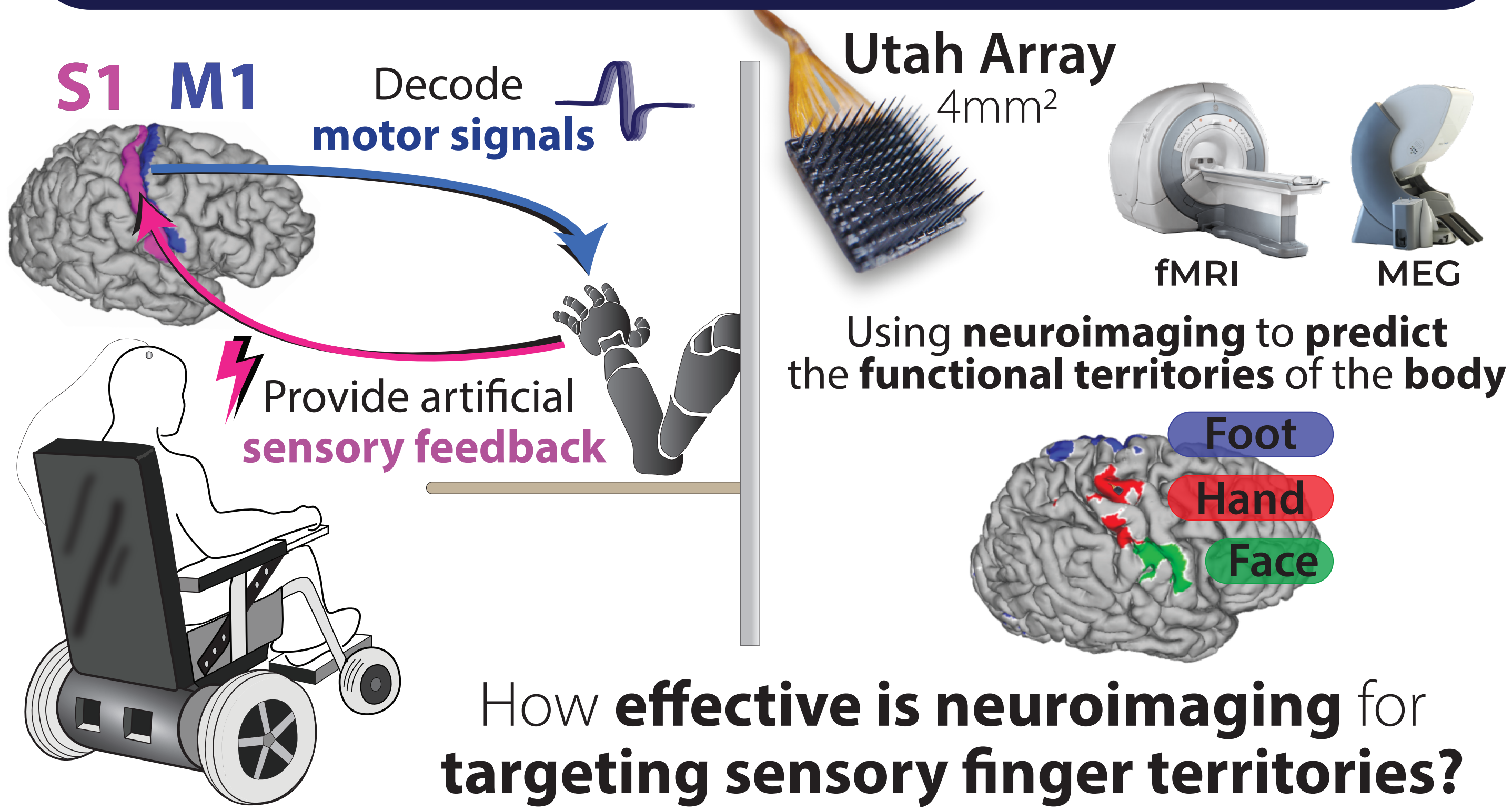# USING **MULTIMODAL NEUROIMAGING** TO GUIDE **IMPLANTATION** OF **BRAIN-COMPUTER INTERFACES**

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1 How do we target **electrode placement** for **brain-computer interfaces**?

