Surround inhibition on the fingertips of human and non-human primates

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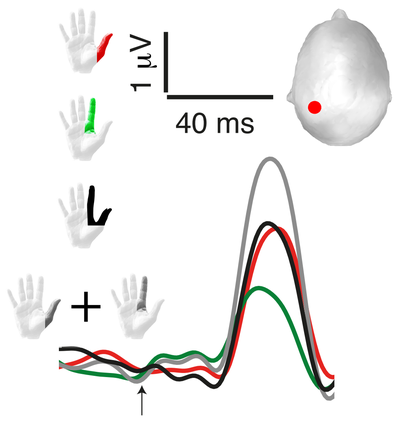
Introduction

According to the idea of *surround* (or *lateral*) *inhibition*, sensory stimulation excites the corresponding cortical circuits while it inhibits the neighboring cortical circuits. This helps towards enhancing the stimulus contrast. This feature of cortical processing is well addressed in the visual and auditory systems of humans and non-human primates, but it is not well explored in the somatosensory system.

We have already helped fill this gap by showing surround inhibition for the human hand when delivering simultaneous tactile stimulations on the thumb and index finger tips (1). Essentially, the amplitude of the neuronal responses was smaller for the simultaneous stimulation than the linear sum of the amplitudes obtained from the individual stimulations.



Summary

- Surround inhibition between the thumb and index finger was observed in both humans and monkeys, with considerable inter-individual variability.
- Surround inhibition was stronger in humans than in monkeys.
- In humans, some extent of the observed surround inhibition could be tuned by tactile inputs coming from the index finger.
- We suggest that surround inhibition is related to the motor abilities of the fingers.

Methods

We delivered identical sets of tactile stimulations on the thumb and index finger tips in macaque monkeys and humans, and used scalp EEG to measure the associated cortical responses to touch.

Subjects:
- 3 adult macaque monkeys (*M. fascicularis*) (5 datasets) under sevoflurane anesthesia
- 54 right-handed, resting humans (54 datasets, 26 ♀, 19-40 yo (median: 24)

Tactile stimulation: Passive tactile stimulation (supra-threshold 2-ms pulses, jittered around 1 Hz) randomly delivered *individually* or *simultaneously* to the fingertips of right thumb and index finger with solenoid tappers (Heijo Research Electronics, UK)

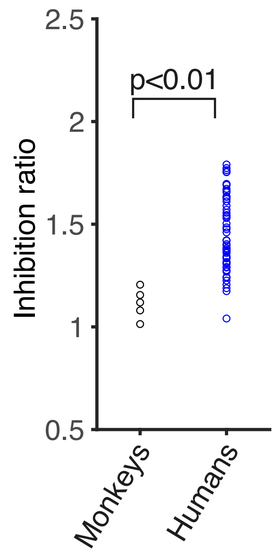
EEG recording: 64-electrode EEG cap for humans (1), 32-electrode EEG cap for monkeys (2) (EASYCAP GmbH, Germany)

Data analysis: Offline processing using EEGLAB (3) involved re-referencing to the average signal, band-pass filtering of the data (1-45 Hz), baseline correction using 200 ms of pre-stimulation data.

Multiple regression analysis was performed by using linear modeling to link subject- and stimulation-derived parameters (age, gender, SSEP amplitude) and EEG signals.

The extent of surround inhibition was quantified by computing the inhibition ratio (IR) between the linear sum of brain activity associated with the *individual* stimulation of each finger, and the activity associated with the *simultaneous* stimulation of both fingers. IR >1 reflects surround inhibition.

$$IR = \frac{\text{SSEP thumb stim} + \text{SSEP index finger stim}}{\text{SSEP (thumb + index finger) stim}}$$



Even though surround inhibition was observed in all subjects (i.e. IR>1), there was considerable inter-individual variability in its extent. Also the IR was larger in humans than in monkeys ($p=1.4822943 \times 10^{-4}$, 2-tailed t test), meaning that surround inhibition was stronger in humans than in monkeys.

Figure 3: Inhibition ratio of the SSEPs from the electrode with maximal positivity, in monkeys and in humans.

Results

Tactile stimulation of the right thumb and index finger resulted in clear somatosensory evoked potentials (SSEPs) in both the species, but as anticipated the signal latency in monkeys was shorter than in humans.

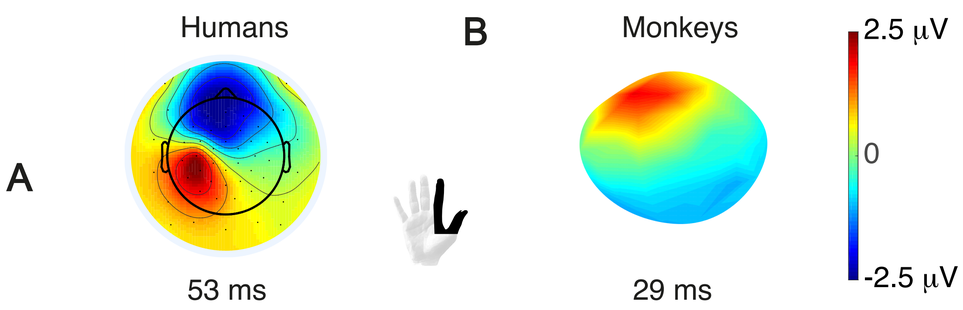


Figure 1: Scalp maps of the mean SSEPs in humans (**A**) and in monkeys (**B**) at latency with maximum mean response amplitude in response to the simultaneous stimulation of the right thumb and index finger tips.

