaging Utilizing Deep Learning

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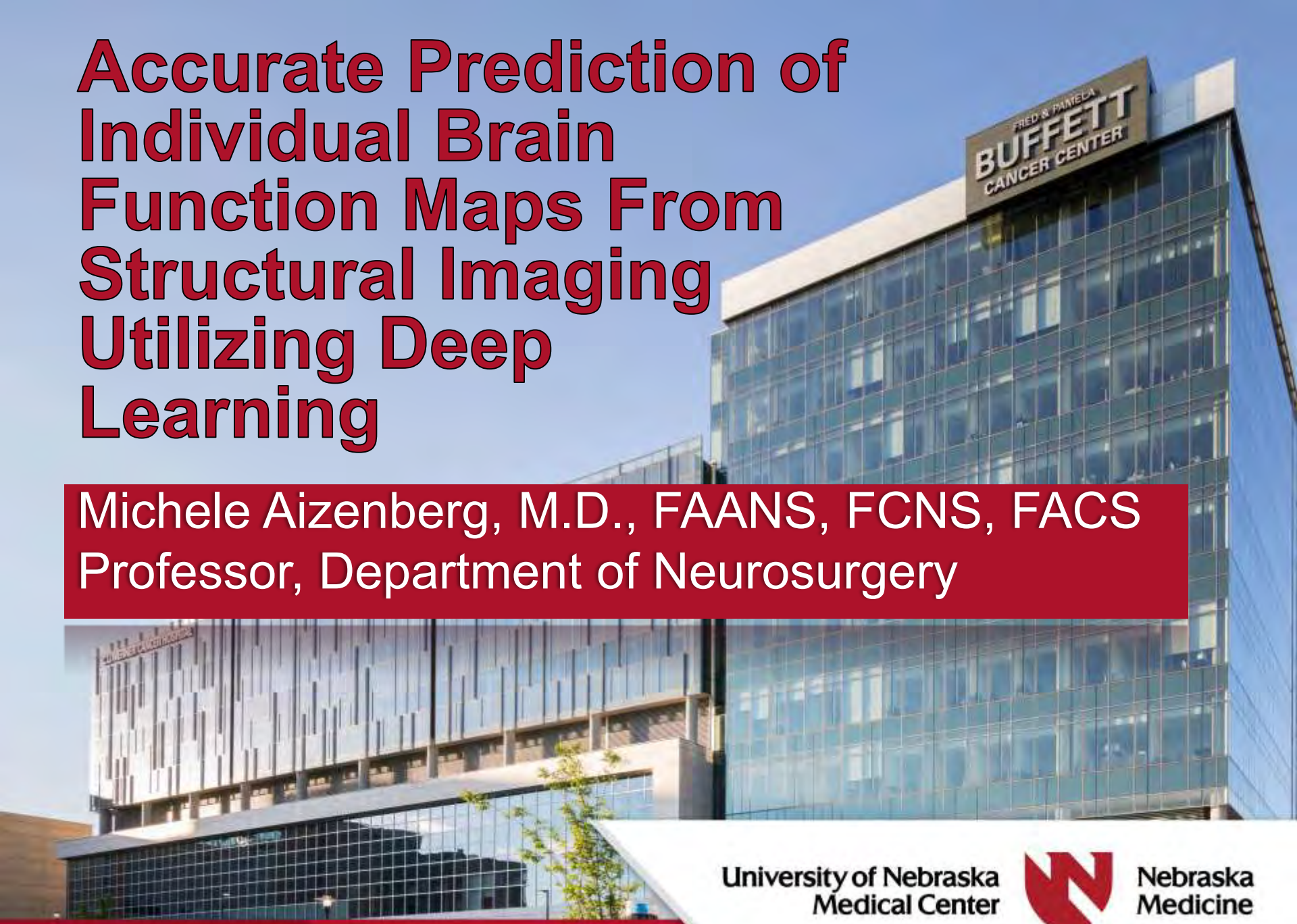



University of Nebraska Medical Center
Nebraska Medicine

# Disclosures

- Azurity Pharmaceuticals, Inc.
  - Study drug for multi-center randomized IIT for brain metastasis

# Overview/Objectives

- Review brain mapping and why its used
- Evaluate accuracy of clinically available methods
- Assess an alternate method of function localization utilizing deep learning
- Discuss possible clinical applications

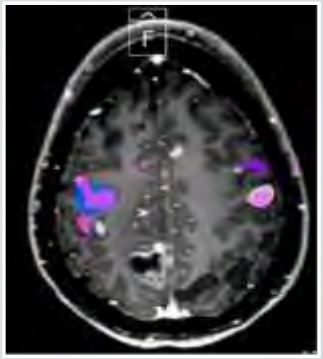
# Brain mapping

- Non-invasive functional brain mapping is used as a neurosurgical planning tool to help preserve eloquent function
  - Identify important areas involved in:
    - Language
    - Motor
    - Sensory
    - Vision
  - Mapping helps achieve maximal safe resection while preventing negative effects on QOL, morbidity, and survival times

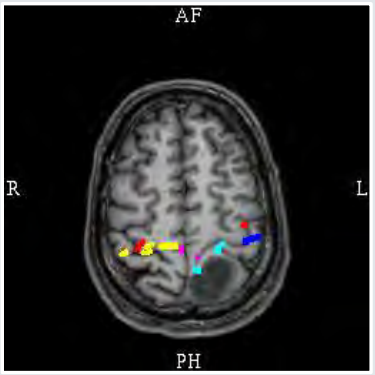
# Brain mapping techniques

## Standard clinical approaches

- Functional MRI (fMRI)
  - Task (t-fMRI) or resting state (rs-fMRI)
    - fMRI measures changes in oxygenated blood flow (BOLD)
    - When a particular brain region is activated, more oxygenated blood is sent to that region
- Magnetoencephalography (MEG)
  - Records magnetic fields produced by electrical currents in the brain
  - Task or resting state
  - Magnetic field changes can be analyzed to estimate the source of the changes (MSI)