S1 M1 · Decode motor signals · Provide artificial **sensory feedback**

Utah Array 4mm²

fMRI · MEG

Using **neuroimaging** to **predict** the **functional territories** of the body

Foot · Hand · Face

How **effective** is neuroimaging for **targeting sensory finger territories?**

2 Our Approach: from **mapping** to **implantation** to **stimulation**

- **5 human** male study **participants** with **cervical spinal cord injuries**
- Pre-implant **fMRI** and/or **MEG** scanning
- Surgically **implanted** with **2x 96-channel arrays** (4x4mm) in **M1** and **2x 60-channel arrays** (2x4mm) in **S1**
- Post-implant **intracortical microstimulation surveys** for each channel

Functional Imaging → Pre-operative Planning → Surgical Implantation → Stimulation Surveys

fMRI / MEG
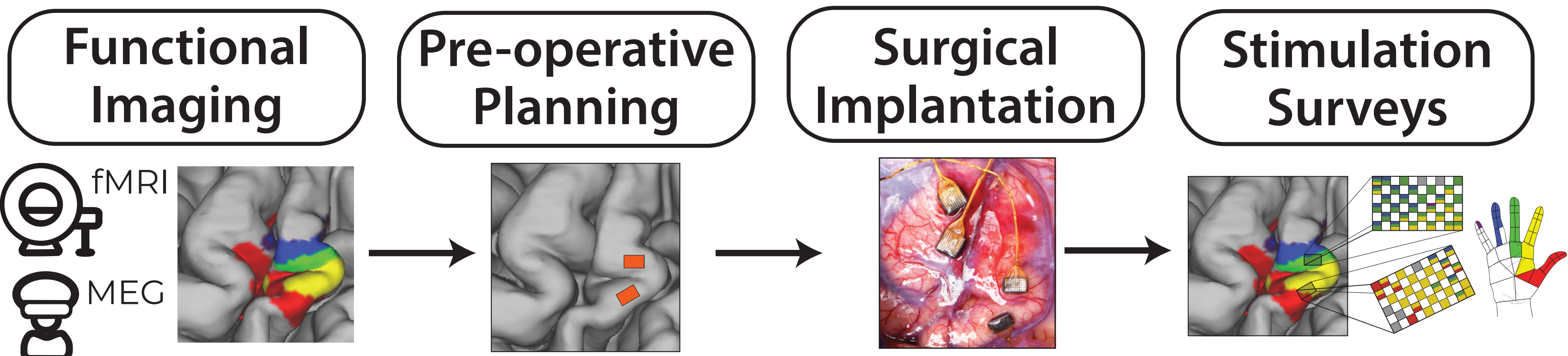
3 **Finger mapping** with **fMRI** and **MEG**

fMRI
- 3 Tesla
- 2mm³ isotropic; TR=1.5 s
- Travelling wave paradigm: cycled forward and backward through finger movements (9s)
- 5 conditions, 8 reps, 5-8 runs
- Visualizing finger selectivity, i.e each finger vs. all others

MEG
- 306-channel MEG
- Random visually cued finger movements
- Subset of fingers tested
- 3 fingers, each with a varying number of trial repetitions (54-121)
- Visualizing finger vs. rest
- Thresholding 50% max z-statistic

Considerations:
Claustraphobia & Implanted hardware

Task
Attempted finger tapping

C2

P2

P3

P4

C1

Thresholding Z-stats > 3.1

4 **Neuroimaging finger maps** versus **intracortical microstimulation surveys**

	Planned Locations	Surgical Photos	Predicted (fMRI) versus Actual (stim) Maps	Stimulation Surveys
C1				
C2				
P2				
P3				
P4				

Neuroimaging finger **prediction accuracy**

medial array · lateral array

C1: 68% ± 17%
C2: 60% ± 21%
P2: 73% ± 17%
P3: 59% ± 20%
P4: 41% ± 13%

5 Can we **rely** on **neuroanatomical landmarks?**

Hand knob position on T1w MRI
Selected by research team & validated by neurosurgeon
Ω = hand knob coordinate

	C1	C2	P2	P3	P4

Hand knob on inflated surfaces
Relative to finger activity
Ω = hand knob coordinate

Hand knob M1-S1 axis on flat surface
Relative to peak finger activity
Ω = hand knob coordinate
● = S1 hand knob homologue

BA 4 · BA 1

Distances (mm) | 1.5mm - 19.7mm | 3.2mm - 16.2mm | 6.1mm - 22.0mm | 6.2mm - 15.3mm | 15.7mm - 28.1mm

6 Takeaways

- Despite spinal cord injuries, **finger S1 maps could be captured for all participants**
- **Neuroimaging** is an **effective predictor** of targeting distinct sensory finger territories (average 60%)
- The **anatomical hand knob** is a **poor predictor** of sensory finger territories

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