EEG assessment of the cortical mechanisms underlying sensory integration from the fingers in non-human primates

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Introduction

- The integration of sensory inputs originating from different fingers allows us to feel and skilfully manipulate objects. The neuronal processes underlying this crucial integration remain poorly understood. Nevertheless, several phenomena conserved across the different sensory systems have already been shown in the somatosensory system as well, namely lateral inhibition, adaptation to the stimulation and use-dependent plasticity.
- Adaptation has already been largely investigated in terms of decrease in amplitude of EEG signal over time following a continuous stimulation and was demonstrated after both electrical and vibrotactile peripheral stimulations. Conversely, only few studies focused on adaptation in terms of changes in EEG component latency.
- Somatosensory evoked potentials (SSEPs) are a powerful tool to evaluate the plastic changes occurring in the central nervous system (see e.g. Andrew et al., 2014).

Goal

- The aim of the present study was to investigate whether the primate brain processes the same tactile inputs differently when the stimuli are presented repeatedly. We focused on the fingertips as they contain a high density of tactile sensors. By using scalp electrodes we were able to detect the neuronal activity in a large population of neurons to survey the overall changes in signal processing as a consequence of repeating a stimulus.
- As the monkeys were anaesthetised the recordings could be fully insulated from movements and muscular artifacts, allowing us to detect even small changes in sensory processing with high sensitivity. Moreover, we could perform repeated measures on the same animal and study whether the repetition-effects in the first experimental session were carried over or diminished in subsequent sessions or after an experimental intervention (e.g. cortical lesion or pharmacological agent).

Material and methods

Subjects
2 adult female macaque monkeys (*Macaca fascicularis*) - Mk-DI and Mk-CA - under sevoflurane anaesthesia

Stimulation
- Individual or simultaneous tactile stimulation randomly delivered to the fingertips of thumb (D1), index finger (D2) and middle finger (D3) of the right hand
- solenoid tappers (Heijo Research Electronics, Beckenham, UK)
- stimulation parameters: suprathreshold 2-ms pulses, jittered around 1 Hz

(image from Heijo Electronics)

EEG
32-electrode EEG recordings of SSEPs (Gindrat et al., 2014)

Data analysis
EEG data were analysed by using EEGLAB and customised MATLAB scripts (threshold: ± 70 µV, filters: 1-80 Hz, average reference).

Refrences

Andrew,D., Haavik,H., Dancey,E., Yielder,P., and Murphy,B. (2014). Somatosensory evoked potentials show plastic changes following a novel motor training task with the thumb. Clin. Neurophysiol.

Dan,Y., and Poo,M.M. (2006). Spike timing-dependent plasticity: from synapse to perception. Physiol Rev. 86, 1033-1048.

Feldman,D.E. (2012). The spike-timing dependence of plasticity. Neuron 75, 556-571.

Gindrat,A.D., Quairiaux,C., Britz,J., Brunet,D., Lanz,F., Michel,C., and Rouiller,E. (2014). Whole-scalp EEG mapping of somatosensory evoked potentials in macaque monkeys. Brain Struct Funct 1-22.

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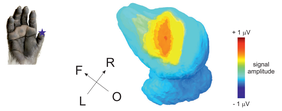
Results

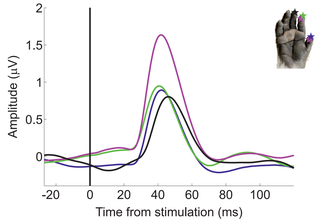
Tactile stimulation evoked potentials

A) Voltage topography after thumb stimulation in Mk-CA

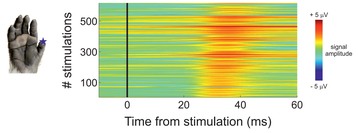


35 ms

B) Brain activation after tactile stimulation in Mk-CA
(from contralateral electrode)



