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Reconstructing neural representations of tactile space in the sensorimotor areas

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University of Kent

Trier, 28 March 2023

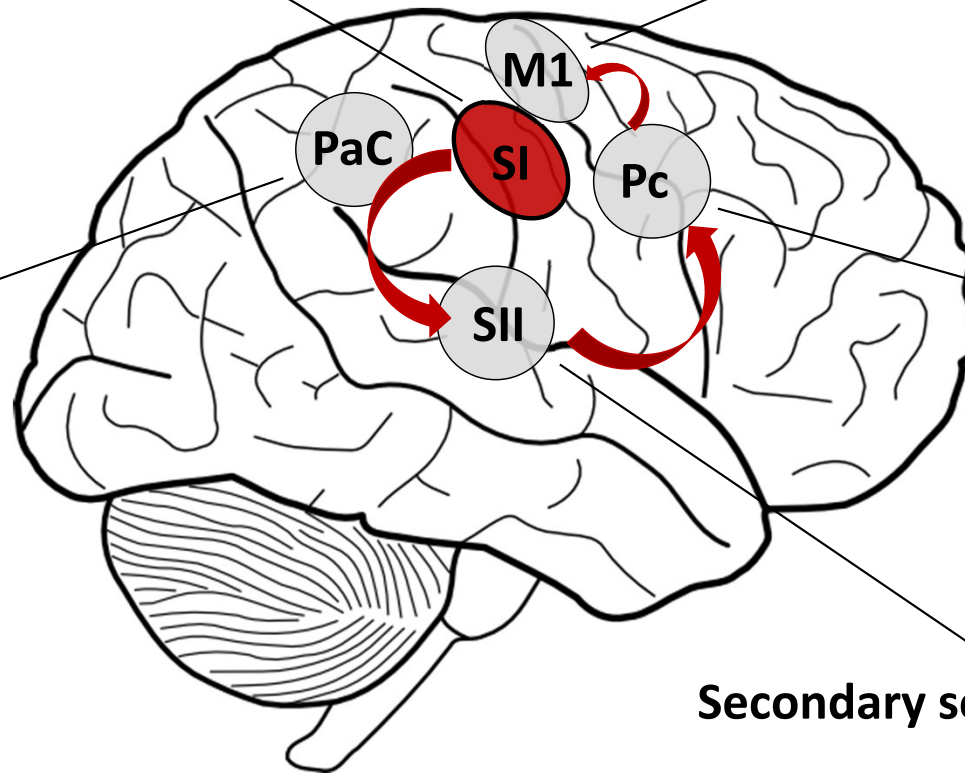
Flow of somatosensory information

Primary somatosensory cortex

Primary motor cortex

Parietal cortex

Premotor cortex



Secondary somatosensory cortex

**PRIMARY SITE FOR
TOUCH**

**BILATERAL
INTERACTIONS**

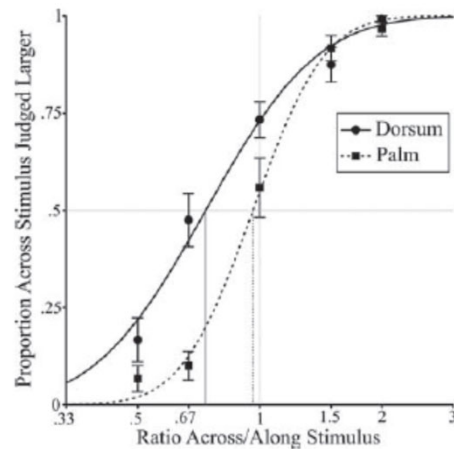
**DISTORTED
REPRESENTATIONS**

Distortions and misperceptions of the body are a familiar result of several psychiatric and neurological conditions

Phantom limbs, Anosognosia for hemiplegia, Somatoparaphrenia
Anorexia nervosa, body dysmorphic disorder

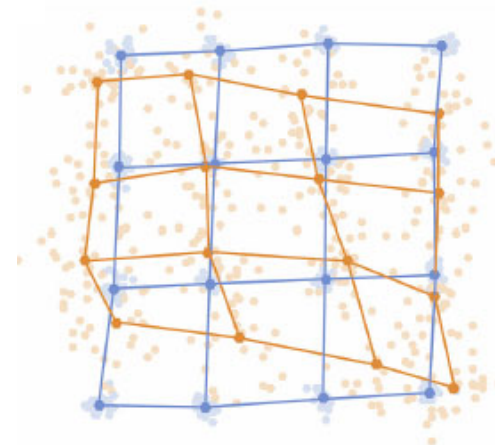
Large and systematic distortions of body representation in healthy adults

Tactile size



Longo & Haggard, 2011, JEP:HPP

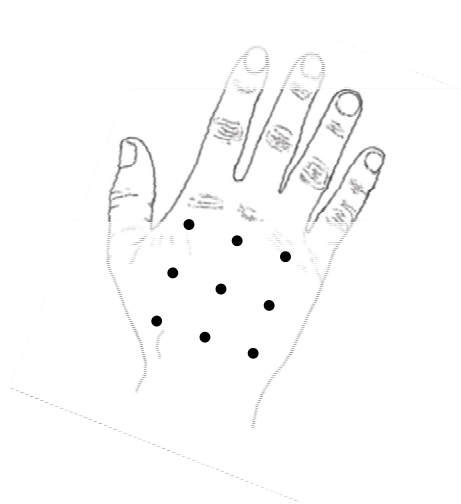
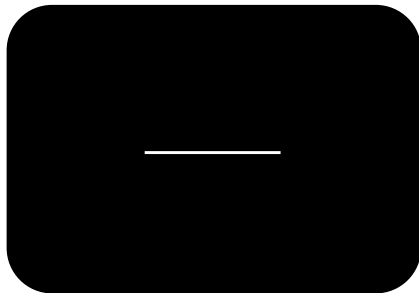
Perceptual distance