PURPLE- L MOTOR FOOT
**WHITE**- L FOOT SENSORY
BLUE- L INDEX FINGER TAPPING
PINK- L HAND SENSORY

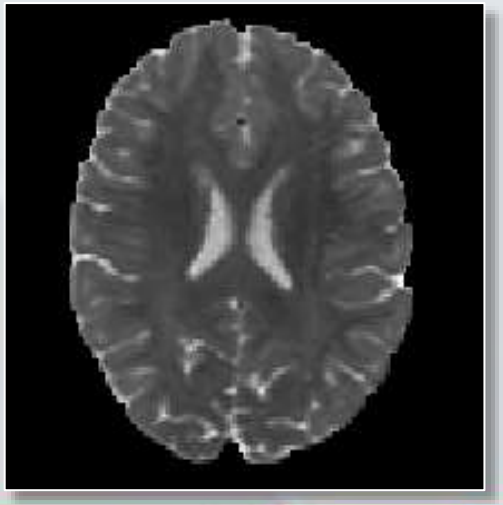


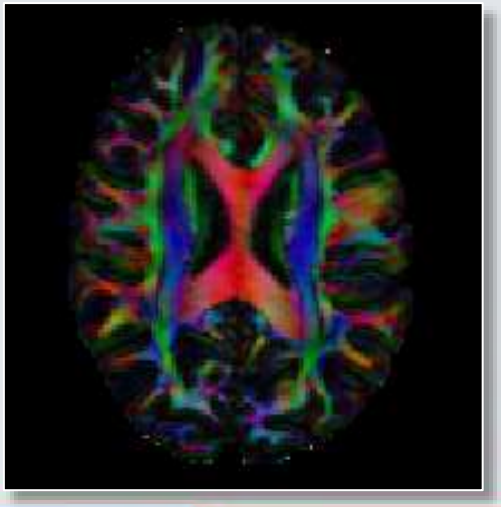

**MEG** sensory and motor
RED-MOTOR HAND
AQUA- SENSORY FOOT
BLUE- SENSORY HAND
MAGENTA-MOTOR FOOT

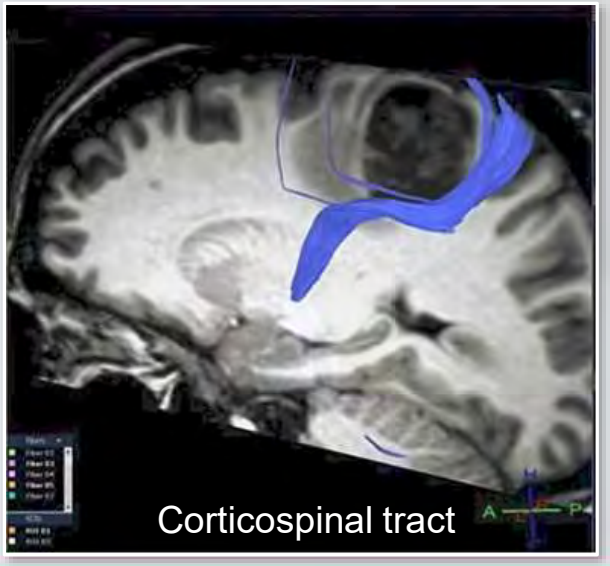
# Brain mapping techniques

## Standard clinical approaches

- Diffusion imaging provides information as to the integrity and directionality of groups of neurons in the brain
- Tractography to visualize important tracts of interest
  - Corticospinal (motor)
  - Thalamocortical (sensory)
  - Arcuate fasciculus (language)
  - Optic radiations (vision)



