

# Altered digit maps in human primary somatosensory cortex following hand nerve repair.

Ken Valyear

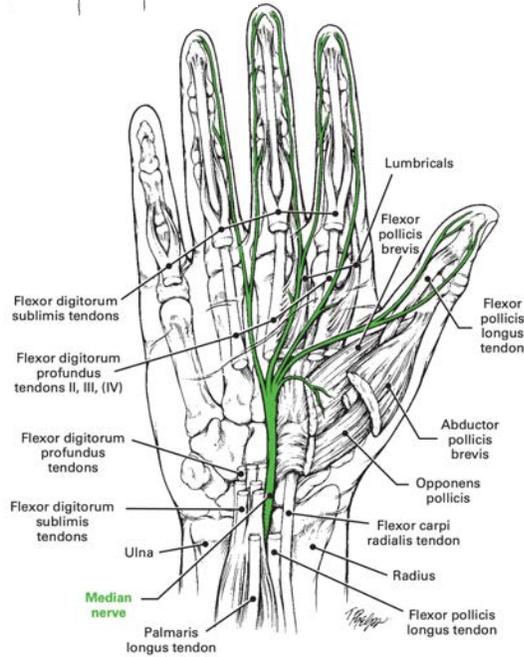
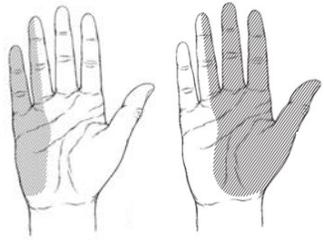


YSGOL SEICOLEG A GWYDDOR CHWARAEON  
SCHOOL OF PSYCHOLOGY AND SPORT SCIENCE

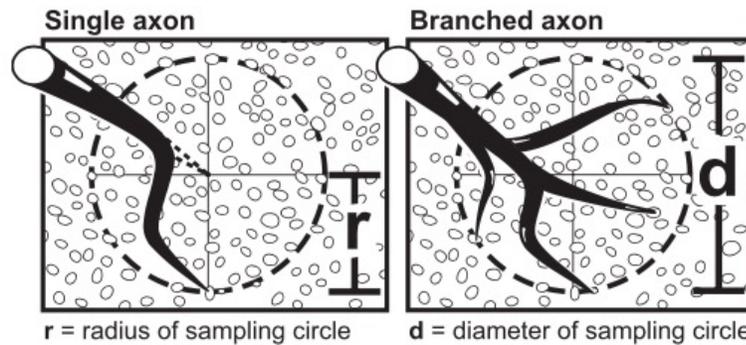
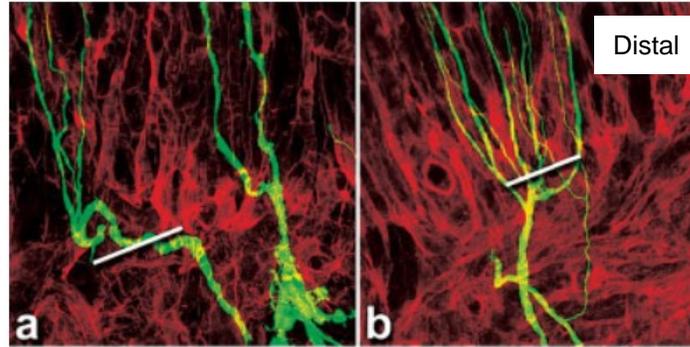


# Nerve regeneration is not topographically guided

Innervation  
Ulnar    Median

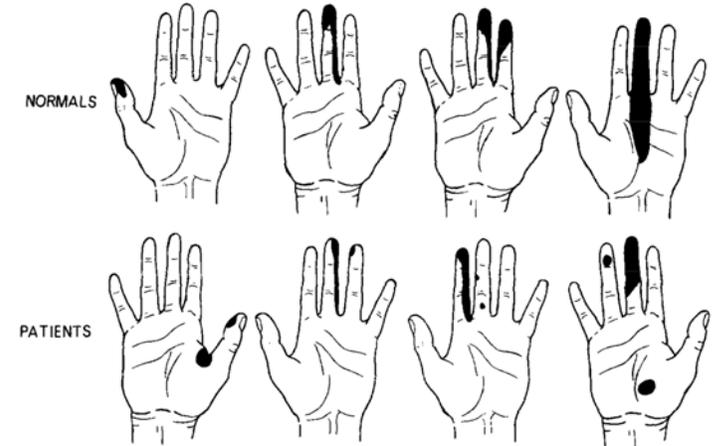


Reinnervation errors

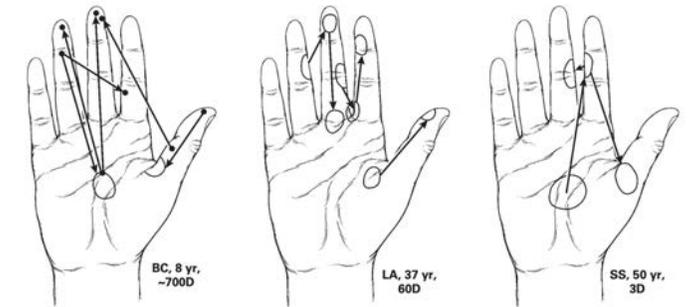


Witzel et al. (2005). *J Comp Neurology*.

Discontinuous receptive fields



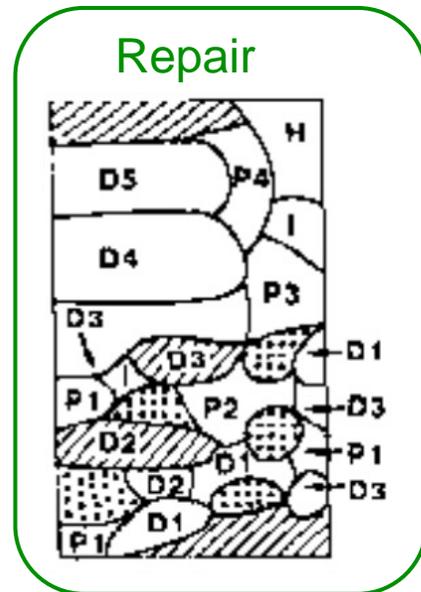
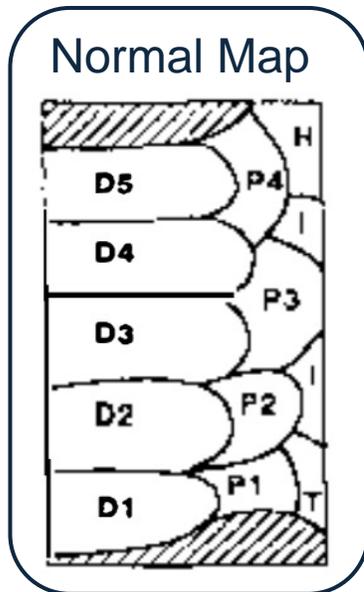
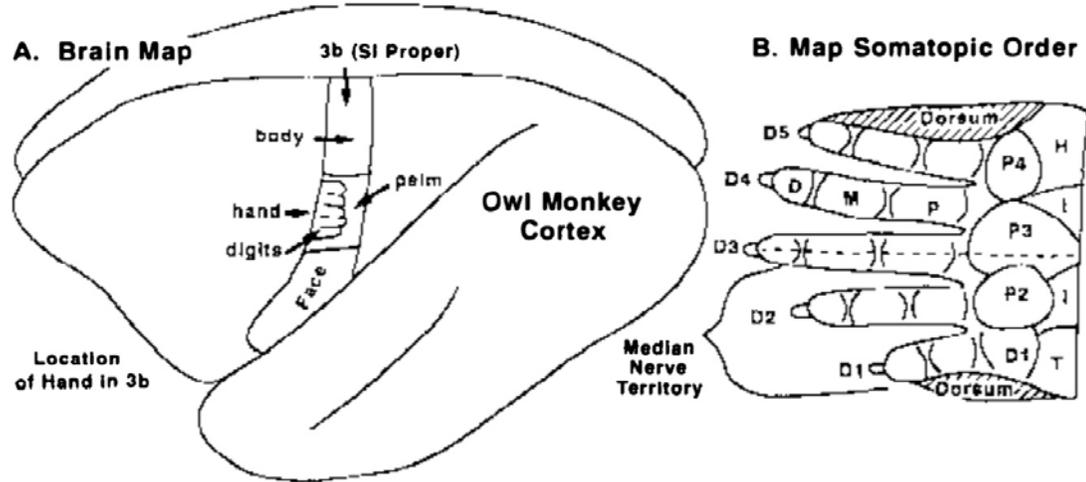
Impaired touch localisation