Surround inhibition was observed in both monkeys and humans: the SSEP amplitude was smaller for the simultaneous stimulation of the thumb and index finger (black) than the linear sum of the amplitudes obtained from the individual stimulations (red + green).

To evaluate whether the surround inhibition strength scaled corresponding to the SSEPs associated with each individual finger, we performed multiple regression analysis using the age, gender, thumb SSEP and index finger SSEP as variables.

Due to the low number of monkey datasets, we could not perform any statistical analysis but we could still observe a tendency towards a positive linear relationship between the index finger SSEP and the IR.

This trend was further confirmed in humans: a significant relationship was found between the human index finger SSEP variable and the IR ($p=0.0139$). Essentially, the larger the index finger SSEP, the larger the IR, i.e. the stronger the surround inhibition. All other variables did not contribute significantly to the regression model (full model $R^2=0.21$).

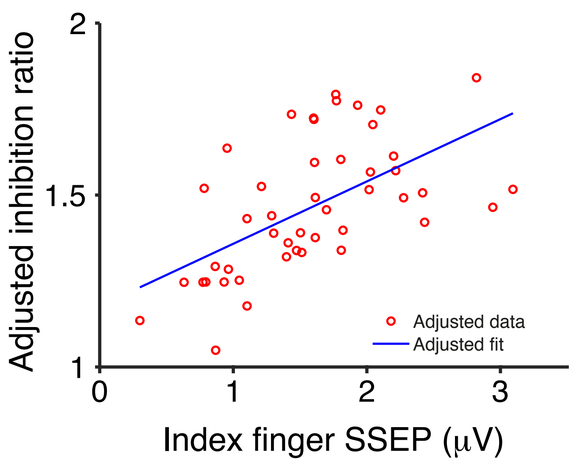


Figure 4: Regression analysis between the index finger SSEP from the electrode with maximal positivity, and the adjusted inhibition ratio in humans.

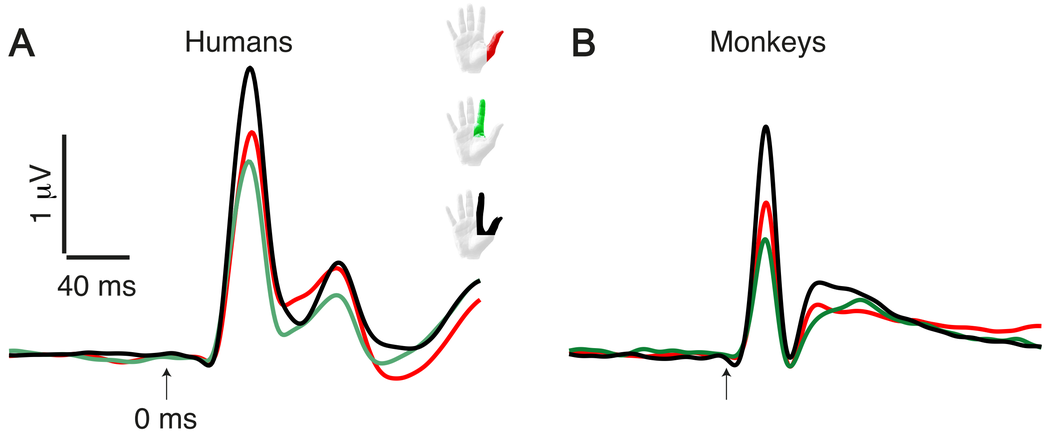


Figure 2: Group means of the SSEPs from the electrode with maximal positivity in response to the individual and simultaneous stimulation of the thumb and index finger tips in humans (**A**) and in monkeys (**B**).

Discussion

- The stronger surround inhibition on the human fingertips observed here may be related to a more independent somatosensory processing from the thumb and index finger in humans than in macaque monkeys.
- Humans more than all other primates are characterised by their outstanding manual dexterity (4). In particular, humans can perform more independent finger movements than macaque monkeys (5). We suggest that the more independent somatosensory processing from the human fingertips may be related to the more sophisticated motor abilities of the human fingers.
- The extent of surround inhibition in humans depends on the somatosensory activation of the index fingertip. This suggests that the inter-individual variation in inhibition is not mere measurement noise, and that surround inhibition between the thumb and index finger is selectively tuned by the inputs from the index finger.

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References

1) Gindrat, A.D., Chytiris, M., Balerna, M., Rouiller, E.M., and Ghosh, A. (2015). Current Biology 25, 109-116.
2) Gindrat, A.D., Quairiaux, C., Britz, J., Brunet, D., Lanz, F., Michel, C.M., and Rouiller, E.M. (2014). Brain Struct Funct 220, 2121-2142.
3) Delorme, A., and Makeig, S. (2004). J Neurosci Methods 134, 9-21.
4) Napier, J. (1962). Scientific American 207, 56-62.
5) Schieber, M.H., and Santello, M. (2004). J Appl Physiol 96, 2293-2300.