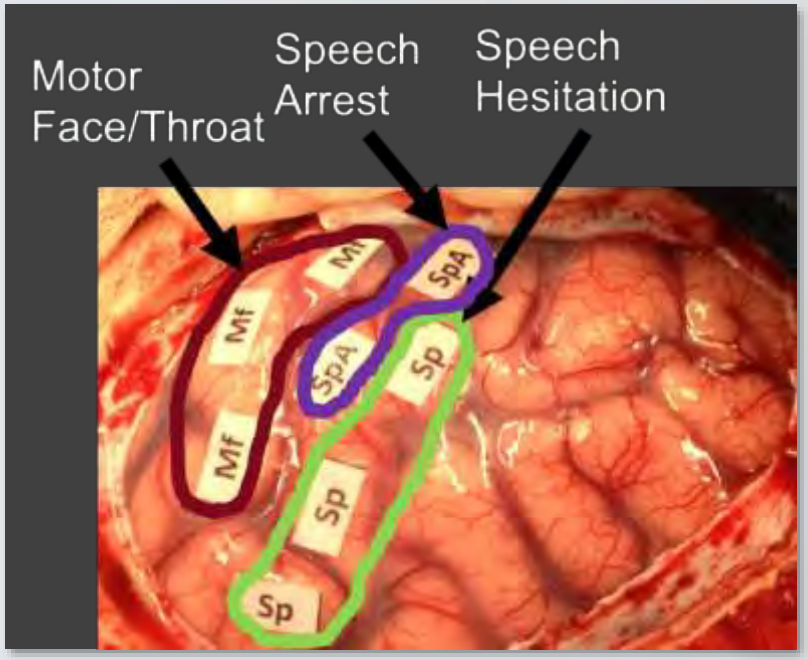




# Brain mapping techniques

## Standard clinical approaches

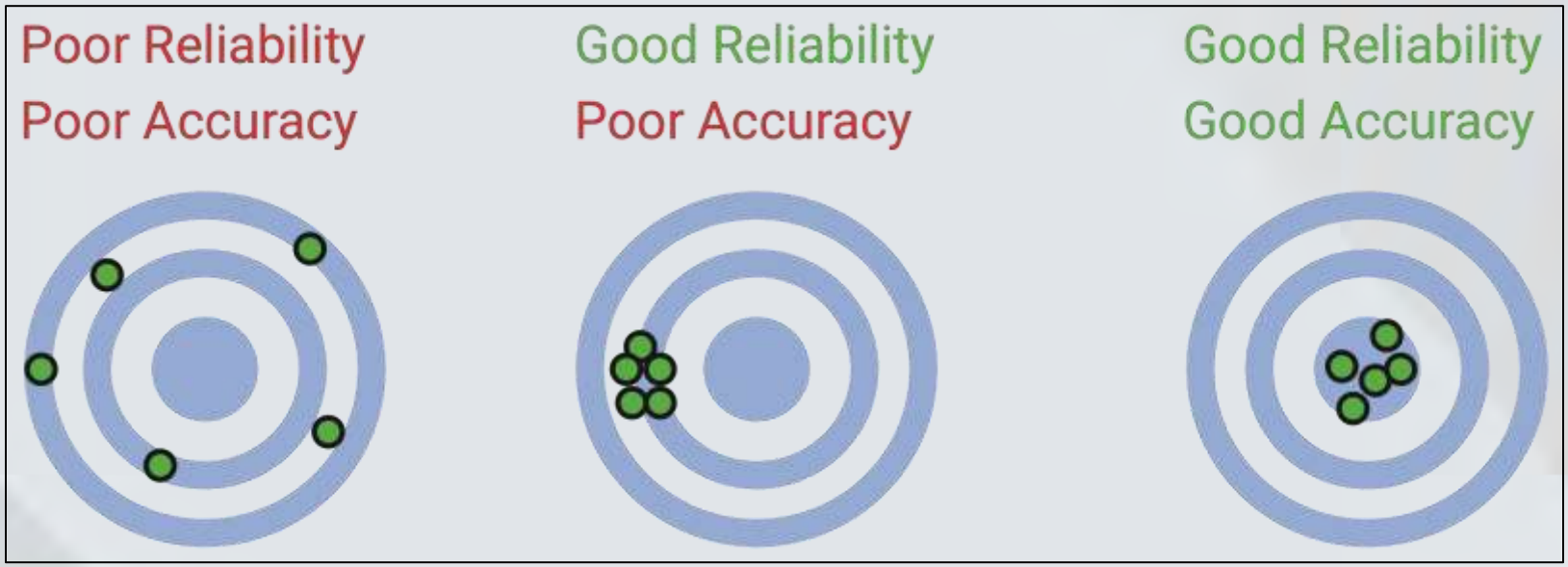
- Intra-operative mapping (invasive)
  - awake or asleep
  - both cortical and subcortical mapping
  - considered gold standard for localizing function



# Brain mapping techniques

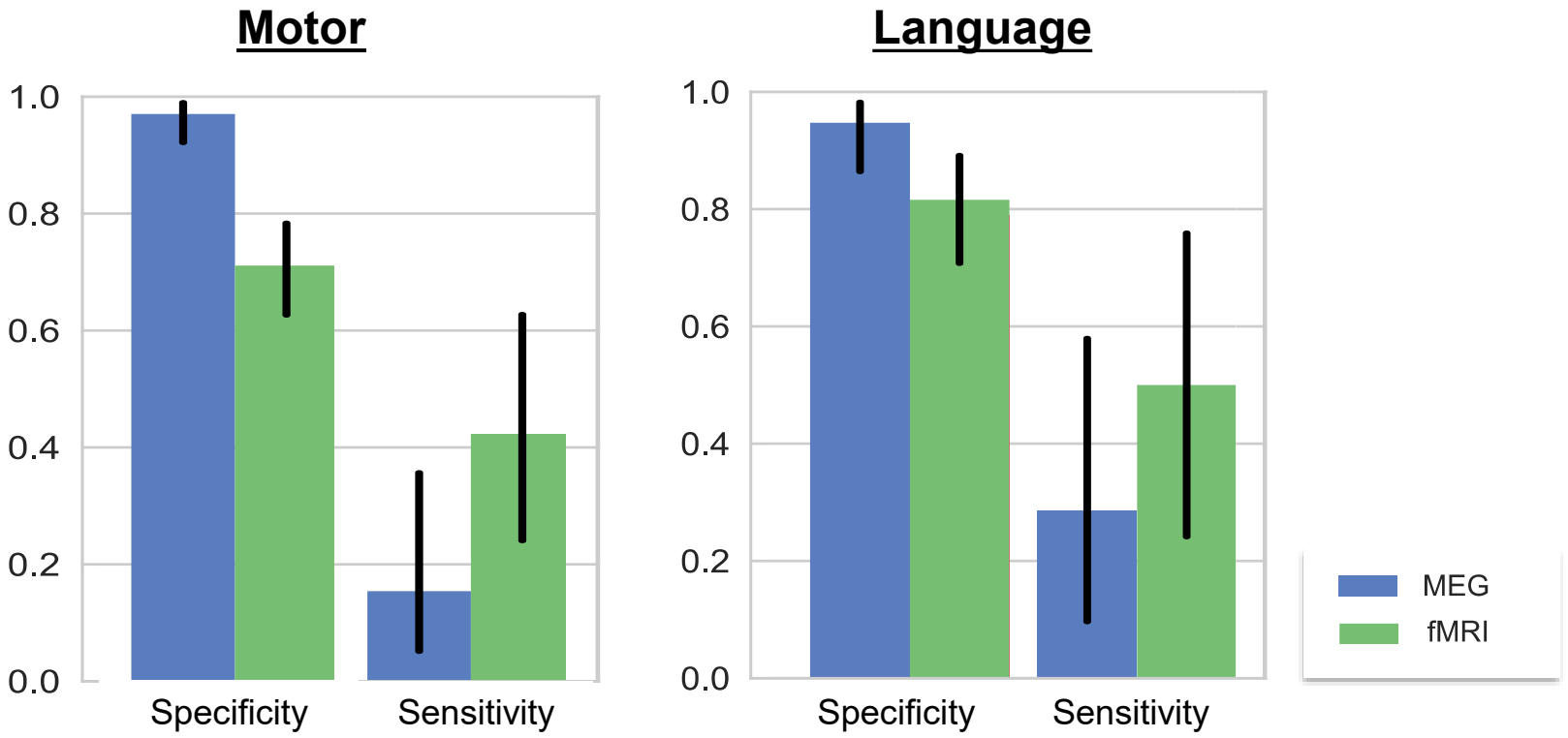
## Accuracy and Reliability

In thinking about scientific measurements and experiments….