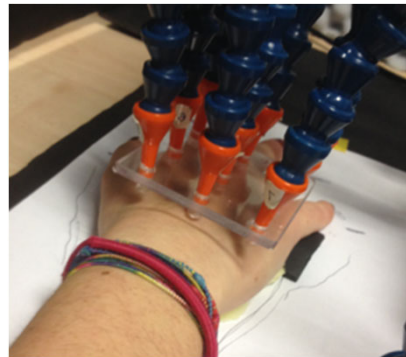
Longo & Morcom, 2016, Frontiers

The **aim** of this project is to **define the neural basis of these distortions**

Behavioral experiment
(tactile distance estimation)

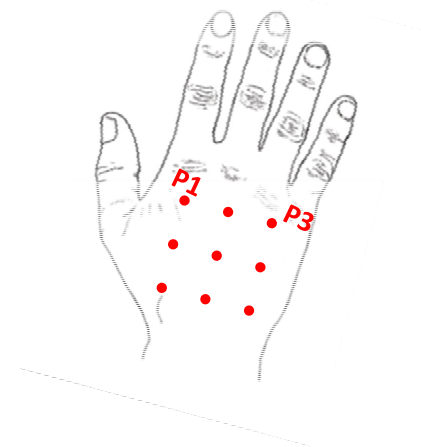


Air-puff tactile stimulator



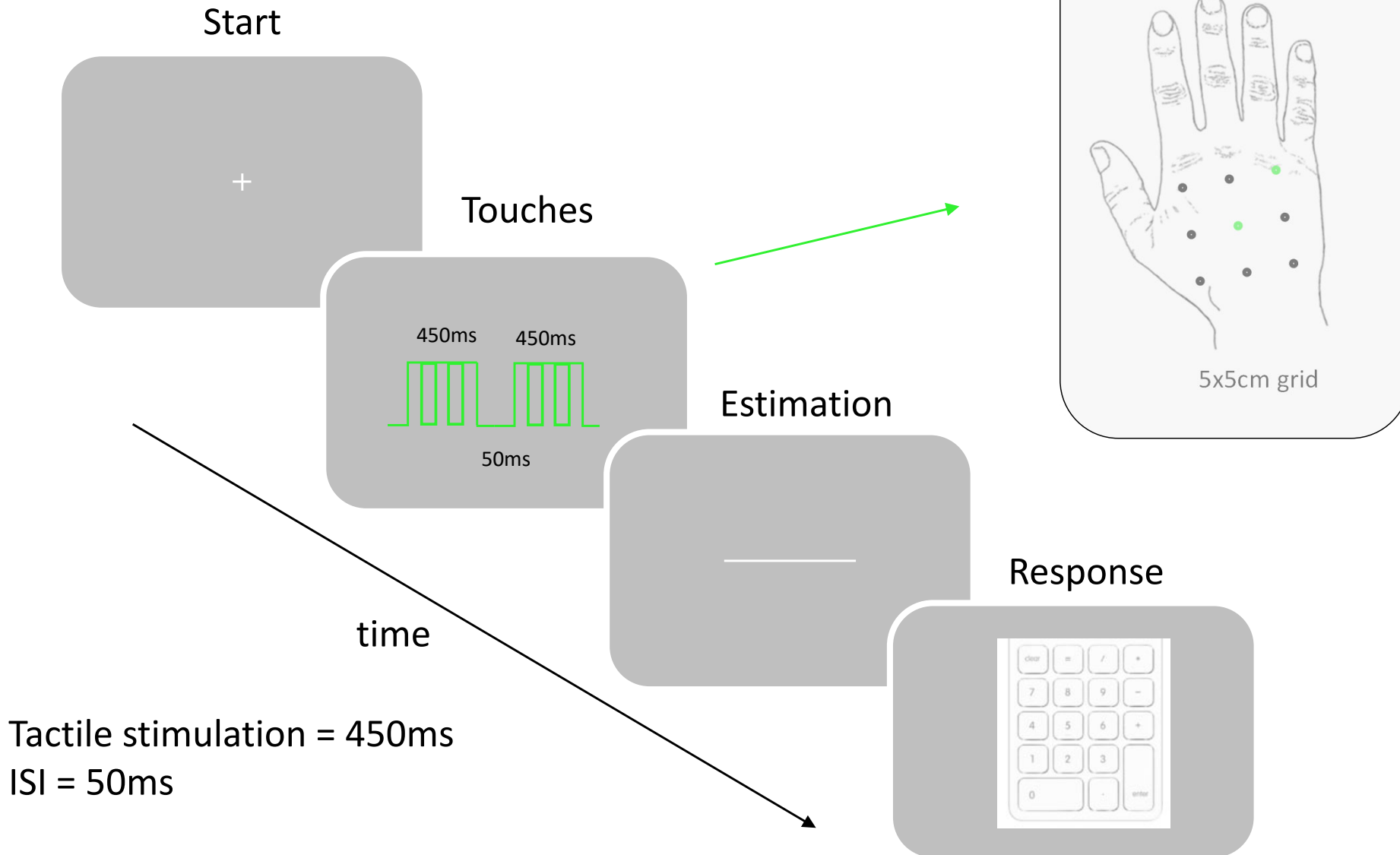
fMRI experiment
(stimulation of the 9 points)

Pay attention to
the stimulation



N = 12

Vision of the hand was prevented



Multidimensional Scaling (MDS)

Table 1 Flying Mileages Between 10 American Cities

Atlanta	Chicago	Denver	Houston	Los Angeles	Miami	New York	San Francisco	Seattle	Washington, DC	
0	587	1212	701	1936	604	748	2139	2182	543	Atlanta
587	0	920	940	1745	1188	713	1858	1737	597	Chicago
1212	920	0	879	831	1726	1631	949	1021	1494	Denver
701	940	879	0	1374	968	1420	1645	1891	1220	Houston
1936	1745	831	1374	0	2339	2451	347	959	2300	Los Angeles
604	1188	1726	968	2339	0	1092	2594	2734	923	Miami
748	713	1631	1420	2451	1092	0	2571	2408	205	New York
2139	1858	949	1645	347	2594	2571	0	678	2442	San Francisco
2182	1737	1021	1891	959	2734	2408	678	0	2329	Seattle
543	597	1494	1220	2300	923	205	2442	2329	0	Washington, DC