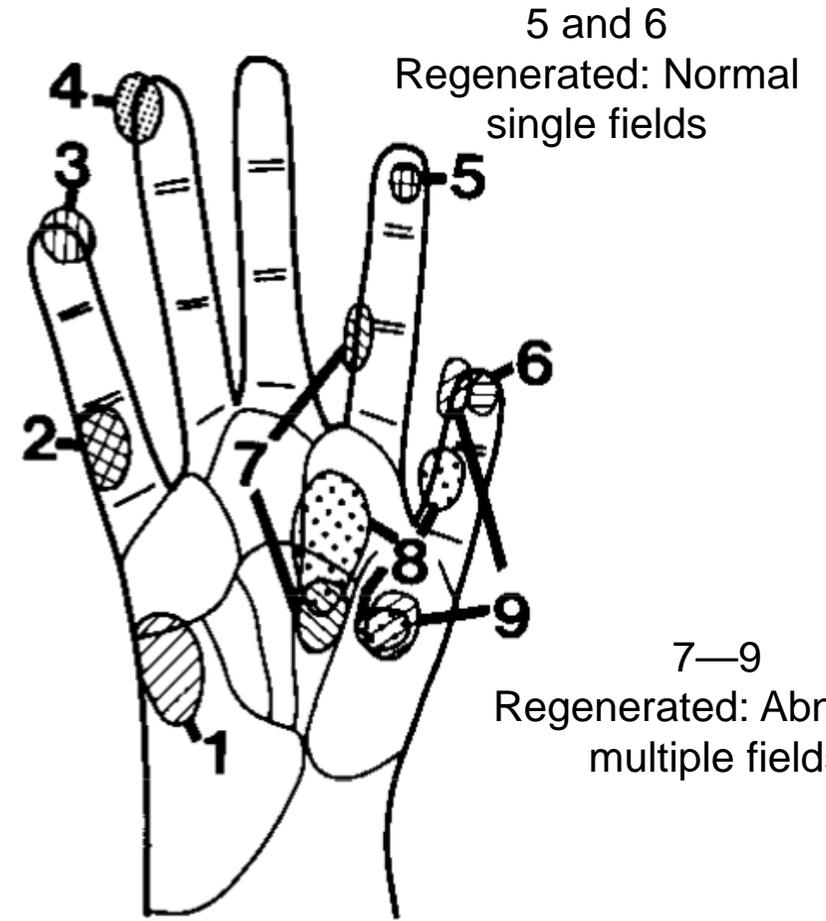
Hallin et al. (1981). *Exp Neurology*.

Brushart, 2011. *Nerve Repair*.

# Disordered digit maps after nerve repair



1—4  
Normal  
single fields



Wall et al. (1986). *J Neuroscience*

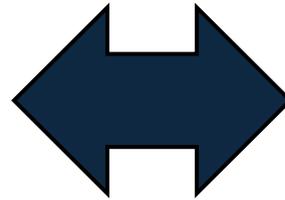
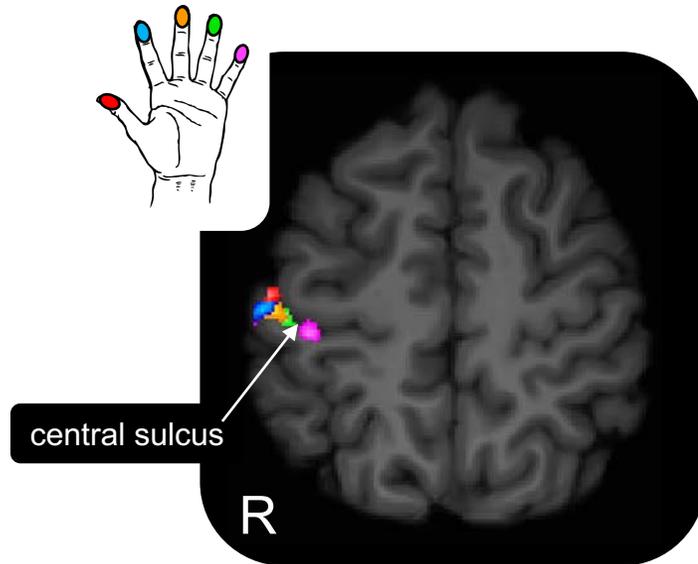
Kaas (1991). *Annual Review of Neuroscience*

[See also, Merzenich & Jenkins, 1993; Paul et al., 1972; Florence et al., 1994; Florence et al., 2001]

# Purpose

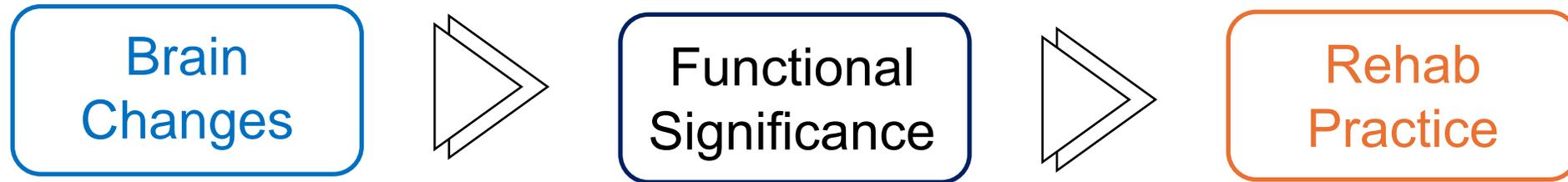
Are the digit maps in S1 altered after hand nerve repair?  
If so, what do these changes mean for patient recovery?

*fMRI data: Control participant  
showing typical 'digitopy'*



# Rehab theory

- Current therapies — unsubstantiated assumptions



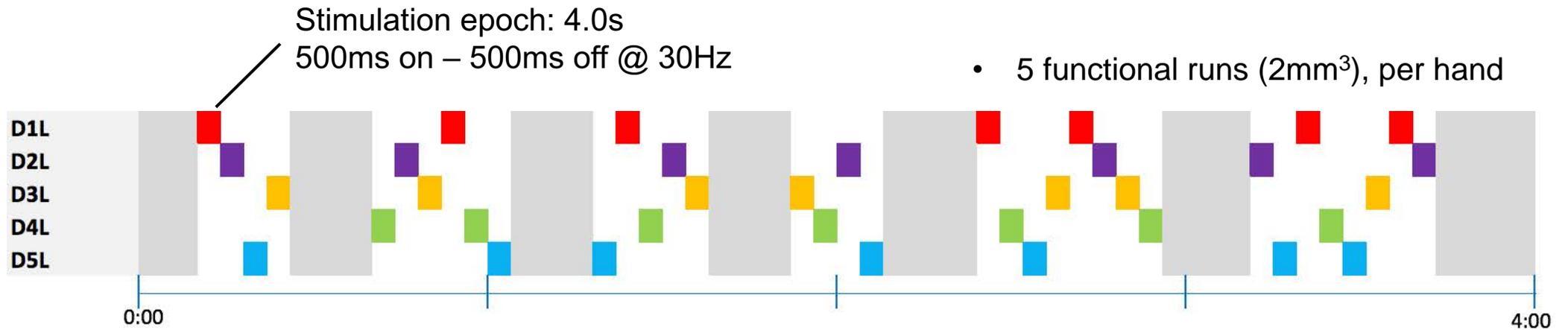
- Disordered hand maps.

- Sensory Re-education Therapy—'re-educate' touch  
(may include sensory substitution and mirror therapy)

H<sub>1</sub>: Hand nerve repair alters the organisation of digit maps in S1

H<sub>2</sub>: And these changes limit patient recovery.

# Methods: MRI



Vibrotactile stimulators

## Patients: N = 21

- 10 ulnar; 6 median; 5 'both'
- Age: mean = 40 y, range: 21–75 y
- Gender: 7 female
- Handedness: 18 right

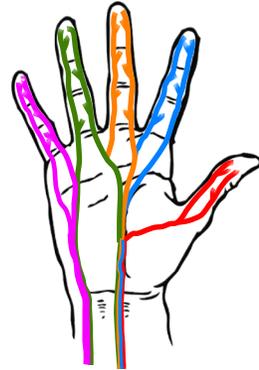
## Controls: N = 30

- Age: mean = 31 y, range: 19–63 y
- Gender: 13 female
- Handedness: 28 right

# Rewiring hypothesis

No nerve injury

typical innervation  
in the hand

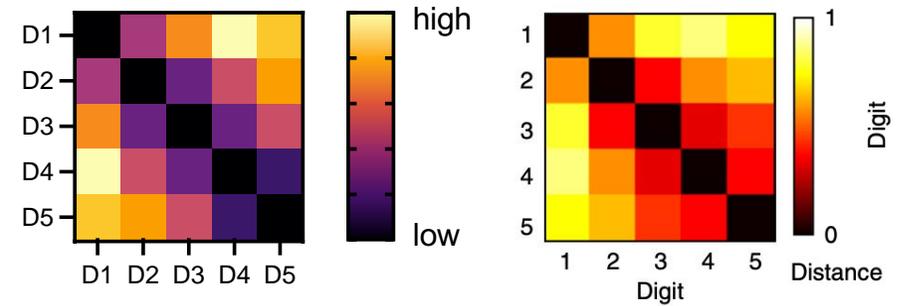


typical spatial  
arrangement of digit  
response maps in S1



Representational Distances  
(cross-validated Mahalanobis distance)

typical pattern of  
interdigit response  
separability in S1

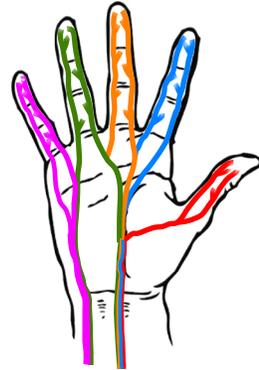


*Ejaz et al. 2015*

# Rewiring hypothesis

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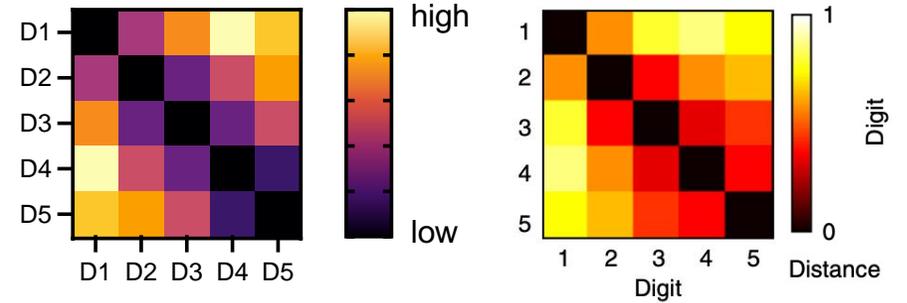


typical spatial  
arrangement of digit  
response maps in S1



Representational Distances  
(cross-validated Mahalanobis distance)