# Brain mapping techniques
## Accuracy and Reliability

- fMRI and MEG comparison to intraoperative mapping




Ellis, David G., et al. *Neurosurgical focus* (2020)

# Brain mapping techniques

## Alternative options

- Are there alternative methods for localizing task function from imaging?
  - Task fMRI can be predicted from resting state fMRI
  - Could it also be predicted from *diffusion MRI*?

# Pre-surgical Mapping

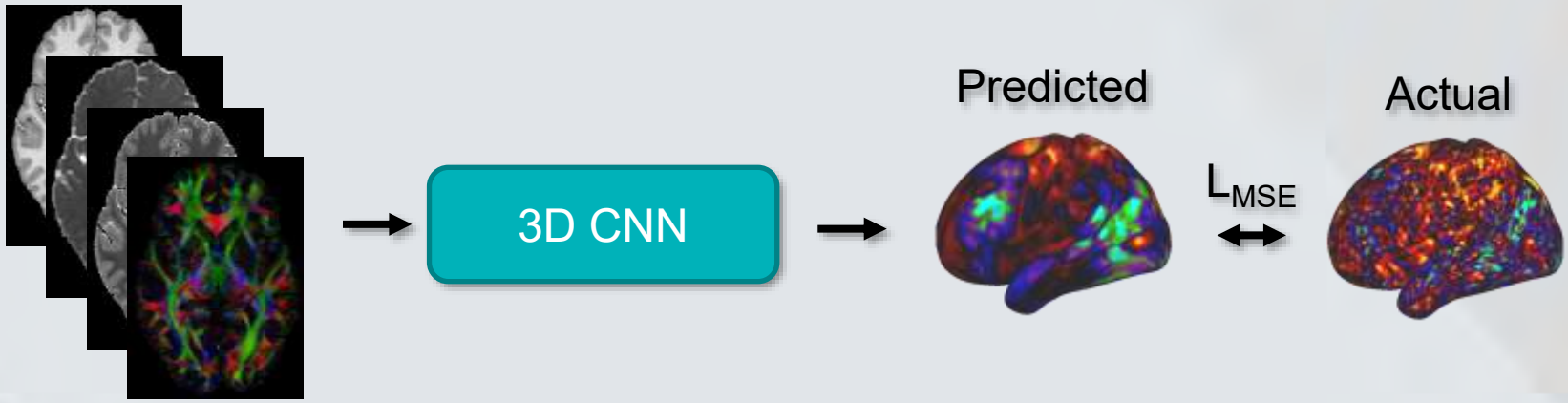
## Advantages of using diffusion images

- Diffusion imaging benefits:
  - Routinely acquired for presurgical evaluation
  - Does not require task performance by the patient
  - Has high test-retest reliability

# Pre-surgical Mapping

## Training structure-to-function model

We trained an AI model, a 3D convolutional neural network (CNN), to **predict functional brain activations (*task fMRI*) from structural brain images (*diffusion*) in healthy subjects**

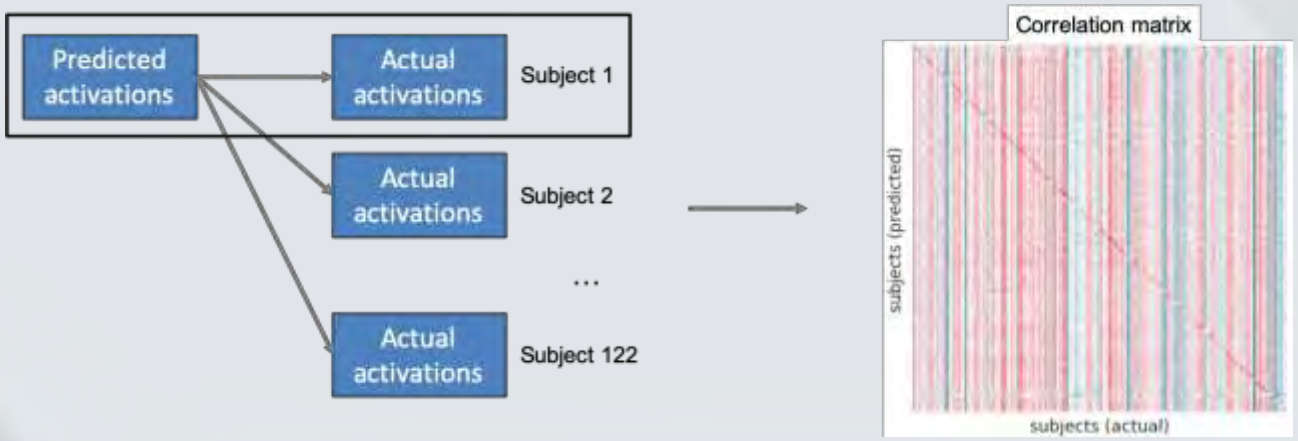



47 unique task activation volumes from seven different task domains from the HCP were used for model training and testing

Ellis, David G., and Michele R. Aizenberg. *Frontiers in Neuroimaging* (2022)

# Pre-surgical Mapping
## Evaluating structure-to-function model

- We evaluated the ability of the predictions to differentiate between individuals by using a correlation matrix
  - predicted task activation maps of a given subject were then compared to the actual activation maps for that subject as well as to the activation maps for all the other test subjects and a correlation matrix was constructed