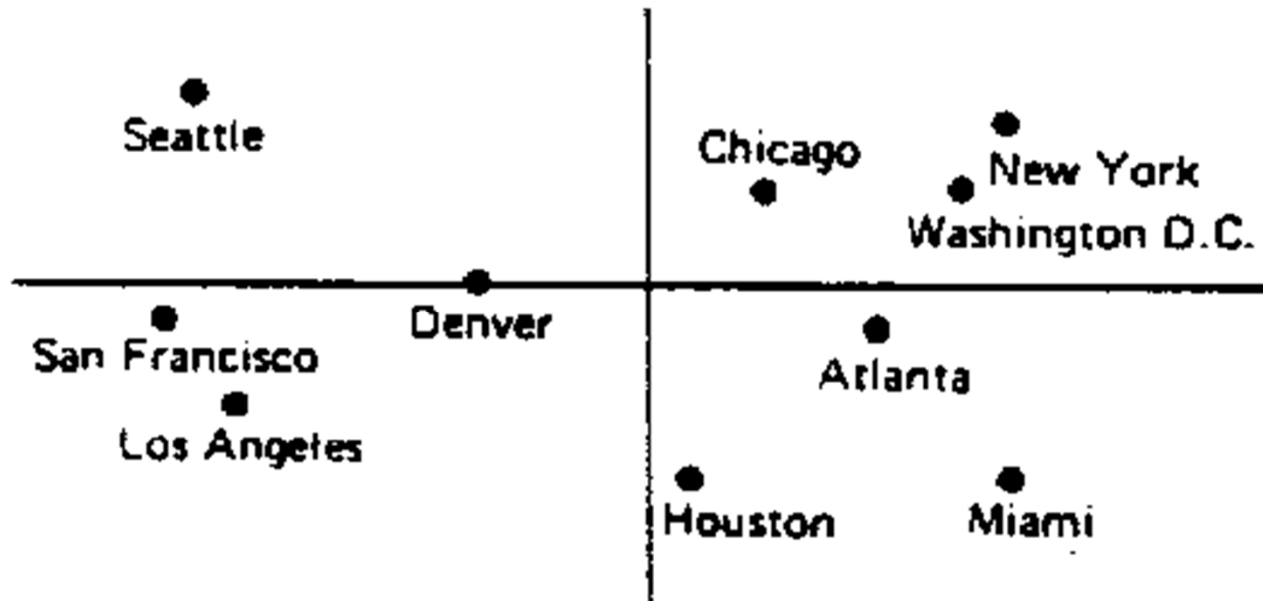
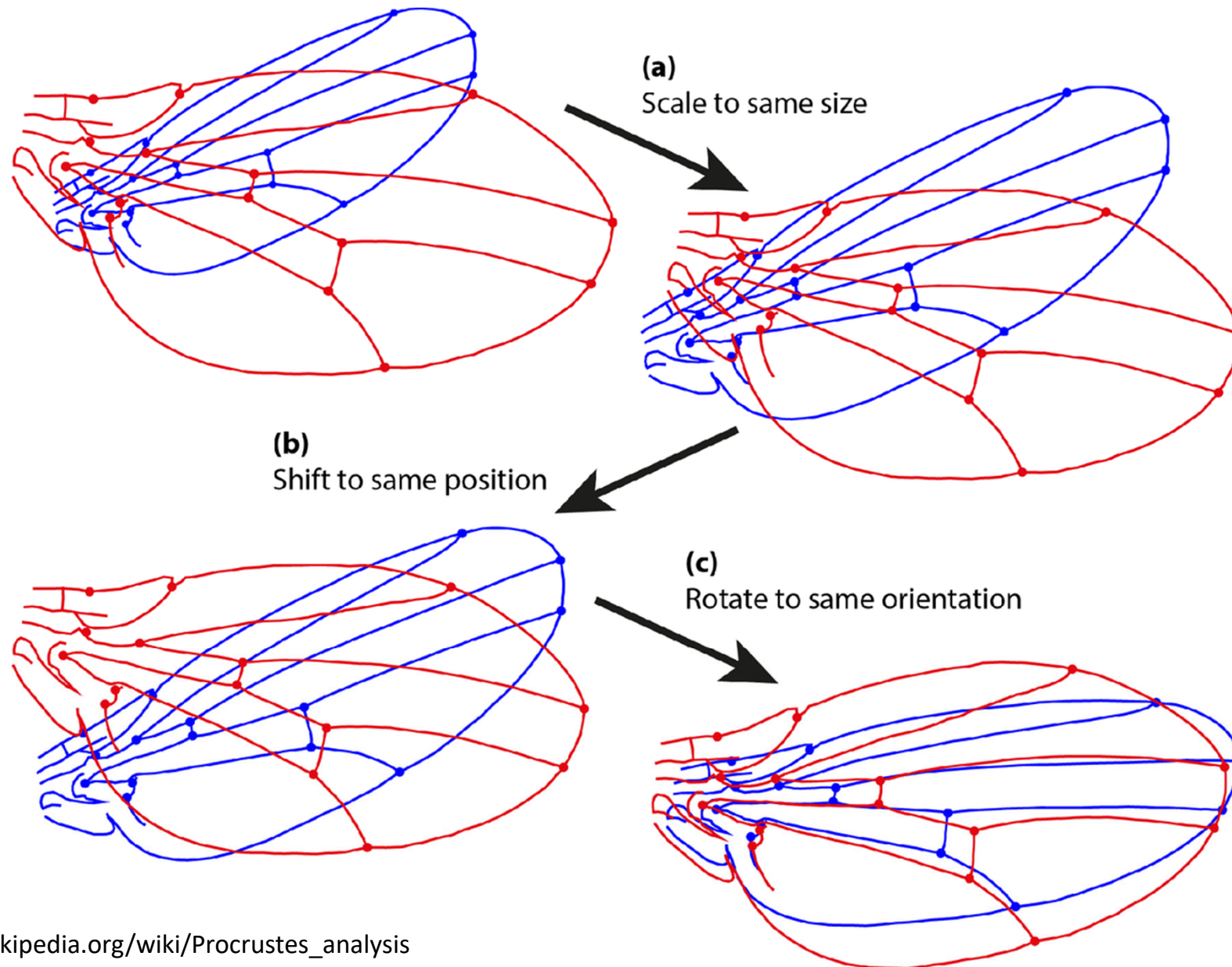
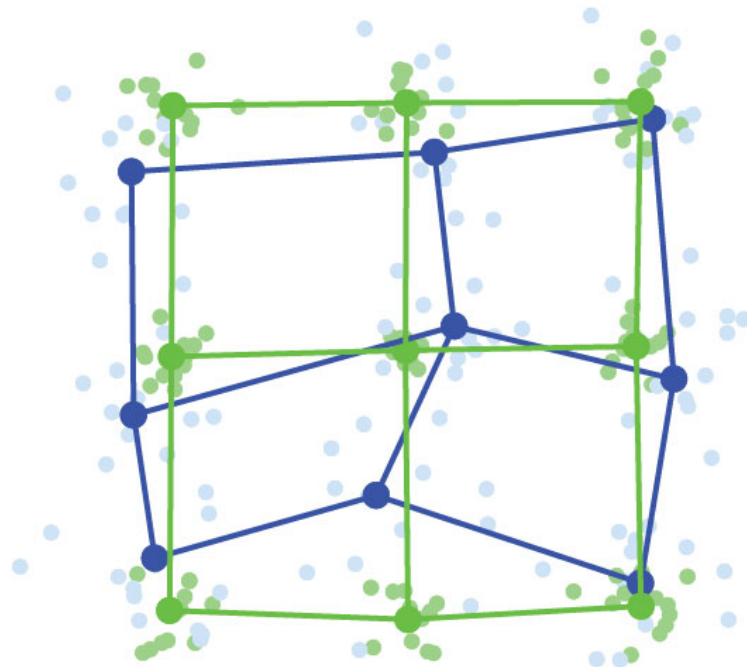