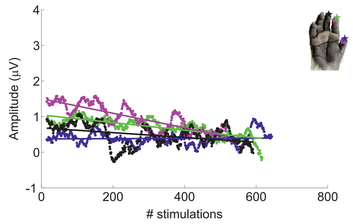
C) «Drift» in latency after thumb stimulation in Mk-DI



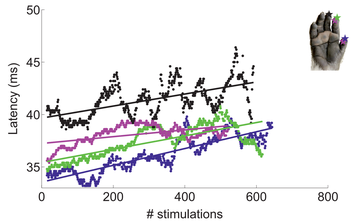
- Tactile stimulation of the fingers elicited a focal contralateral brain activity with a high signal-to-noise ratio in anaesthetised macaque monkeys (**A**, **B**).
- The mean amplitude of activity following a simultaneous finger stimulation (D1 + D2) was less than the theoretical sum of individual amplitudes (**B**).
- Single-trial analysis revealed a «drift» in latency of early cortical component over time after repeated tactile stimulation of the fingers (**C**).

Trial-to-trial delay in sensory processing

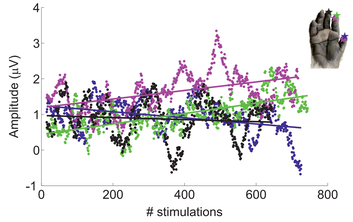
D) Trial-to-trial variation in amplitude



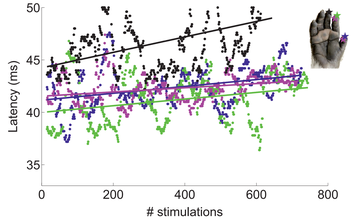
E) Trial-to-trial variation in latency



F) Trial-to-trial variation in amplitude



G) Trial-to-trial variation in latency



H) Change in latency and amplitude per trial

		D1	D2	D1+D2	D3
Mk-DI	Δ ms/trial	3.9000	6.1000	3.0400	5.4800
	Δ µV/trial	-0.0612	-1.0394	-2.0060	-0.6692
Mk-CA	Δ ms/trial	4.6400	3.2000	0.8200	7.1400
	Δ µV/trial	0.8436	-1.4188	-1.1540	0.2818

All values are multiplied by 10^{-3}

All these plots and values in the table were obtained from the first experimental session with each monkey. Data were analysed using a moving average of 40 stimulations.

- In both monkeys, we saw a consistent latency adaptation («drift») (**E**, **G**, **H**) but not amplitude adaptation (**D**, **F**, **H**) in response to the four conditions of tactile stimulation of the fingertips.
- In both animals, the latency adaptation was the smallest after combined stimulation of D1 + D2 (in the first experimental session) while individual stimulation of the three fingers resulted in variable patterns of latency adaptation (**E**, **G**, **H**). The first derivative of latencies (*d*latency/*d*stimulation) did not correlate between any two stimulations. Furthermore, the D3 latency fluctuations were visibly different from the rest of the stimulations - note the larger latency fluctuations from trial to trial in both Mk-DI and Mk-CA. These patterns of data suggest that the trial-to-trial latency changes were stimuli-specific.

Conclusion

- From these data, we show that adaptation affects the temporal domain, as reflected by a latency «drift». We propose that this increase in evoked potential latency observed with repeated stimulation is due to spike-timing dependent plasticity (Dan et al., 2006; Feldman, 2012) leading to weakening of synaptic efficacy. We think that such a weakening of synapses could result in temporal prioritisation for novel stimuli as compared to repeated inputs.
- Our results suggest that the latency changes are independently regulated for each tactile stimulus location, are subject-dependent, and arguably do not result from the side effect of anaesthesia.
- The initial cortical processing studied here (before 60 ms) is open to significant fluctuations within an experimental session and the underlying neuronal circuits processing individual finger inputs can be modified separately from the circuits responsible for simultaneous inputs.

Highlights

- In the present tactile stimulation paradigm, repetitive fingertip stimulation elicits a prominent adaptation in the time domain.
- This temporal «drift» may enable the brain to amplify novel stimuli by delaying the sensory processing of repeated inputs.