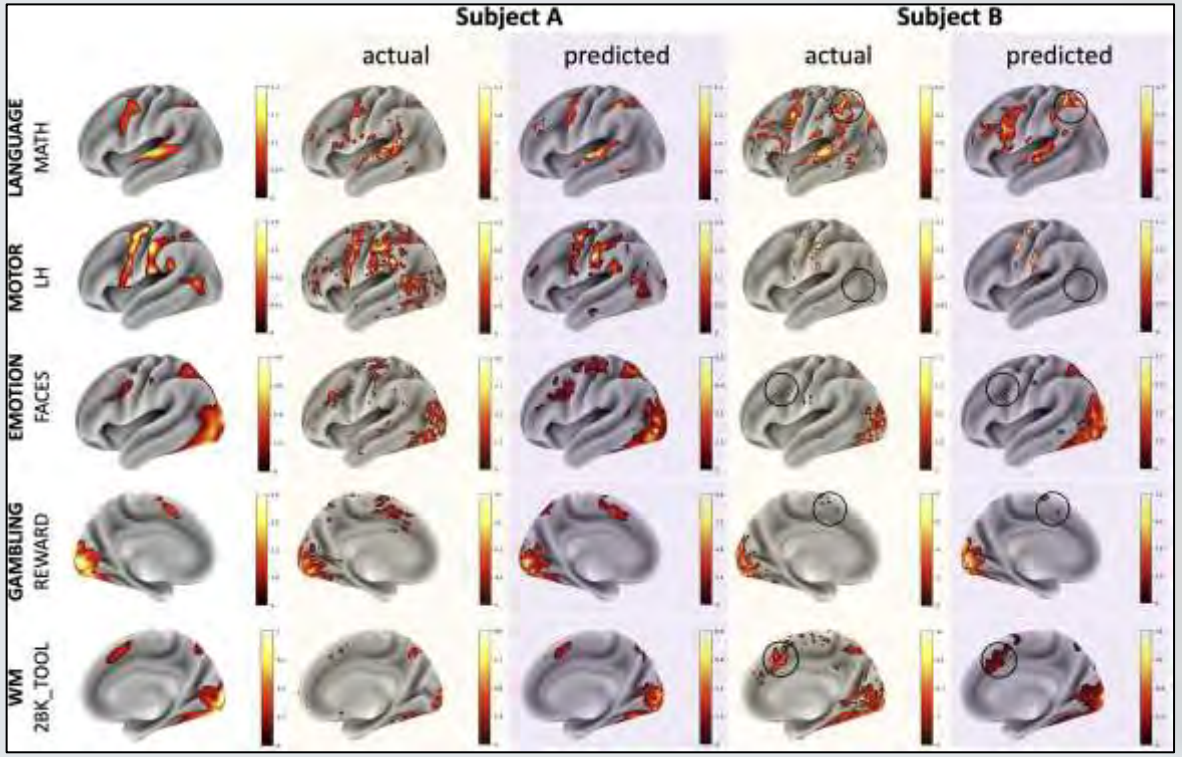



Ellis, David G., and Michele R. Aizenberg. *Frontiers in Neuroimaging* (2022)

# Pre-surgical Mapping

## Evaluating structure-to-function model

The CNN was able to use structural imaging to predict activation patterns of individual subjects that matched the group average as well as activations that deviated from the group average




Ellis, David G., and Michele R. Aizenberg. *Frontiers in Neuroimaging* (2022)

# Pre-surgical Mapping

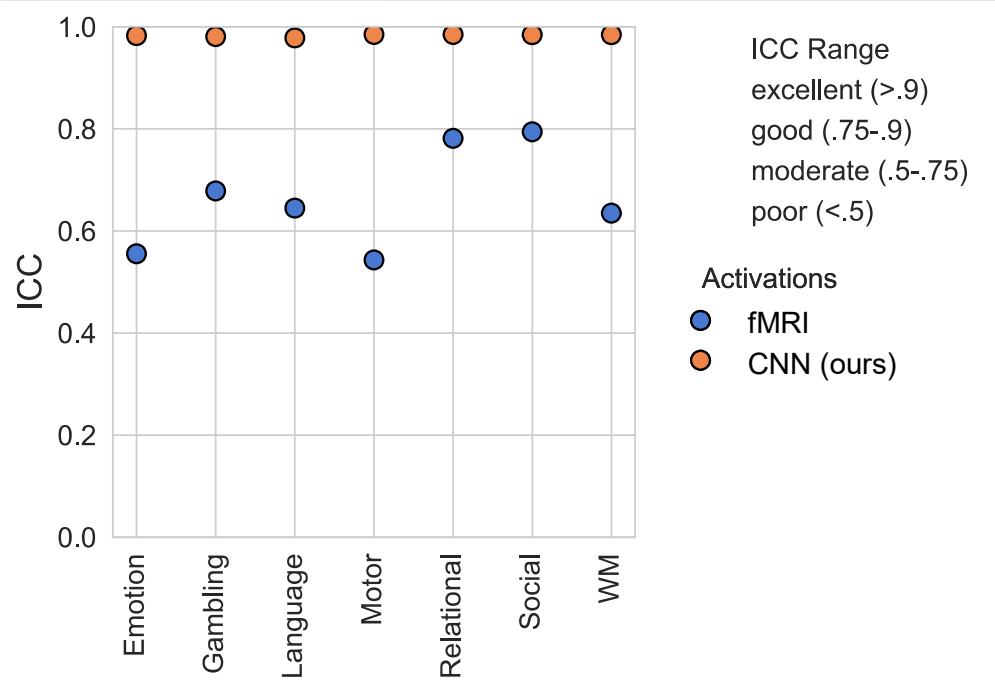
## Evaluating structure-to-function model

- Are predictions reliable when tested on repeated scans?