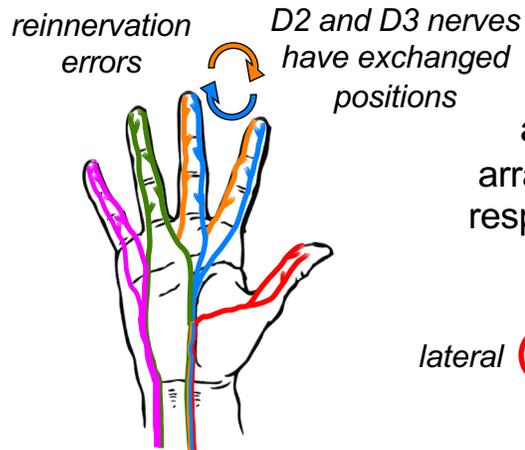
typical pattern of  
interdigit response  
separability in S1



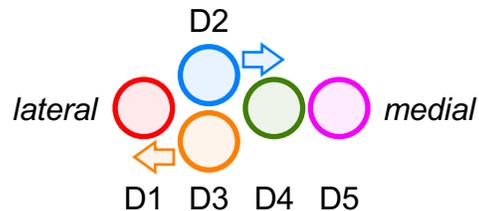
*Ejaz et al. 2015*

After median nerve repair

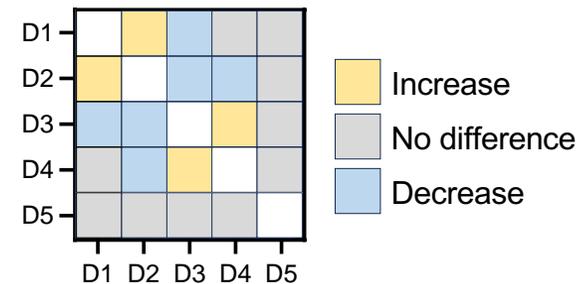
atypical innervation  
in the hand



atypical spatial  
arrangement of digit  
response maps in S1

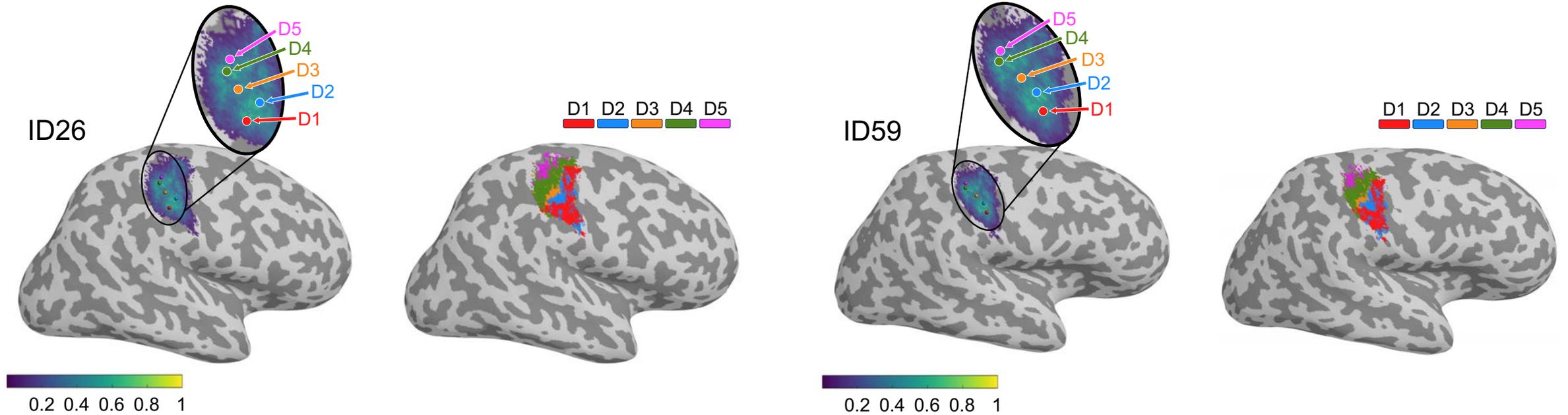


atypical pattern of  
interdigit response  
separability in S1



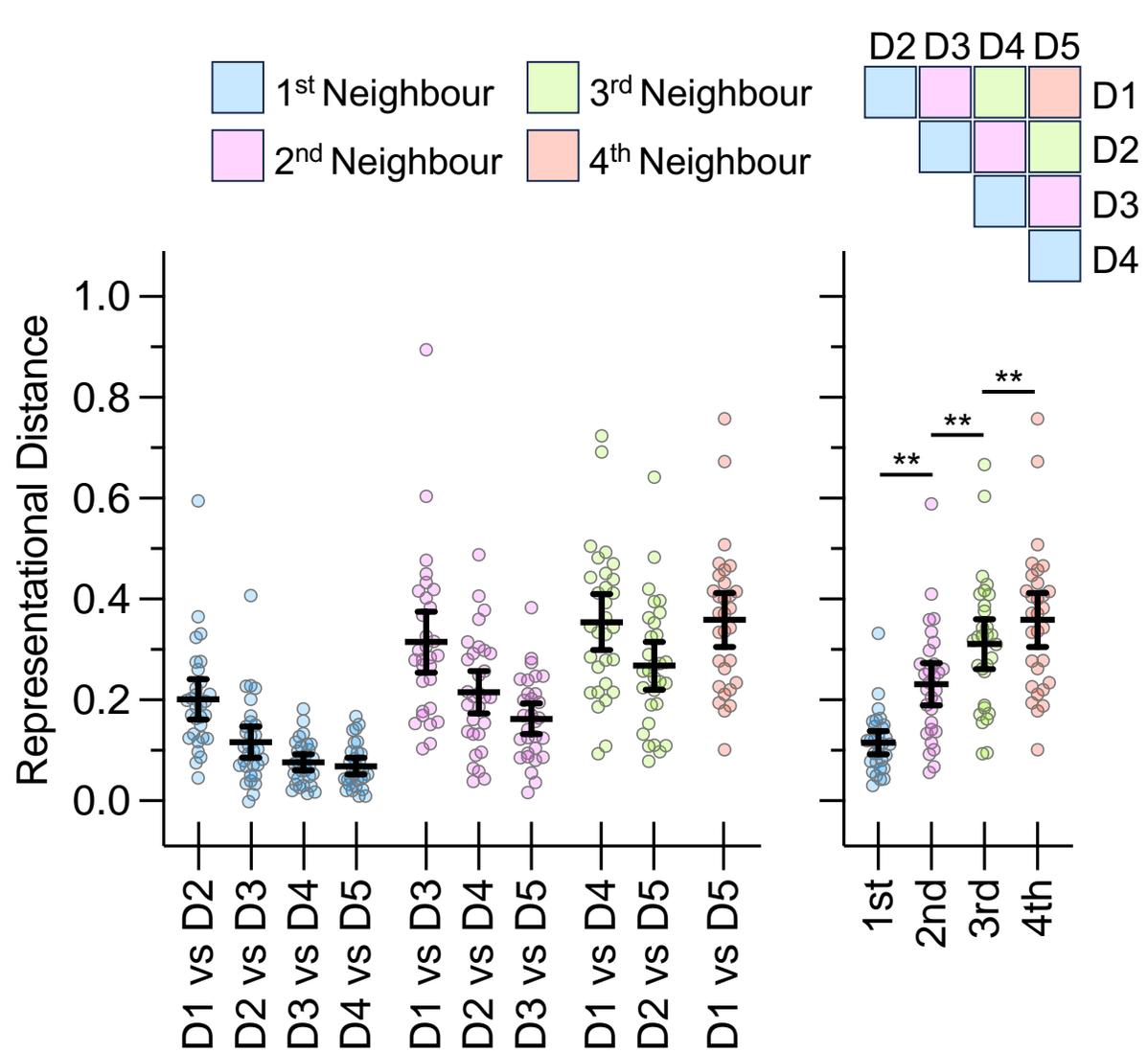
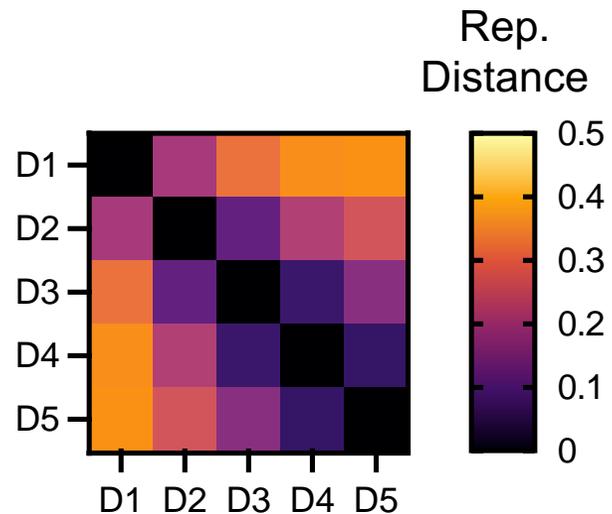
RDM's are altered

