Synchronous and asynchronous tactile coactivation differentially effect human somatosensory cortical organisation and tactile discrimination performance

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Introduction

"when the axon of cell A is near enough to excite a cell B and repeatedly or persistently takes part in firing it, some growth process or metabolic change takes place in one or both cells such that A’s efficiency, as one of the cells firing B, is increased" 

Since many years, the importance of temporally correlated inputs and thus the characteristics of the input statistics had been hypothesized to play a key role. In fact, since Hebb (1949) the aspect of simultaneity has become a metaphor in neural plasticity, although the exact role of Hebbian mechanisms in use-dependent-plasticity remains controversial.

Here we try to figure out whether there is an analogue for Hebbian mechanisms on the level of cortical organisation in correlation with behaviour.

Methods

- Cistimulation
- Three hours of associative pairing of tactile stimuli were applied via loudspeakers to the distal phalanges of index, middle, and ring fingers of the right hand.
- Either index or ring finger were stimulated asynchronously, the other two fingers were stimulated synchronously.

- Psychophysics (present)
- Pneumatically driven tactile stimuli were applied to index, middle and ring fingers of both left (control) and right (test) hand in block design.
- The Euclidean distance was calculated between the coordinates of the local maxima of activation for the three fingers of one hand.

IMRI

- Localisation abilities were tested with von Frey hairs on two locations –3 mm left and right of the center of the distal phalanges of the fingers.
- The tip of von Frey hair was applied manually to one of the tested locations.
- Subjects had to respond as fast as possible on which of the locations they felt the stimulus.
- For each session (pretest, posttest, recovery) the amount of mislocalisations between fingers being coactivated synchronously and asynchronously were calculated as the percentage of the total amount of mislocalisations within that session.

Results

Pattern of activation for one subject for index (red), middle (green) and ring (blue) finger of left (control) and right (test) hand. For the test hand, pattern of activation for synchronously activated fingers overlap, whereas the pattern of activation for the asynchronously activated finger moved further apart. Pattern of activation of the fingers of the control hand are clearly separated.

Psychophysics

Percentage of mislocalisations across synchronously and asynchronously coactivated fingers for pretest, posttest and recovery (mean and standard errors of the mean (SEM)). The number of mislocalisations between synchronously coactivated fingers increases, whereas it decreases between asynchronously coactivated fingers.

Euclidean distance between synchronously and asynchronously coactivated fingers (mean and SEM). The distance between the local maxima of activation of asynchronously coactivated fingers increases compared to the distance between synchronously coactivated fingers.

Conclusions

- Several hours of both synchronous and asynchronous passive tactile coactivation induced plastic changes on a cortical level.
- Cortical reorganisation does not require long-term modifications in the somatosensory input statistics and can be induced without attention or reinforcement.
- Cortical reorganisation was accompanied by altered behavioural performance in a tactile localisation task, suggesting a relationship between cortical reorganisation and the perceptual capacity of an individual.

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