# Pre-surgical Mapping

## Reliability of structure-to-function model

### test-retest reliability




- Intraclass correlation coefficient (ICC) of activation in healthy subjects scanned twice, 4 months apart

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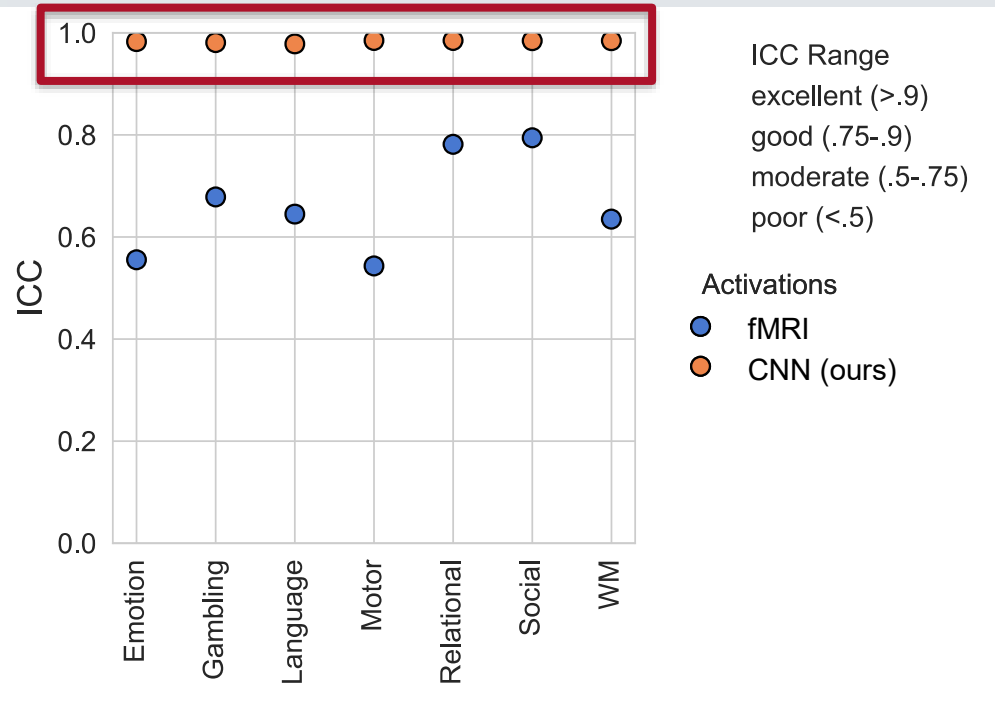
# Pre-surgical Mapping

## Reliability of structure-to-function model

### test-retest reliability




- Intraclass correlation coefficient (ICC) of activation in healthy subjects scanned twice, 4 months apart
- Activation predictions had **excellent reliability** for all task fMRI domains.

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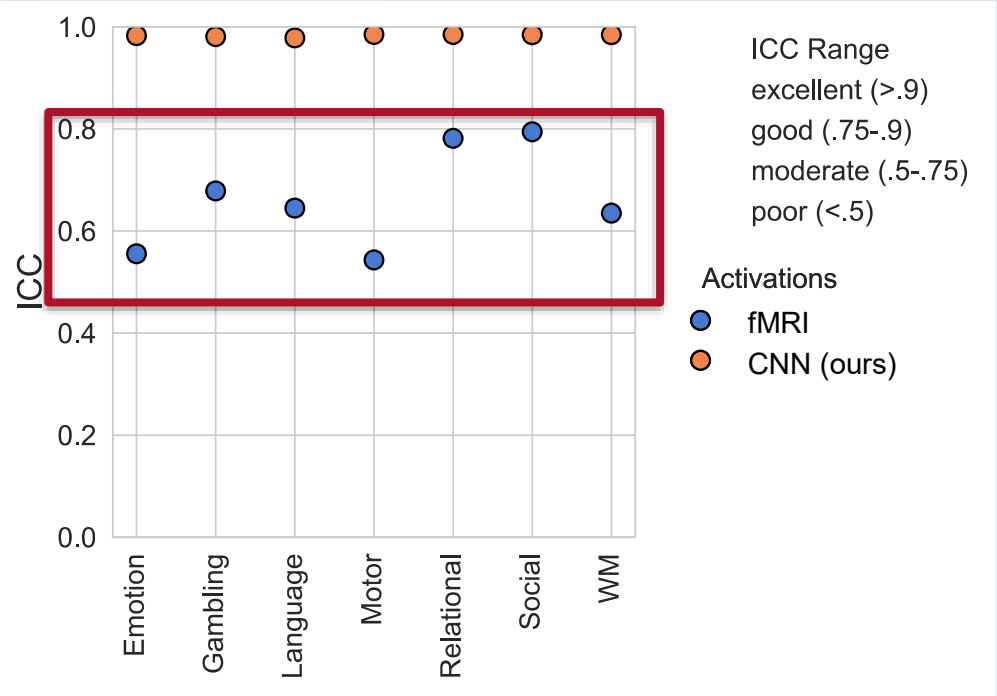
# Pre-surgical Mapping

## Reliability of structure-to-function model

### test-retest reliability




- Intraclass correlation coefficient (ICC) of activation in healthy subjects scanned twice, 4 months apart
- Activation predictions had **excellent reliability** for all task fMRI domains.
- The actual fMRI data performed worse, with only good to moderate reliability.

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# Pre-surgical Mapping

## Structure-to-function model

- Our AI model produced **highly reliable** predictions of task activation while also detecting **individual-level variations** in *healthy subjects*

