Visually blind behavioural assessment of functional recovery of manual dexterity from motor cortex lesion in macaque monkeys

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Introduction

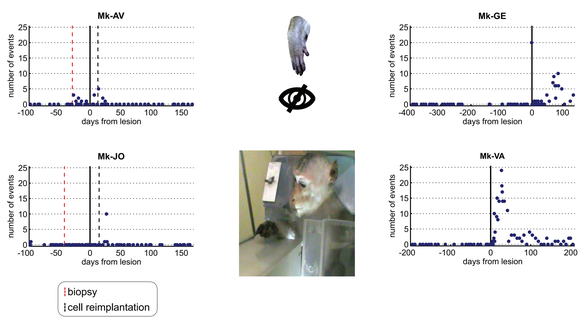
Motor and somatosensory cortical areas are densely interconnected and participate together to the motor control, forming the functional sensorimotor system. The primary somatosensory cortex (S1) sends both somatosensory inputs to the primary motor cortex (M1) and corticospinal projections, contributing to the control of voluntary movements such as the precision grip. Moreover, the somatosensory system plays a key role in active motor exploration by palpation in the absence of visual feedback.

A behavioural task was initially developed by Brinkman and Kuypers (1973) to test the precision grip ability in non-human primates, and an improved version - the modified Brinkman board task - is currently used in our laboratory: the animal has to retrieve banana pellets contained in 25 vertically and 25 horizontally oriented wells distributed on a rectangular board.

Hypothesis

After a lesion in M1, the sensorimotor system will be affected in parallel with the motor control itself. The resulting impairments can be highlighted with another test derived from the modified Brinkman board task: the **Brinkman box (BB) task,** which was specifically designed to assess the role of sensory inputs in a precision grip task performed with or **without** visual feedback before and after a unilateral lesion of the hand representation of M1.

Somatosensory-related deficits of the contralesional hand



Some monkeys exhibited post-lesion somatosensory-related deficits comparable to a sensory agnosia: in several trials (*number of events* above), they performed a precision grip but failed to grasp the pellet, withdrew the hand from the well to the mouth, then visually inspected the empty palm and only at that time realised that they did not retrieve any pellet (empty hand).

Conclusion

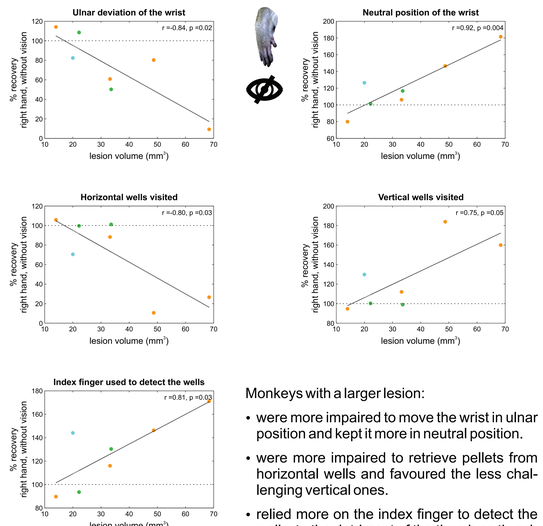
The Brinkman box task is very sensitive and relevant to test the exploratory ability and tactile sense in a lesional context. It allows detecting subtle impairments and highlights the importance of somatosensory feedback, especially in tasks performed without visual control.

The distinct pattern of recovery according to the presence/absence of visual feedback suggests a compensatory role played by the other sensory systems (vision here) in case of sensorimotor impairments.

Complementary information about the cortical mechanisms underlying the functional recovery after the lesion can be obtained from EEG mapping of somatosensory evoked potentials from the scalp (Gindrat et al., 2014).

Results

Increasing deficits of the contralesional hand are observed in BB task without vision after a larger cortical lesion of the M1 hand representation.