Figure 1 CMDS of flying mileages between 10 American cities.

Generalized Procrustes alignment (GPA)

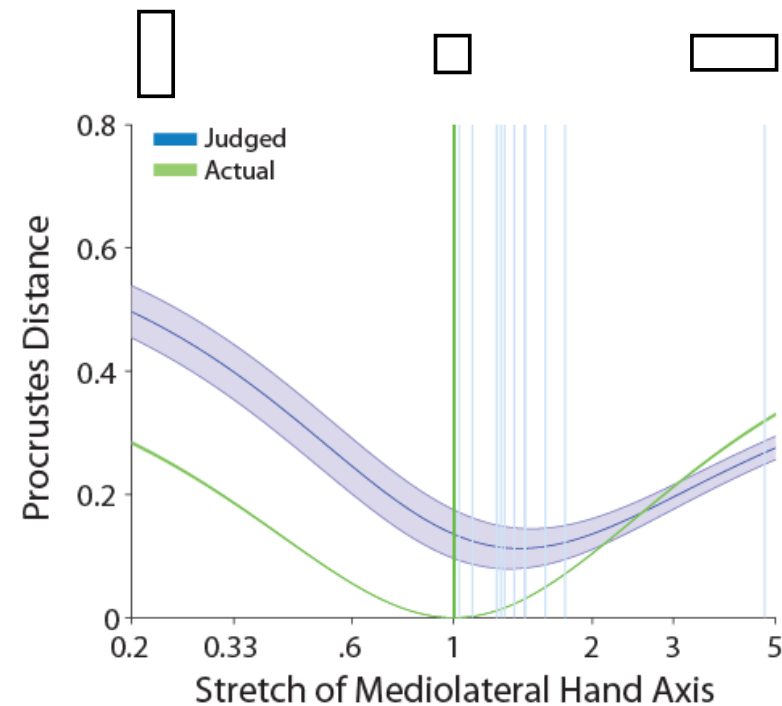


Generalized Procrustes alignment

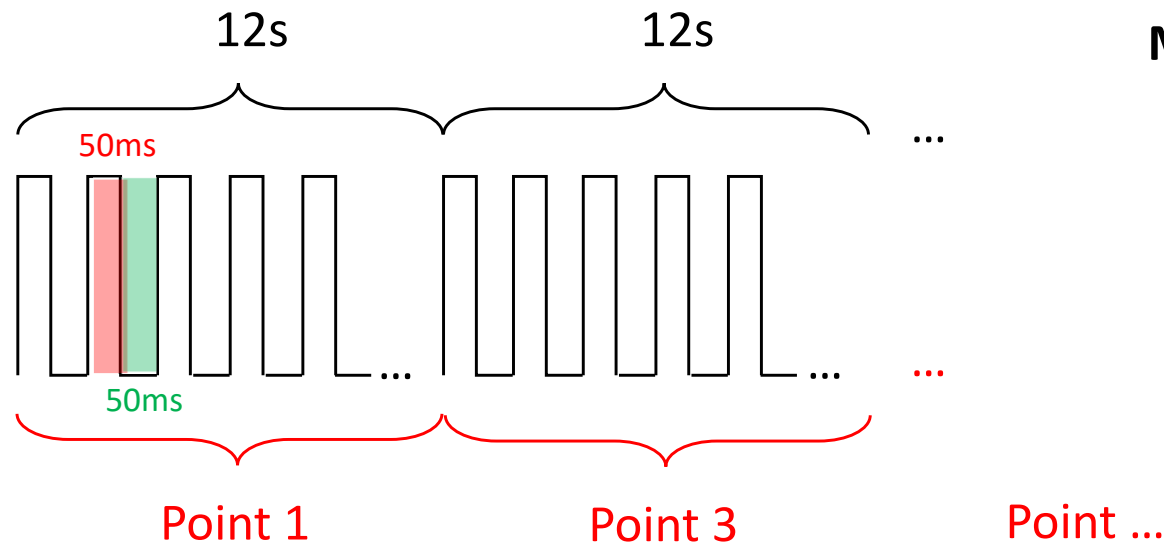
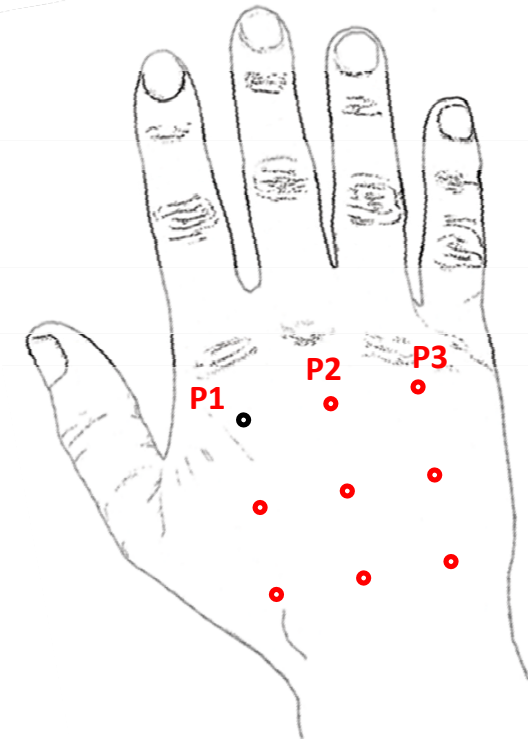


■ Judged ■ Actual

Mean Procrustes distance of the maps and idealized grid stretched



Skin space is stretched along the medio-lateral axis of the hand dorsum, compatibly with previous reports (e.g., Longo and Haggard 2010, 2012; Longo and Golubova 2017)

**MR = 1.5T**

Each point stimulated 5 times + 10 times of no-stimulation
Random Block Design (4 Runs)

TR=1s

voxel size=2.3mm³

Volumes=670 (662+8skip)

Sequence: Ec4-2.3m-36-1628-1s-55e (functional)

4x multiband sequence

Length: 11.7 minutes

Participant task: count how many asynch stimulations there were in the run

Eyes closed

Sequence: HiResMPRAGE-1.0m (anatomical)

Sequence: AlignMPRAGE 1x1x2 (Alignment scan)

