Cortical Representation of Phantom Limb in Lower Limb Amputees

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Introduction

Sensorimotor cortex (SMC) is typically organized according to a somatotopic map comprising distinct limb representations. SMC organization and cortical limb representations may be altered in individuals suffering from limb loss. Although cortical representation changes appear to relate to alterations in the sensorimotor functions of individuals suffering from a loss of upper limbs, much less is known regarding SMC reorganization and its relationship to behavioral outcomes in individuals suffering from lower-limb loss. We measured BOLD fMRI signals in individuals with lower-limb loss as they performed simple motor actions to characterize sensorimotor cortex reorganization after limb loss.

Objectives

- To determine whether deprived cortex continues to represent the lost limb in amputees
- To determine whether sensorimotor regions outside of deprived cortex change with limb loss
- To determine if cortical activity relates to individual clinical details

Methods

Functional neuroimaging procedures

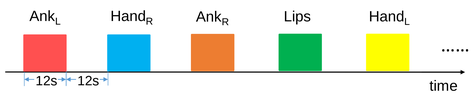
- 3T Prisma scanner. Multi-band accelerated (SMS) EPI sequence: TR = 1500 ms; TE = 34 ms; number of slices = 69; FOV = 192 mm.

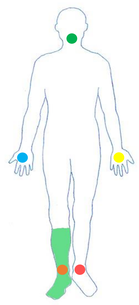
Data analysis

- fMRI data processing using AFNI, FreeSurfer and Matlab

Motor task during scanning

- Participants were asked to move specific body parts during different blocks: Left ankle (Ank_L), right ankle (Ank_R), left hand ($Hand_L$), right hand ($Hand_R$), lips.





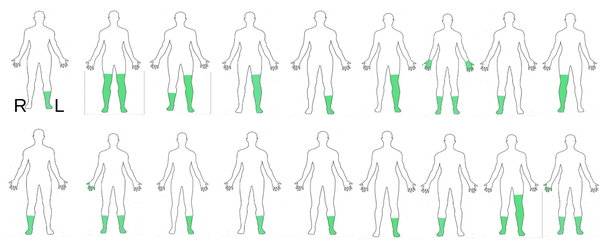
Resting state scanning

- Subjects were asked to rest with their eyes open for 15 min

Participants

- N = 18 (12 unilateral amputees and 6 bilateral amputees)

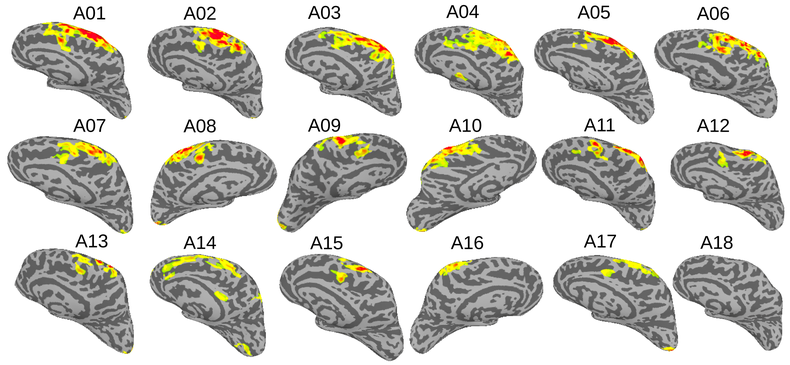
Body templates of amputees



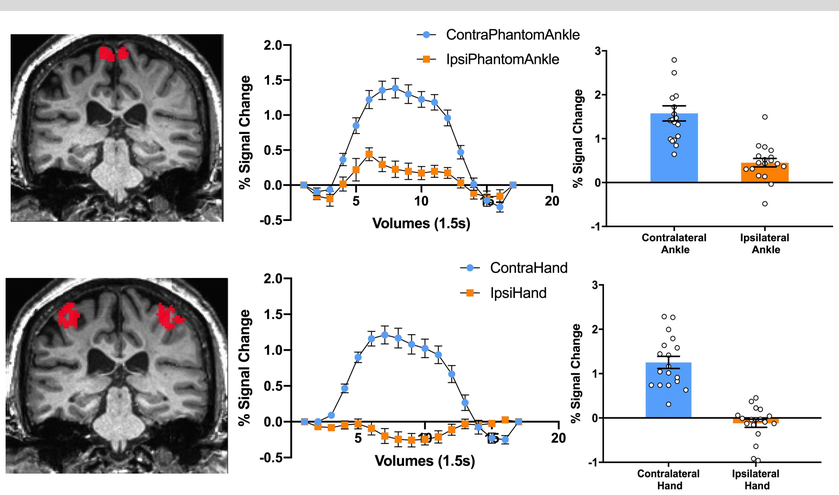
	A01	A02	A03	A04	A05	A06	A07	A08	A09
Age	57	48	61	62	61	23	57	62	28
Amp.Yrs	15	1	22	6	1	3	3.7	22	3
	A10	**A11**	**A12**	**A13**	**A14**	**A15**	**A16**	**A17**	**A18**
Age	50	60	49	36	67	47	48	41	51
Amp.Yrs	2	2	2	2	47	3.5	3.7	11.6	2.8