# Methods: Regions of interest

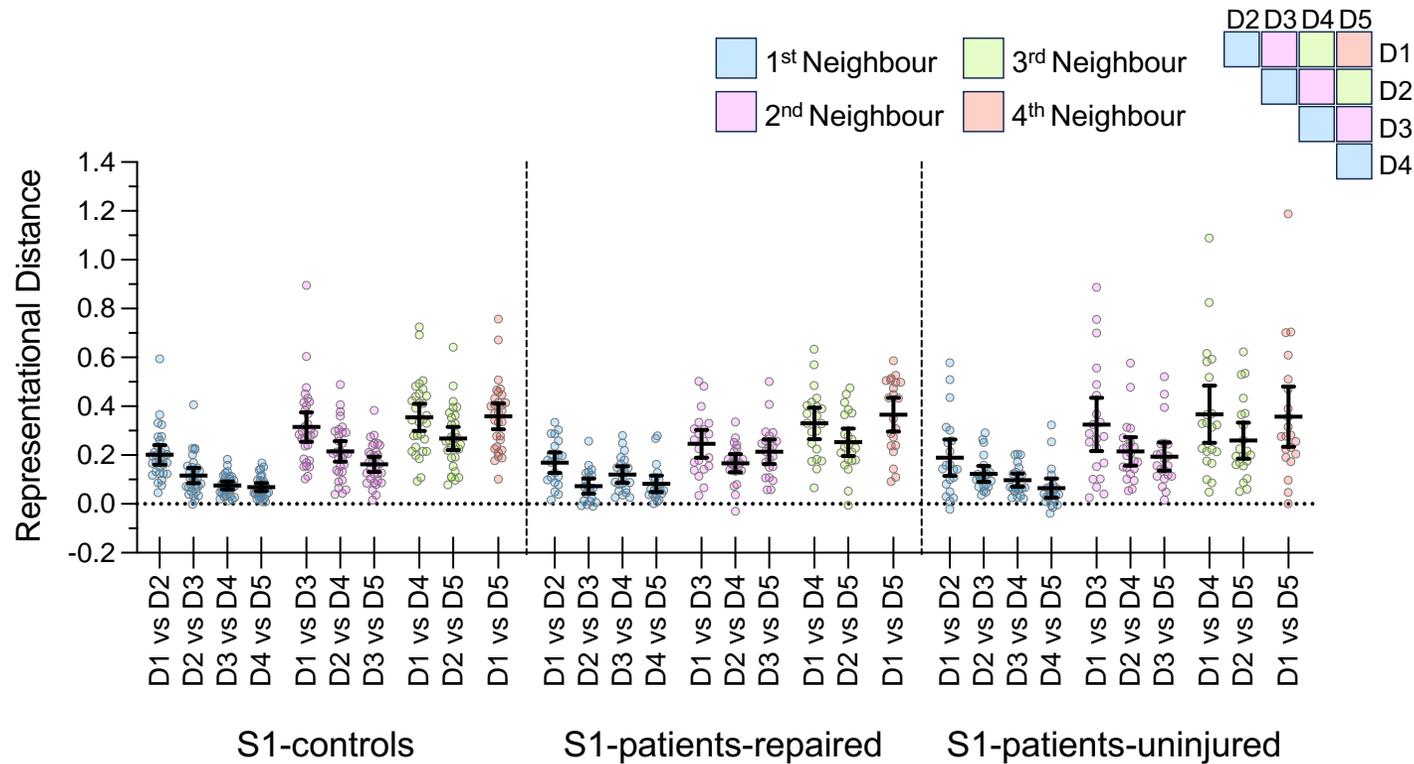
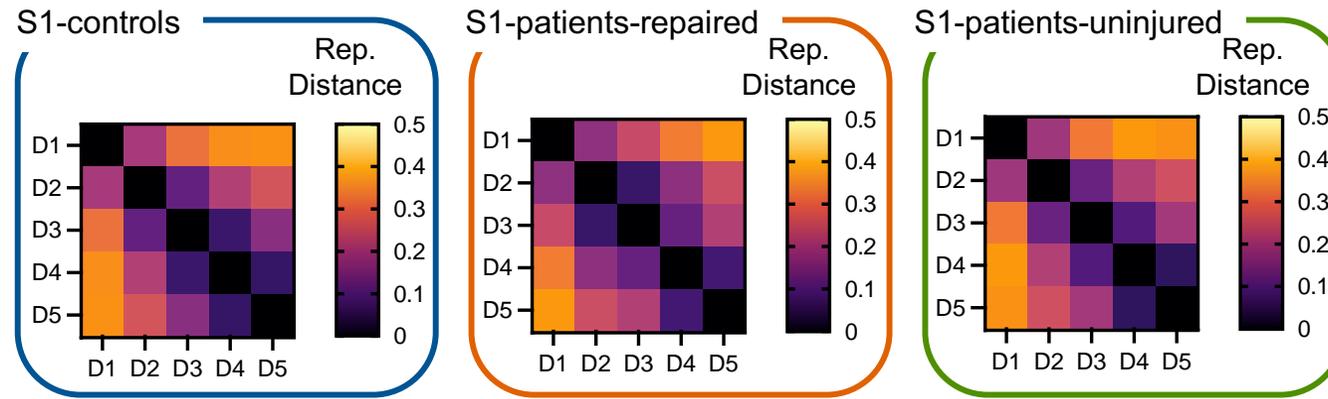


O'Neil et al. (2020). A probabilistic atlas of finger dominance in the primary somatosensory cortex. *NeuroImage*

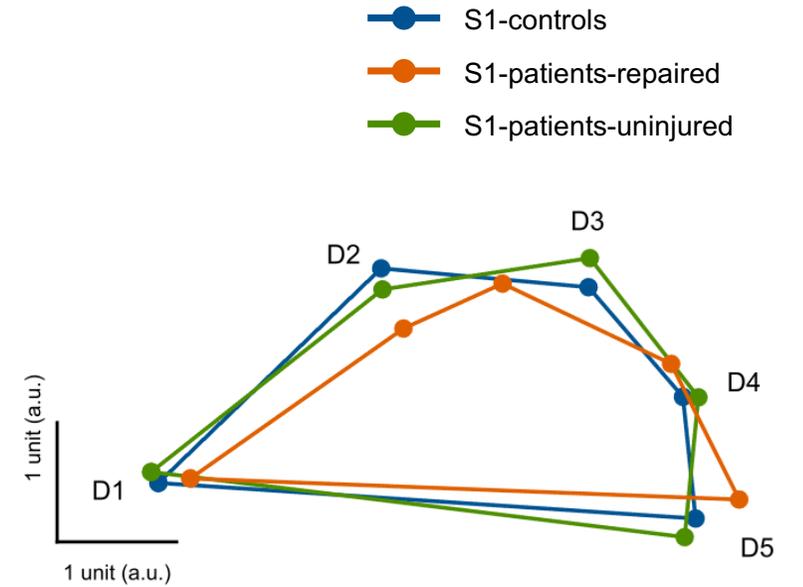
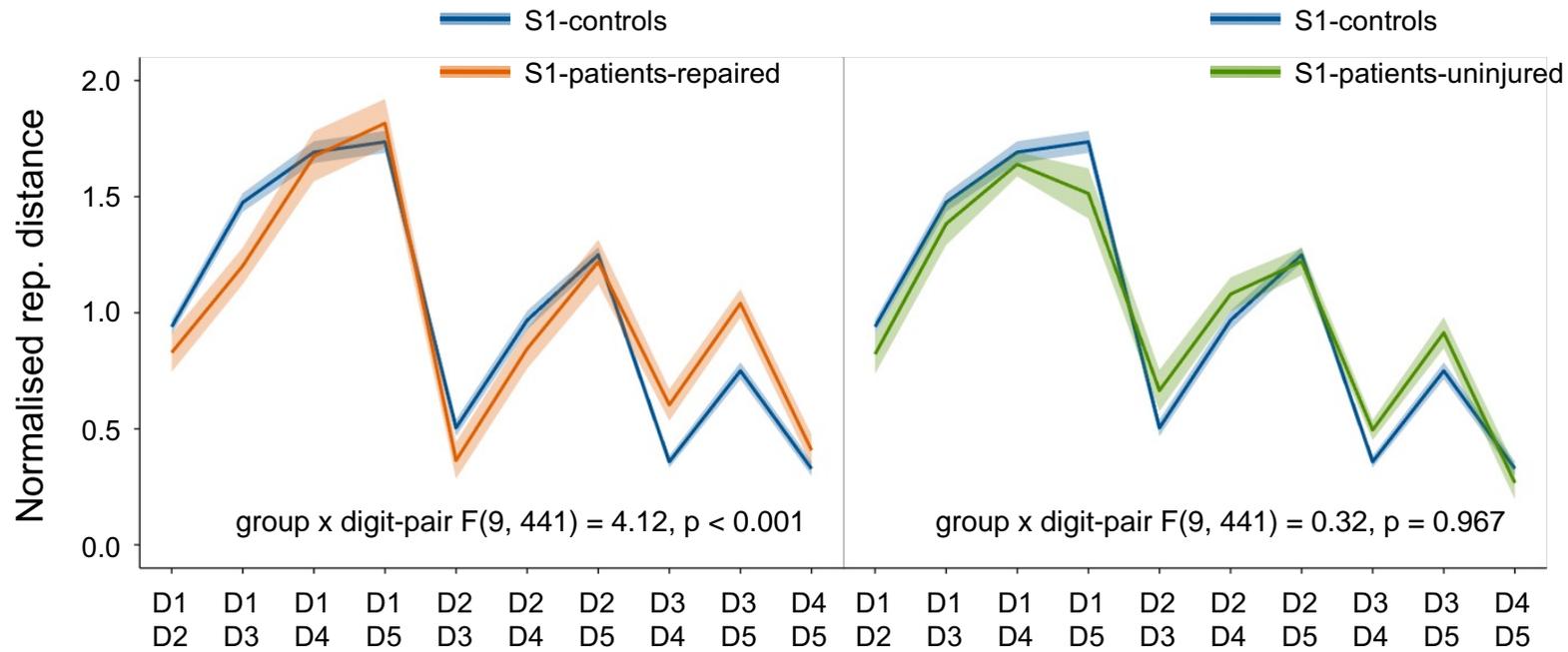
# Controls show normative RDM structure