Table 1 Flying Mileages Between 10 American Cities

	Atlanta	Chicago	Denver	Houston	Los Angeles	Miami	New York	San Francisco	Seattle	Washington, DC	
0	587	1212	701	1936	604	748	2139	2182	543	Atlanta	
587	0	920	940	1745	1188	713	1858	1737	597	Chicago	
1212	920	0	879	831	1726	1631	949	1021	1494	Denver	
701	940	879	0	1374	968	1420	1645	1891	1220	Houston	
1936	1745	831	1374	0	2339	2451	347	959	2300	Los Angeles	
604	1188	1726	968	2339	0	1092	2594	2734	923	Miami	
748	713	1631	1420	2451	1092	0	2571	2408	205	New York	
2139	1858	949	1645	347	2594	2571	0	678	2442	San Francisco	
2182	1737	1021	1891	959	2734	2408	678	0	2329	Seattle	
543	597	1494	1220	2300	923	205	2442	2329	0	Washington, DC	

Multidimensional scaling (MDS)

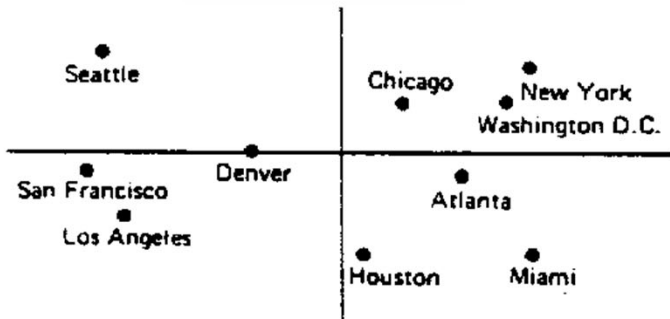
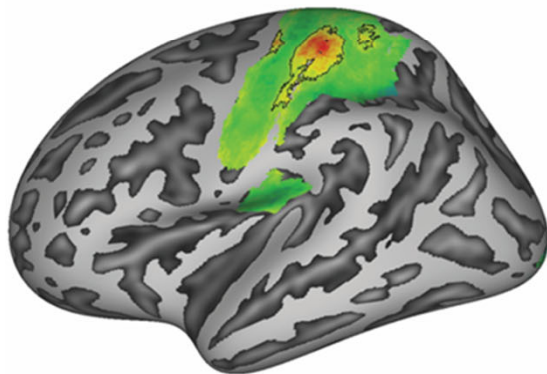
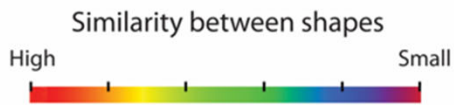
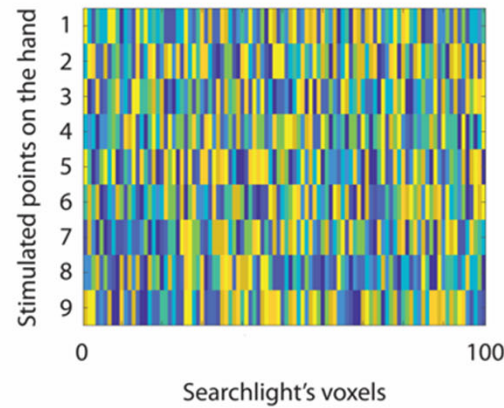


Figure 1 CMDS of flying mileages between 10 American cities.