# Pre-surgical Mapping

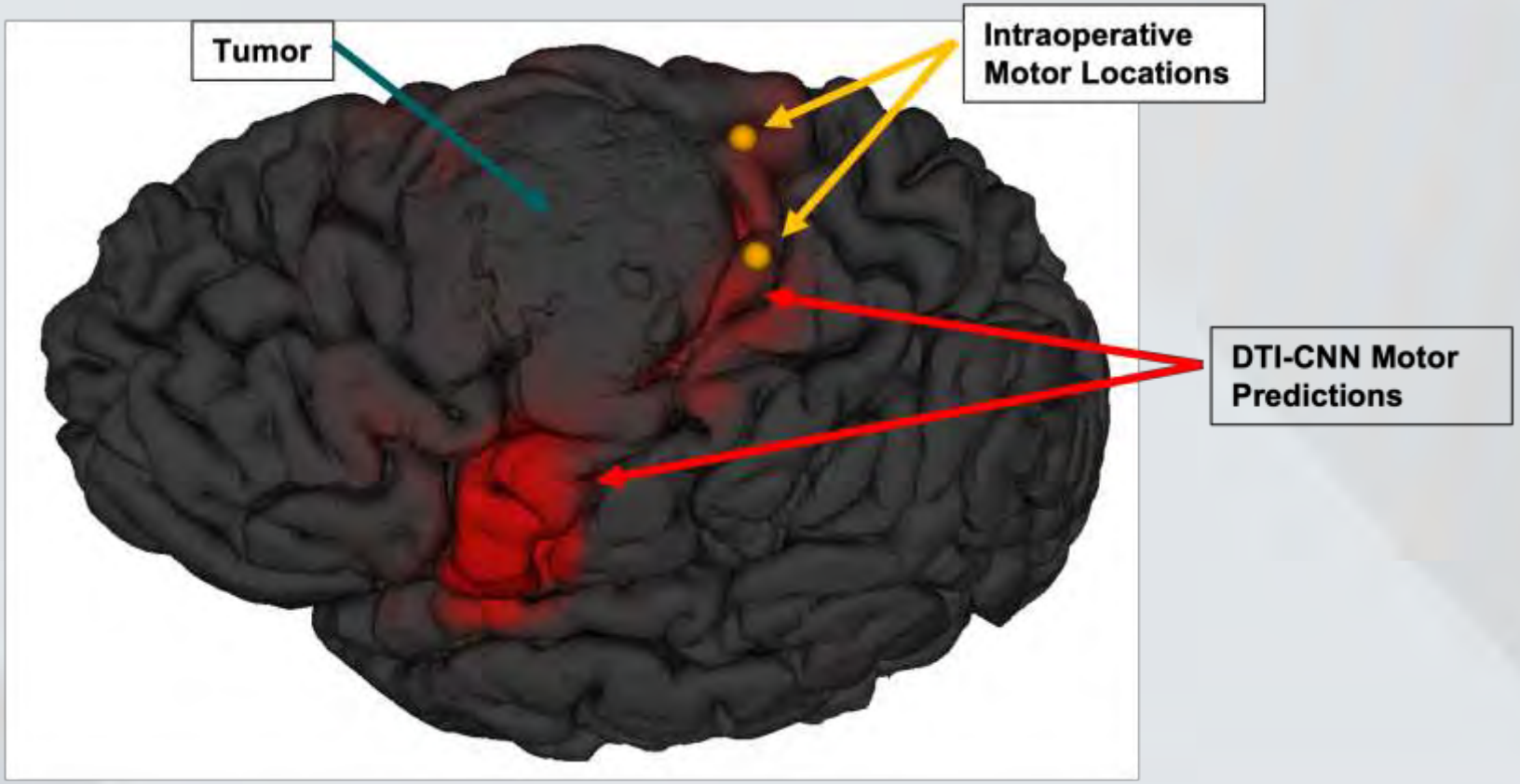
## Structure-to-function in BRAIN TUMORS

- To see if eloquent function location could be accurately predicted from diffusion imaging in *brain tumor patients*, we performed another experiment
  - We trained a similar model to predict the location of the motor cortex from the diffusion imaging in healthy subjects
  - The model was then applied to data from brain tumor patients
  - Intraoperative mapping was used as the ground truth
  - Results were then compared to task-fMRI and other brain mapping approaches