# RDM structure is altered after nerve repair



# RDM structure is altered after nerve repair



# RDM typicality is decreased after nerve repair



Median repair

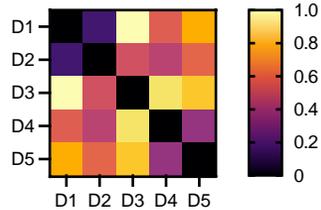


Ulnar repair

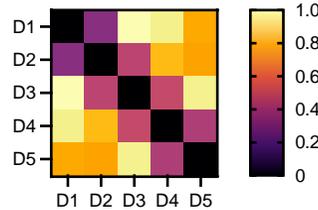


Median and Ulnar repair

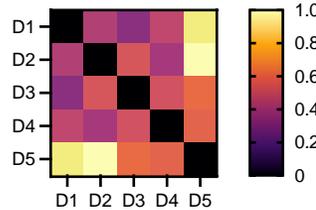
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ID57,  $r_s = 0.56$

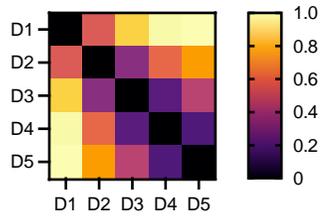


ID26,  $r_s = -0.06$

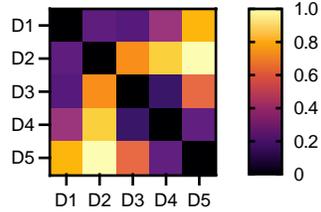


S1-controls

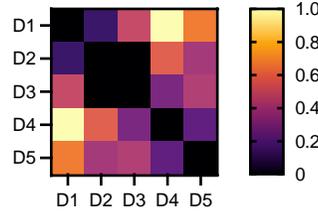
Group mean, N = 30



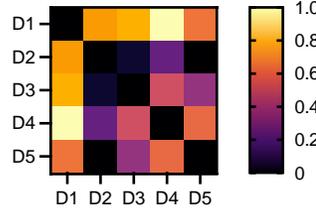
ID39,  $r_s = 0.35$



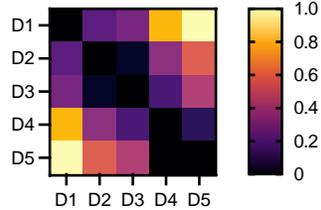
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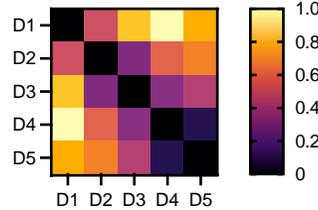
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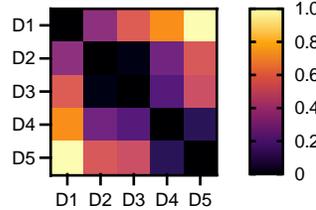
ID33,  $r_s = 0.87$



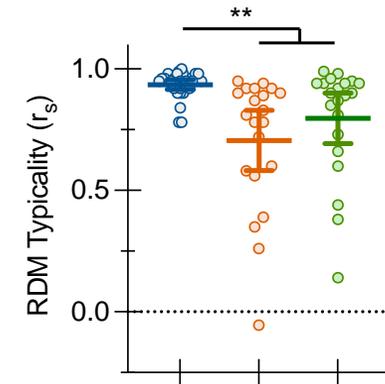
ID30,  $r_s = 0.95$



ID38,  $r_s = 0.92$



○ S1-controls ○ S1-patients-repaired  
○ S1-patients-uninjured



# Summary

## Peripheral rewiring

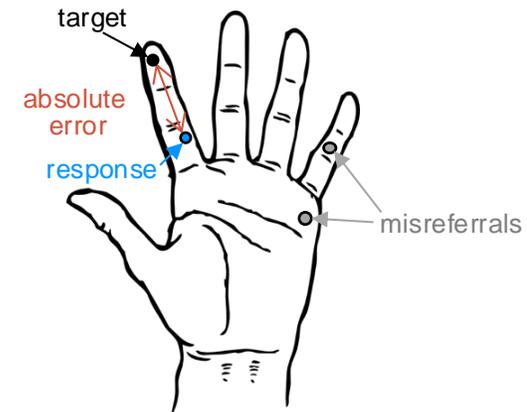
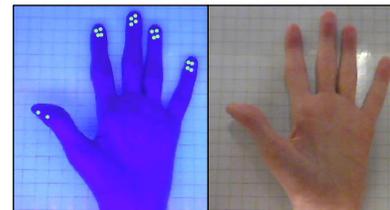
- S1-repaired: Altered maps (RDM structure, RDM typicality)

# Impaired locognosia

\*See



**Ben Govier**  
Poster P2



Weber et al. (2023). *J. Neurophysiology*

## Touch Localisation

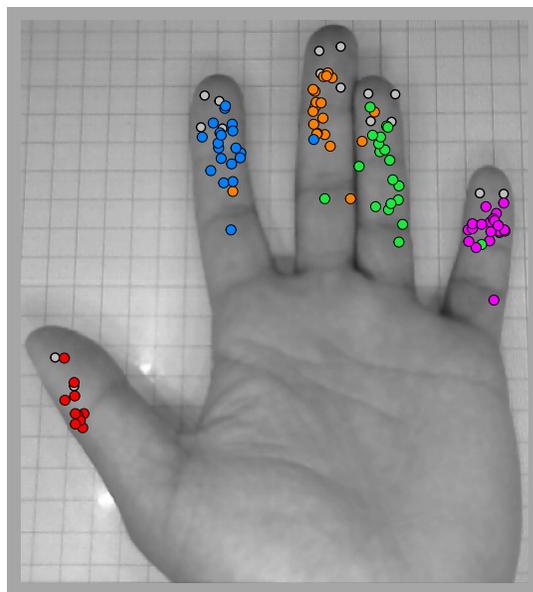
Patient ID35  
'both' repair

Targets ○

Responses ● D1 ● D2 ● D3 ● D4 ● D5



Uninjured Hand  
(absolute error = 7.2 mm)

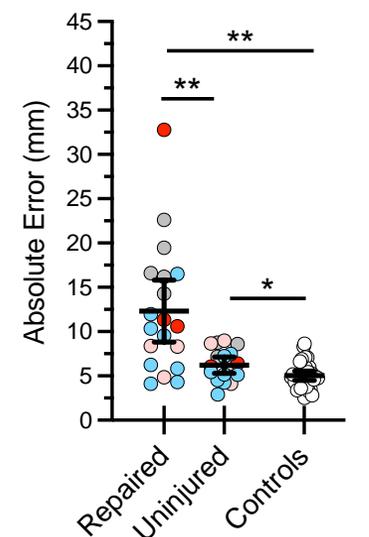


Repaired Hand  
(absolute error = 16.2 mm)