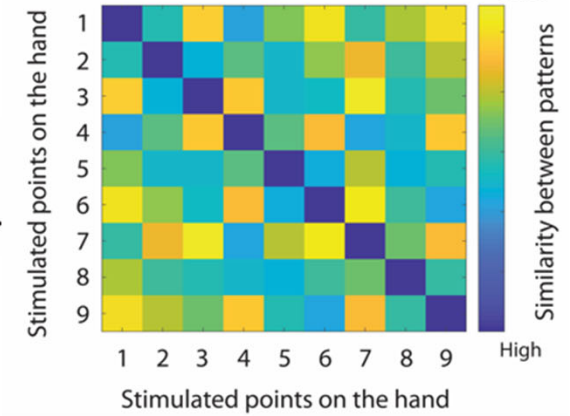
Procrustes distance

Neural patterns (betas)

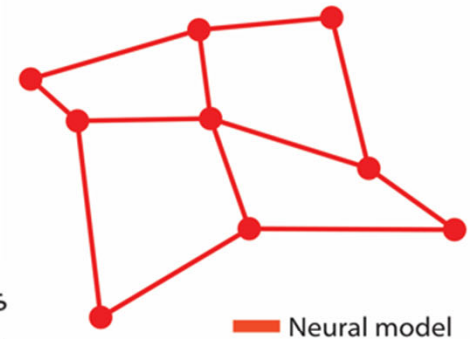


Pairwise Euclidean distance

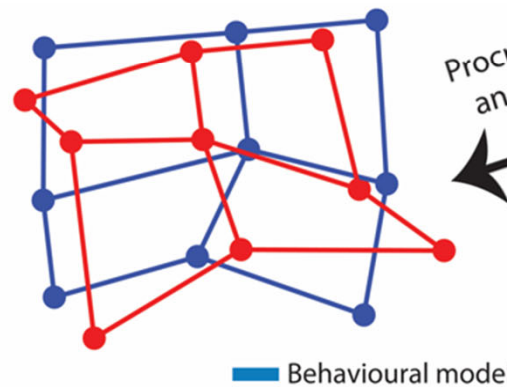
Euclidean distances

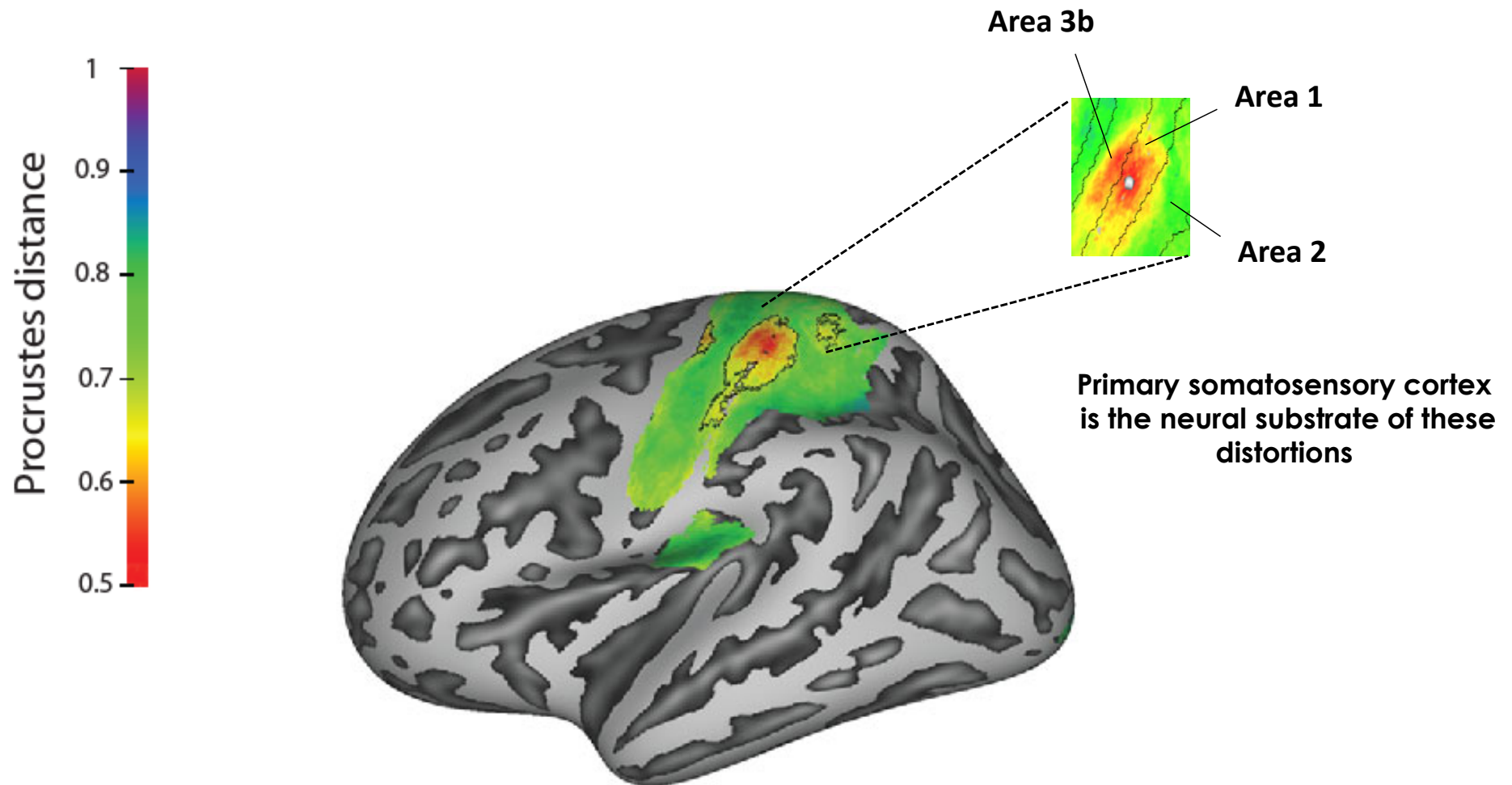


Multidimensional scaling (MDS)