# Pre-surgical Mapping

## Structure-to-function in BRAIN TUMORS

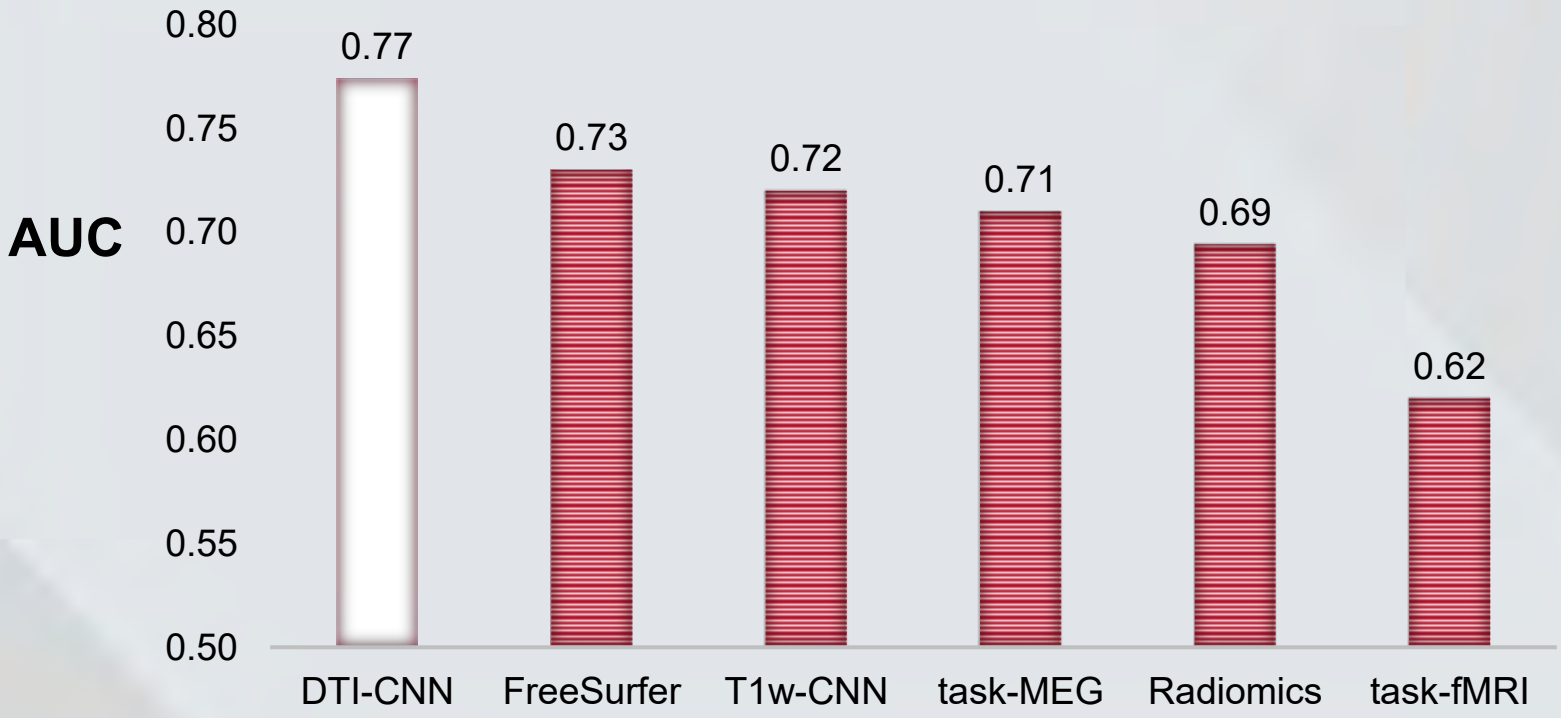
## Motor mapping accuracy – DTI-CNN



# Pre-surgical Mapping

## Structure-to-function in BRAIN TUMORS

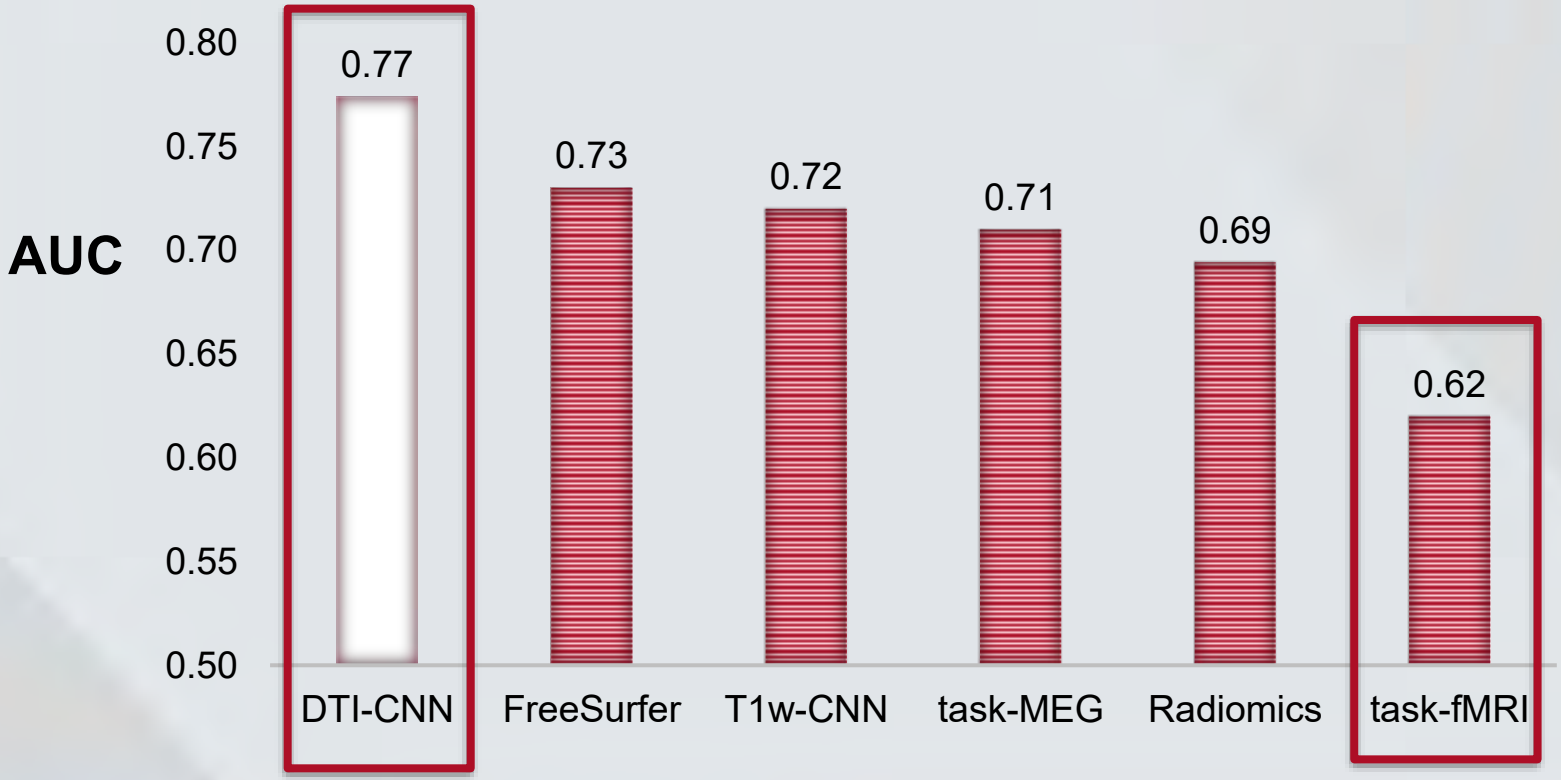
## Motor mapping accuracy – DTI-CNN



# Pre-surgical Mapping

## Structure-to-function in BRAIN TUMORS

## Motor mapping accuracy – DTI-CNN



# Pre-surgical Mapping

## Structure-to-function in BRAIN TUMORS

### Motor mapping accuracy – DTI-CNN

- Our results show that predicting task activation from diffusion imaging produces **more reliable and accurate** mapping results than standard task fMRI

# Conclusions

- This preliminary work shows that a deep learning model can use structural features to predict brain functional activation locations
- In brains where structure is disturbed by tumor, the model accurately predicted location of function
- More work needs to be done to improve and evaluate these predictions in a larger group of brain tumor patients
- When further developed, this methodology could potentially be used when eloquent area information would be useful
  - neurosurgical planning
  - SRS planning
  - Longitudinal assessment of task location over time

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