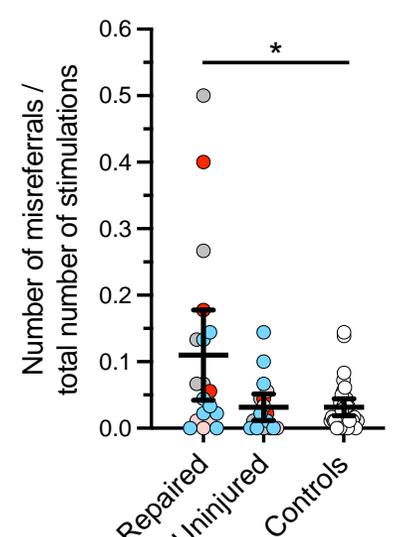
## Absolute error

● Median (3)  
● Part Median (3)

○ Median & Ulnar (5)  
● Ulnar (8)



## Misreferrals

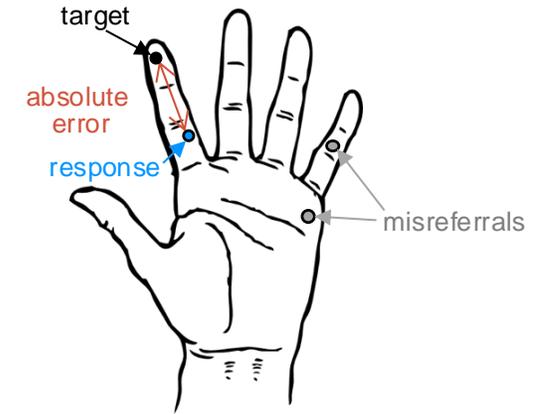
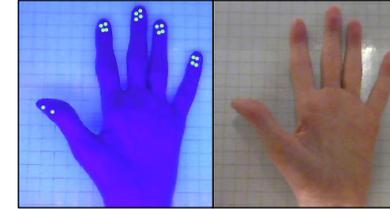


# Impaired locognosia

\*See



**Ben Govier**  
Poster P2



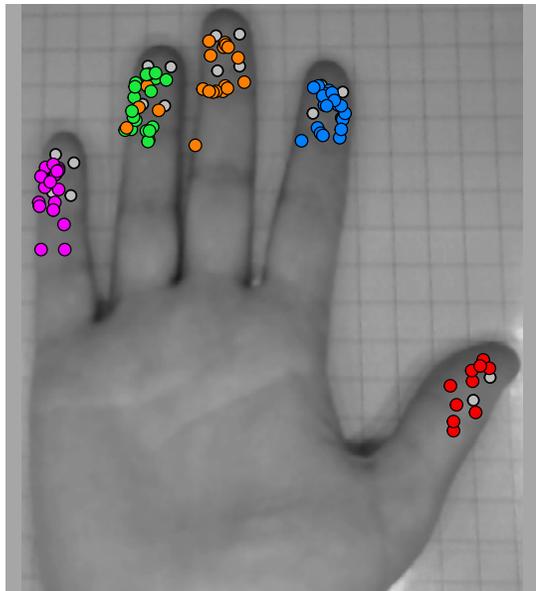
Weber et al. (2023). *J. Neurophysiology*

## Touch Localisation

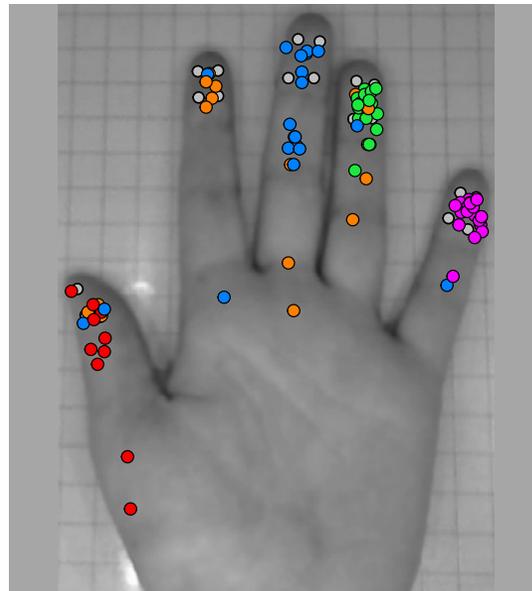
Patient ID21  
median repair

Targets ○

Responses ● D1 ● D2 ● D3 ● D4 ● D5



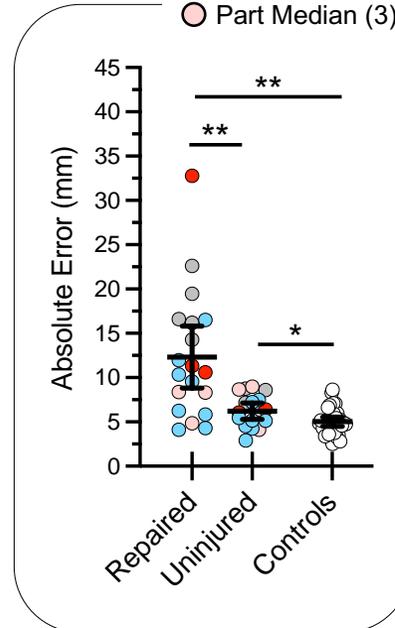
Uninjured Hand  
(absolute error = 6.0 mm)



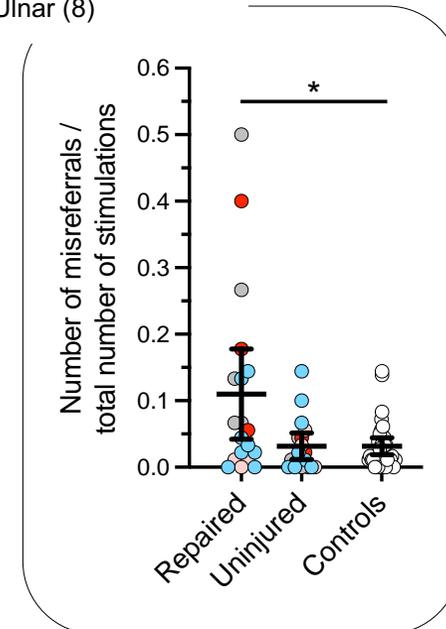
Repaired Hand  
(absolute error = 11.3 mm)

## Absolute error

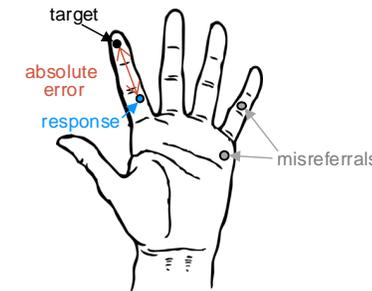
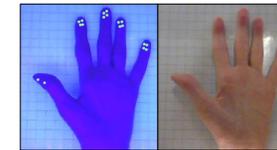
● Median (3)    ○ Median & Ulnar (5)  
○ Part Median (3)    ● Ulnar (8)



## Misreferrals



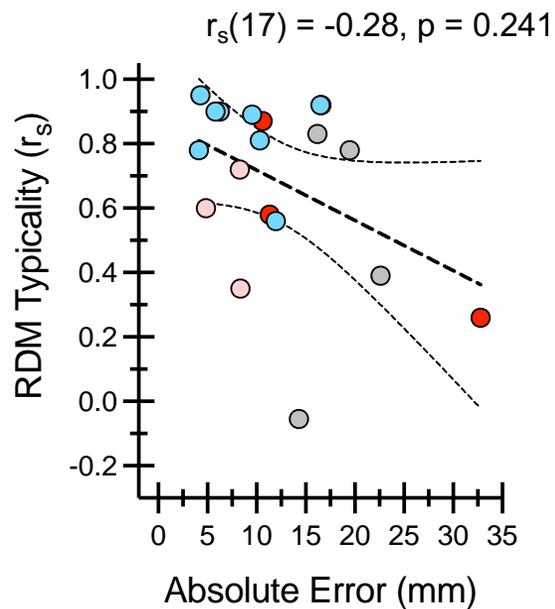
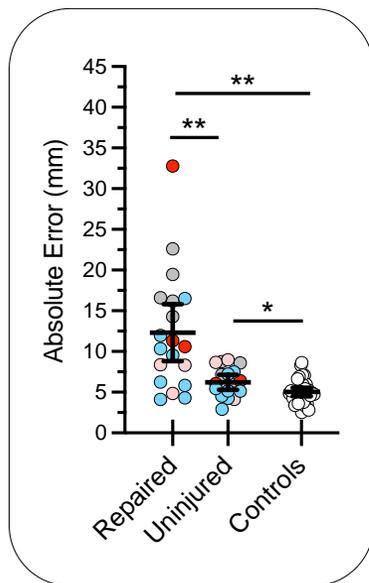
# Impaired locognosia does not correlate with RDM typicality