Procrustes analysis

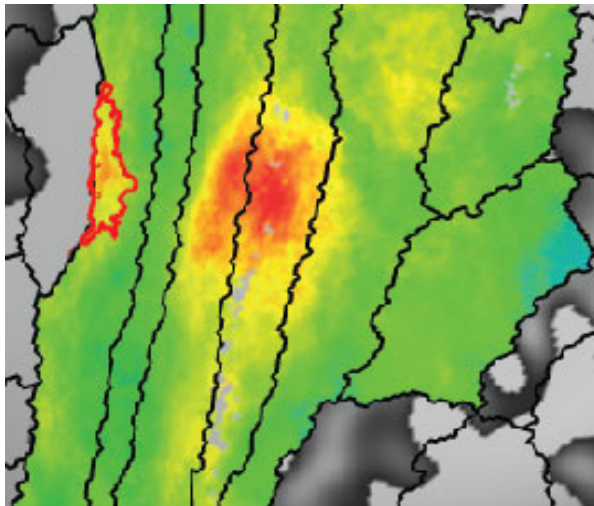




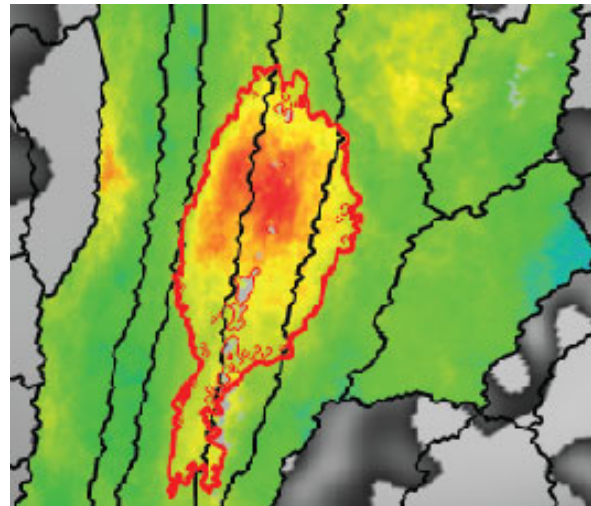
Brain regions in which the spatial geometry of the skin could be reconstructed from the representational pattern of neural activations. Red contours reflect significant cluster resulted from the cluster-based bootstrapping analysis ($p < 0.001$ at the vertex level; $FDR < 0.05$ at the cluster level).

Brain regions in which spatial geometry of the skin can be reconstructed

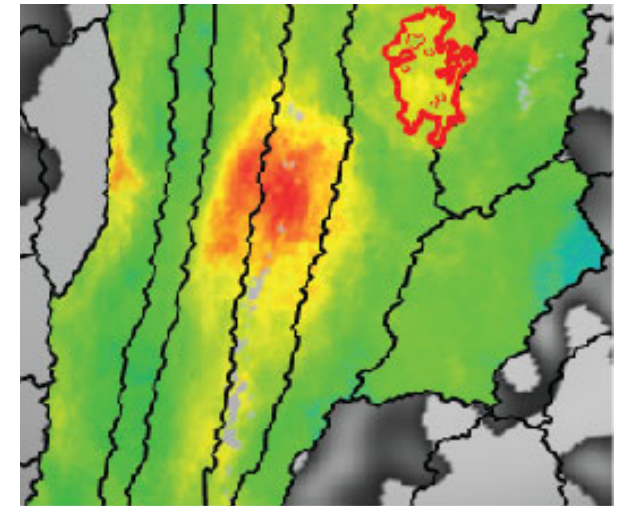
M1 (Area 4)



S1 (Area 3b/1)



S1 (Area 2)

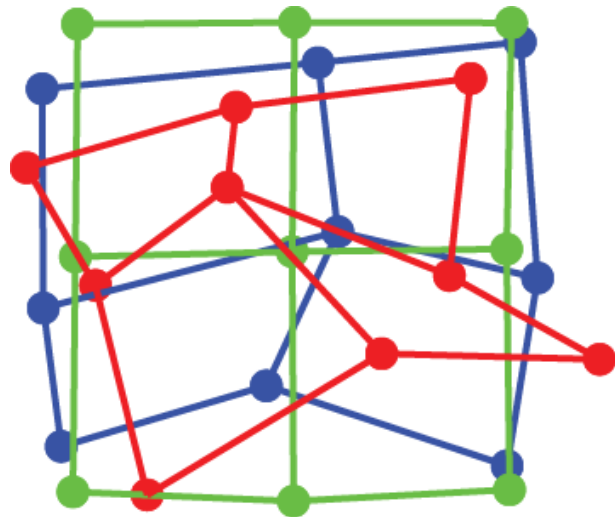


Magnified view of the three significant clusters for area 4 (M1), area 3b/1 (SI) and area 2 (SI), respectively, when comparing the neural and perceptual maps.