Results

1. Phantom ankle movements are associated with activity in deprived cortex



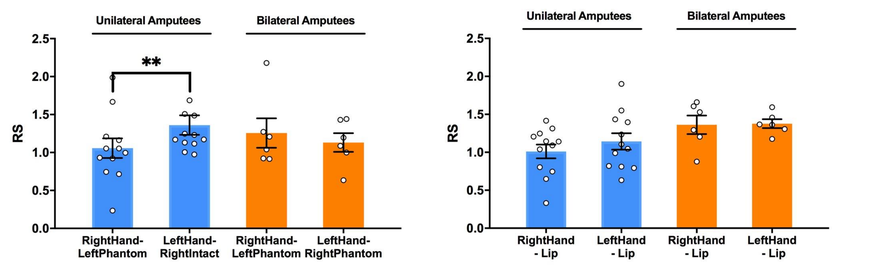
2. Deprived cortex responds preferentially to contralateral phantom ankle



3. Phantom ankle representations may invade ipsilateral hand region

Relative selectivity (RS) represents a cortex's selectivity of it's native limb over a non-native limb.

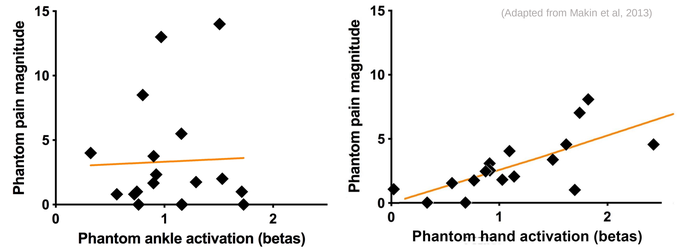
$$RS_{native\ -non\_nativve} = \frac{A_{native} - A_{non\_native}}{A_{native}}$$



Significant interaction effect between amputation type and hemisphere: $F(1,16) = 7.343$; $p = 0.015$

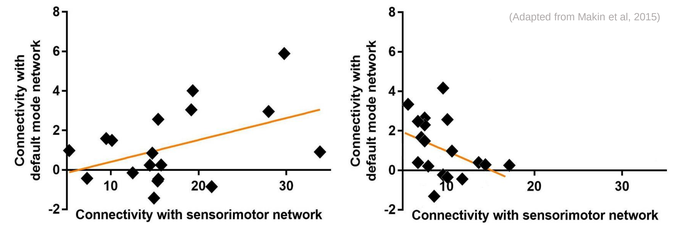
(Unilateral amputees' deprived cortex are all flipped to right hemisphere)

4. Phantom ankle activation in deprived cortex does not predict phantom pain magnitude



(r = 0.04, p = 0.88) (r = 0.67, p = 0.003)

5. There is no relationship between deprived cortex's connectivity with default mode network and sensorimotor network



(r = 0.44, p = 0.067) (r = -0.488, p = 0.04)

Conclusions

- Deprived cortex maintains the representation of the lost limb
- Deprived cortex maintains lateralized selectivity to contralateral phantom limb
- Sensorimotor regions outside of deprived cortex exhibit decreased selectivity of native limb over phantom limb
- Deprived cortex's relationships with phantom pain magnitude and resting state networks are unique in lower amputees

Significance

Our results demonstrate the maintained functional specialization in deprived cortex and cortical reorganization outside of deprived cortex in lower amputees. Moreover, we found deprived cortex's relationships with phantom pain magnitude and resting state networks in lower amputees are different from upper amputees. These findings might provide unique insights to benefit rehabilitation outcomes of lower amputees.

References

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