Weber et al. (2023). *J. Neurophysiology*

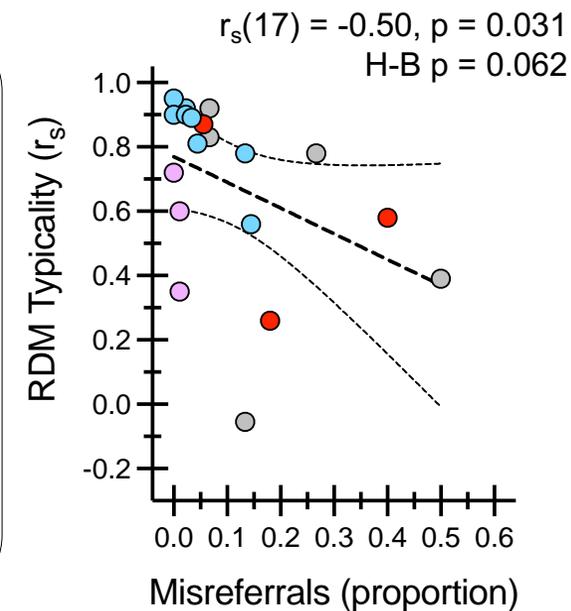
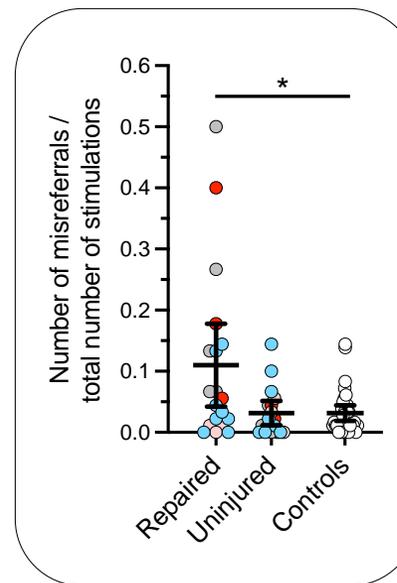
## Absolute error

- Median (3)
- Median & Ulnar (5)
- Part Median (3)
- Ulnar (8)



## Misreferrals

- Median (3)
- Median & Ulnar (5)
- Part Median (3)
- Ulnar (8)



# Summary

## Peripheral rewiring

- S1-repaired: Altered maps (RDM structure, RDM typicality)
  - No credible links to locognosia.

# But what about the other side?



Median repair

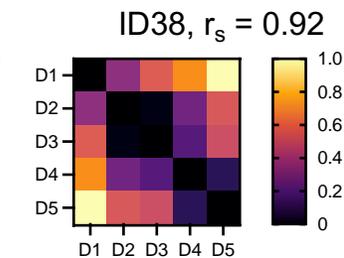
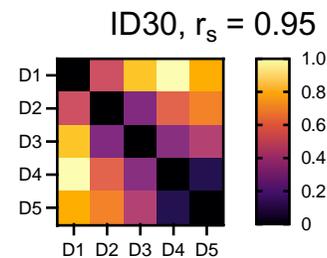
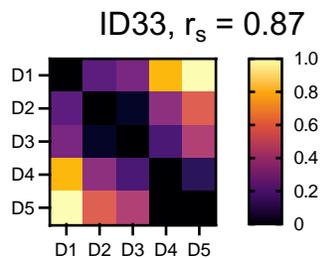
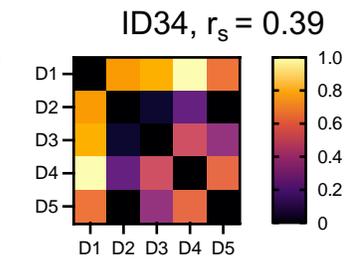
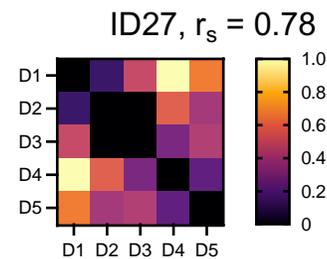
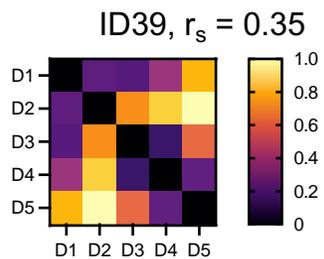
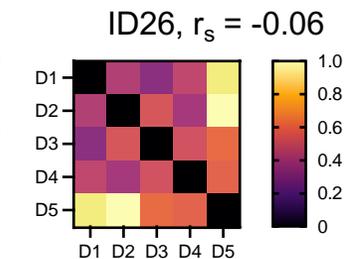
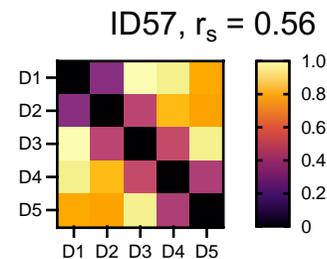
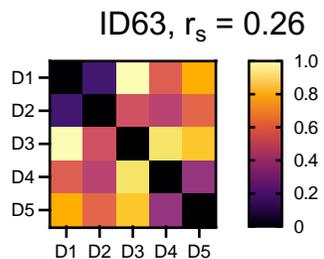
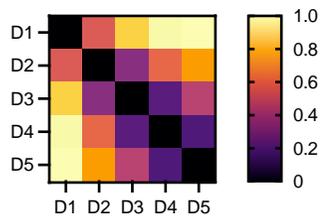


Ulnar repair

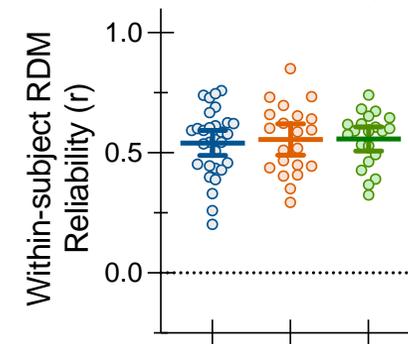
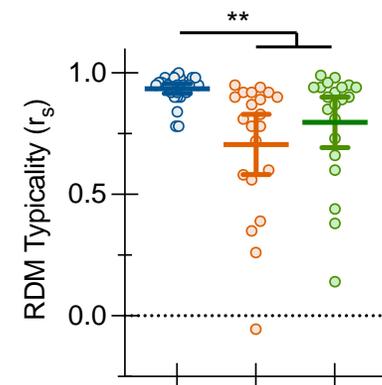