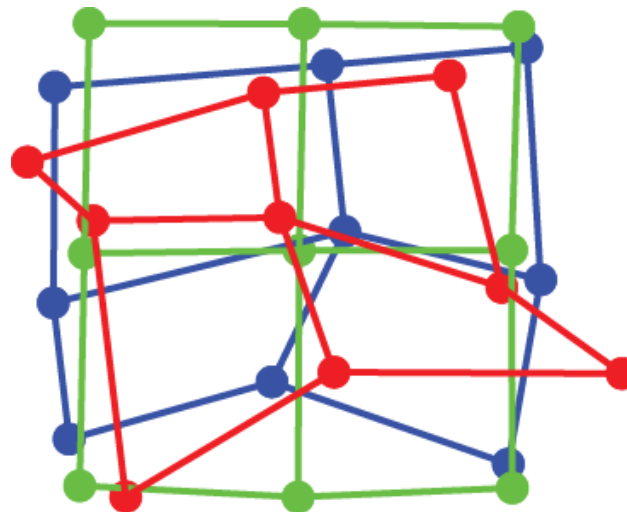
MDS

Generalized Procrustes alignment

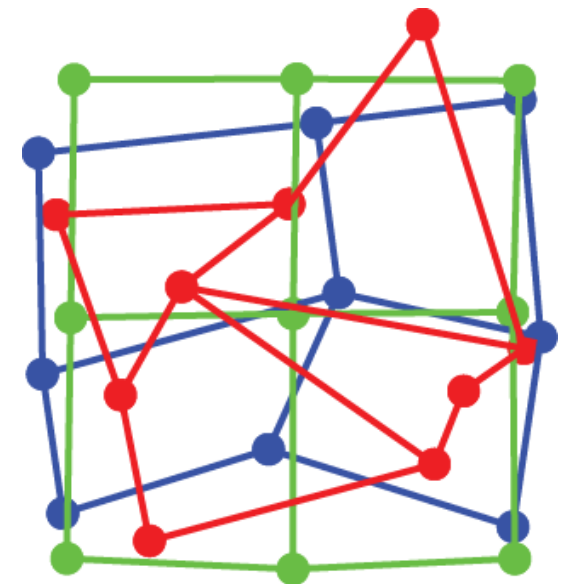
M1 (Area 4)



S1 (Area 3b/1)



S1 (Area 2)

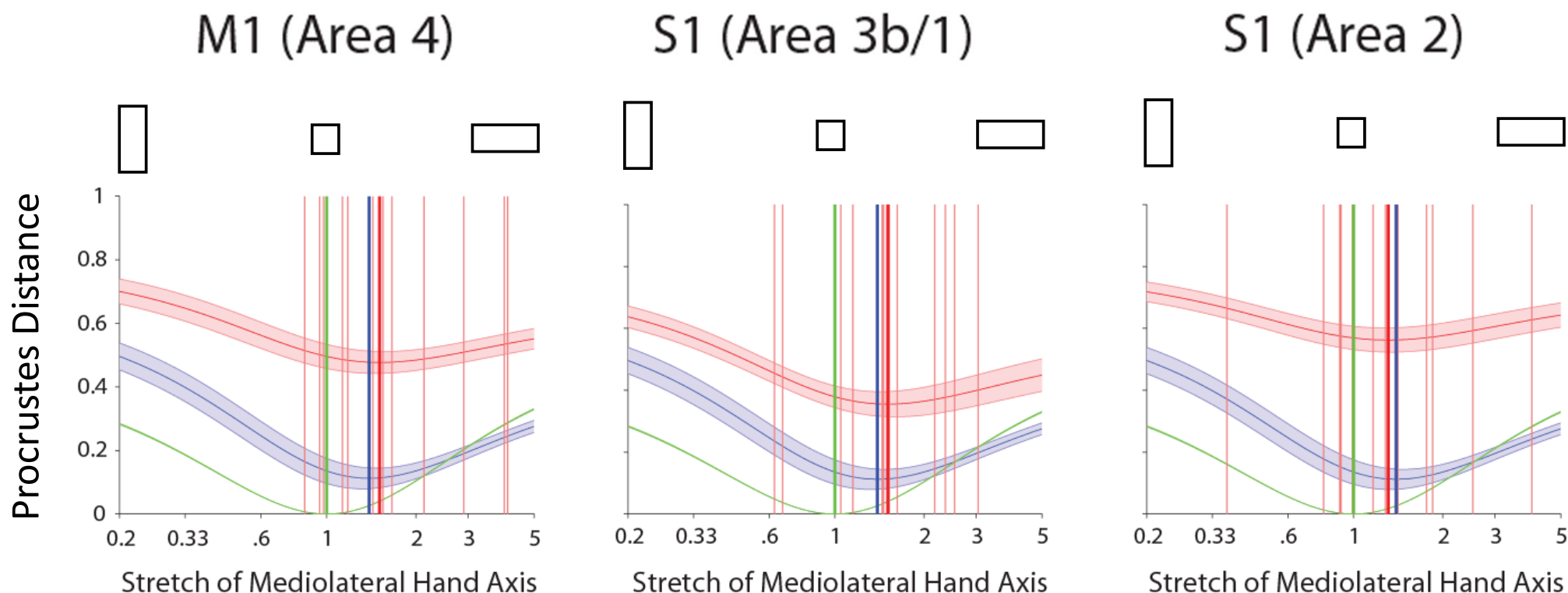


■ Judged

■ Actual

■ Neural

Mean Procrustes distance of the maps and idealized grid stretched



Skin space is stretched along the medio-lateral axis only in the contralateral primary sensorimotor cortices, with respect to the locus of stimulation.

We were able to reconstruct the representations of the internal geometry of tactile space of the skin using MDS, both for behavioral and functional magnetic resonance imaging data.

Using fMRI in combination with MDS we were able to show that similar distortions can be elicited by processing neural data. Strikingly this was evident only in the contralateral primary sensorimotor cortices, with respect to the locus of stimulation.

This low-level cortical brain area carry information about the tactile space of the hand dorsum being stretched along the medio-lateral axis (or, equivalently, compressed in the proximal-distal axis).

Such a pattern that matches the behavioral data did not emerge in any other brain regions tested.



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Thanks for your attention

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