Median and Ulnar repair

S1-controls  
Group mean, N = 30



○ S1-controls    ○ S1-patients-repaired  
○ S1-patients-uninjured



# But what about the other side?



Median repair

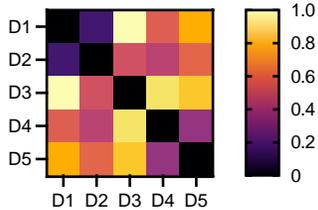


Ulnar repair

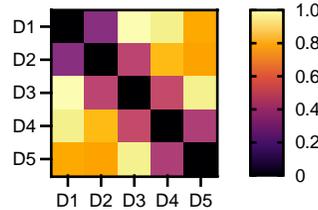


Median and Ulnar repair

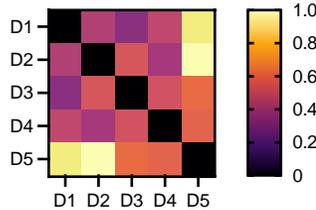
ID63,  $r_s = 0.26$



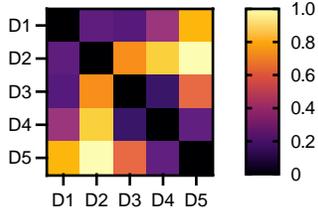
ID57,  $r_s = 0.56$



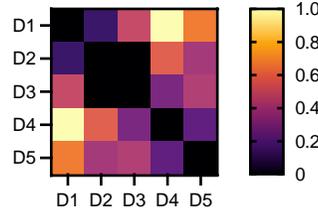
ID26,  $r_s = -0.06$



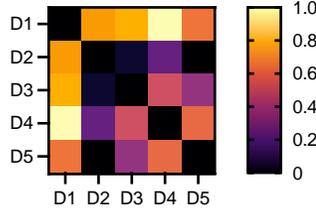
ID39,  $r_s = 0.35$



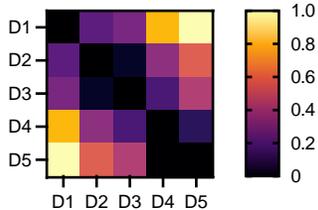
ID27,  $r_s = 0.78$



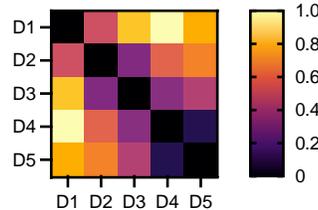
ID34,  $r_s = 0.39$



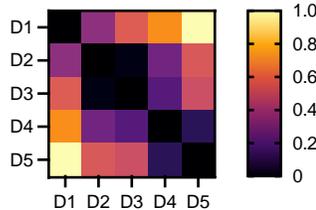
ID33,  $r_s = 0.87$



ID30,  $r_s = 0.95$

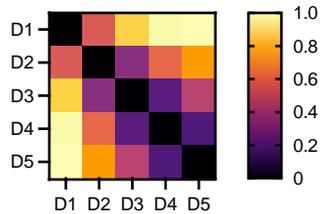


ID38,  $r_s = 0.92$

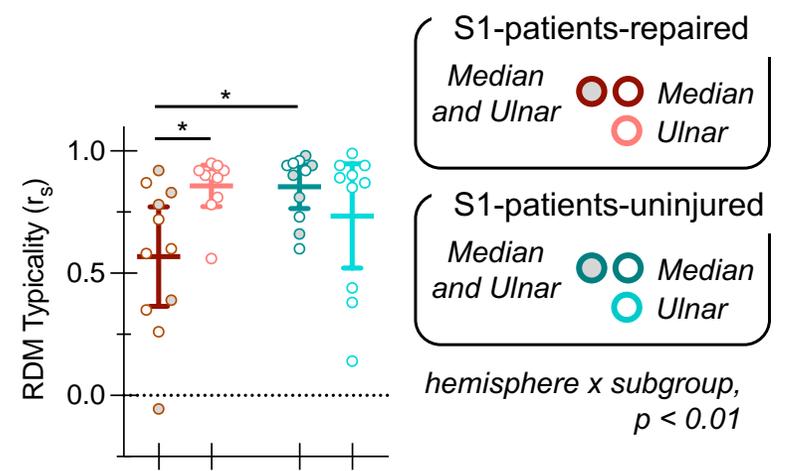
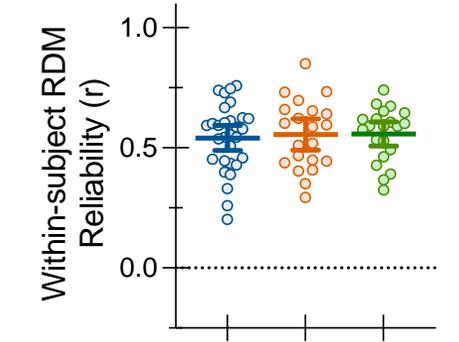
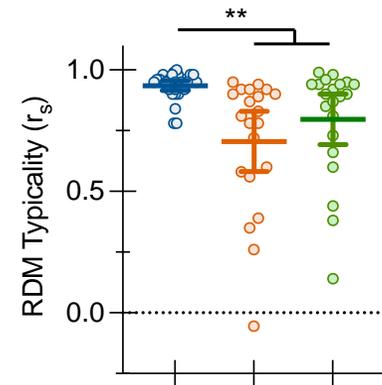


S1-controls

Group mean, N = 30



○ S1-controls ○ S1-patients-repaired ○ S1-patients-uninjured



S1-patients-repaired  
 Median and Ulnar ○ Median ○ Ulnar  
 S1-patients-uninjured  
 Median and Ulnar ○ Median ○ Ulnar  
*hemisphere x subgroup, p < 0.01*

# Summary

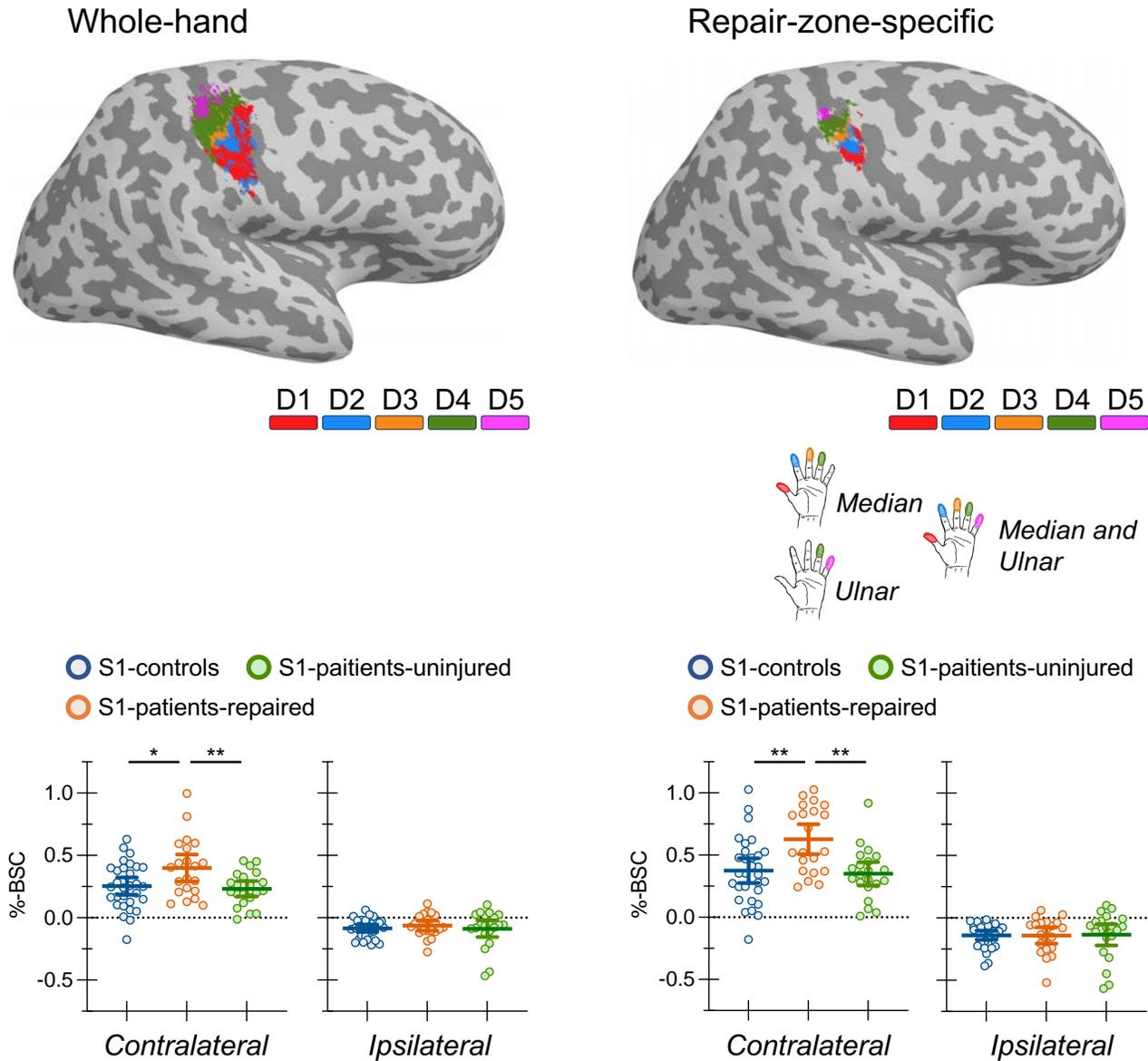
## Peripheral rewiring

- S1-repaired: Altered maps (RDM structure, RDM typicality)
  - No credible links to locognosia.

## Use-dependent plasticity

- S1-uninjured: Altered maps (RDM typicality)
  - Altered hand use (cf. Ejaz et al., 2015; Kolasinski et al., 2016)

# BOLD response amplitudes are elevated on the repaired side



# Summary

## Peripheral rewiring

- S1-repaired: Altered maps (RDM structure, RDM typicality)
  - No credible links to locognosia.

## Use-dependent plasticity

- S1-uninjured: Altered maps (RDM typicality)
  - Altered hand use (*cf. Ejaz et al., 2015; Kolasinski et al., 2016*)

## Homeostatic plasticity

- S1-repaired: Elevated BOLD (*Hansson et al., 2003; Nordmark et al., 2020; Rosen et al., 2012; Chemnitz et al. 2015; Bjorkman et al. 2017; Taylor et al., 2009*).
  - Cortical disinhibition (*cf. Garraghty et al., 2006; Garraghty et al., 1991; Levy et al., 2002; Sammons et al., 2015; Mowery et al., 2015*)

# Thanks!

## Ysbyty Gwynedd | Glan Clwyd



Mr. Edwin Jesudason, Hand Surgeon



Louise Booth, Hand Therapist



Mr. Gareth Payne, Clinical Neurophysiologist



Mrs. Louisa Banks, Hand Surgeon

## Liverpool



Dr. Andrew Marshall, Senior Lecturer in Pain Neuroscience



Dr. Anne Marshall, Postdoctoral researcher

## Wythenshawe



Prof. Vivien Lees, Clinical Academic Professor of Plastic Surgery

Rob Wardle, Patient Co-Applicant



Mr. Hugh Wright, Consultant Plastic & Hand Surgeon

Ms. Jessica Nightingale, Public Patient Involvement & Engagement

## Bangor



HAND & BRAIN LAB



PRIFYSGOL BANGOR UNIVERSITY



Dr. Ken Valyear, Psychology



Dr. Martin Weber, Psychology



Ronan Timircan, Psychology



Ben Govier, Psychology



Elsie Pearce, Psychology

## Birmingham



Dr. Caroline Miller, NIHR Senior Clinical Research Practitioner

## Nottingham



Prof. Susan Francis, Professor in Physics



Dr. Michael Asghar, Postdoctoral researcher



Dr. Alexia Karantana, Clinical Associate Professor in Hand Surgery



University of Nottingham

Sir Peter Mansfield Imaging Centre



Mapping the consequences of peripheral nerve injury on brain organisation and hand function.