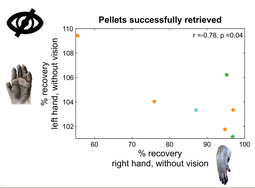


(For points located below the 100-% line, post-lesion level<pre-lesion level)

Monkeys with a larger lesion:

- were more impaired to move the wrist in ulnar position and kept it more in neutral position.
- were more impaired to retrieve pellets from horizontal wells and favoured the less challenging vertical ones.
- relied more on the index finger to detect the wells, to the detriment of the thumb as thumb use usually needed an additional wrist deviation (although no statistically significant correlation for the thumb).

The post-lesion contralesional deficits are counterbalanced by a significant improvement in the ipsilesional performance.



Monkeys with a worse recovery of the contralesional hand after the lesion tended to exhibit a higher level of performance with the non-impaired hand.

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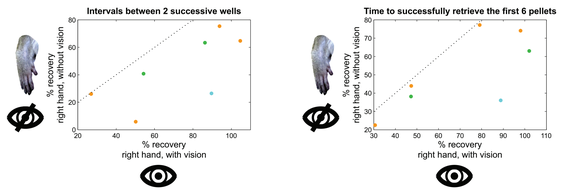
The post-lesion contralesional recovery is better in the BB task with vision than without vision.

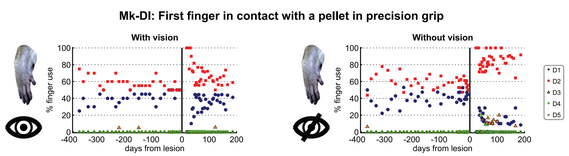
At population level:



The BB task performed without vision is more challenging than with vision because the former almost exclusively relies on tactile inputs from the fingers and on spatial memory.

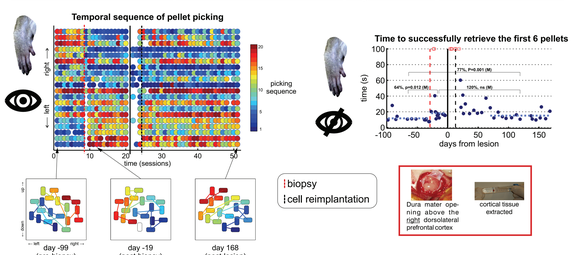
(The unitary line is displayed. For points located below, recovery with vision>recovery without vision)

At individual level:



Mk-DI showed an opposite post-lesion evolution of the finger use according to the task: whereas there was a partial normalisation of thumb and index finger use in the BB task **with vision**, the use of the thumb decreased over time and never recovered in the BB task **without vision**.

Adverse effects of a prefrontal cortical biopsy on the ipsilesional hand



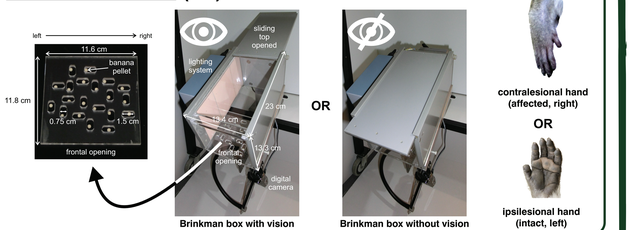
Following a large prefrontal **cortical biopsy**, Mk-AV changed obviously its temporal sequence of pellet picking with the ipsilesional (to the biopsy) hand under visual control, and maintained this behaviour after the motor cortical **lesion**.

The biopsy also altered the behaviour without visual control, inducing among others an increase in the time needed to successfully collect the first 6 pellets, this deficit remaining persistent after the post-lesion recovery.

(Pre- and post-lesion mean plateaux are displayed in light blue. M: Mann-Whitney U test
Partially or completely missing values at a given date (mainly task not performed after the lesion) are represented by o.)

Material and methods

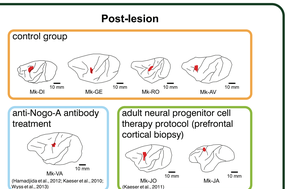
Brinkman box task (BB)



Monkeys

7 adult *Macaca fascicularis*

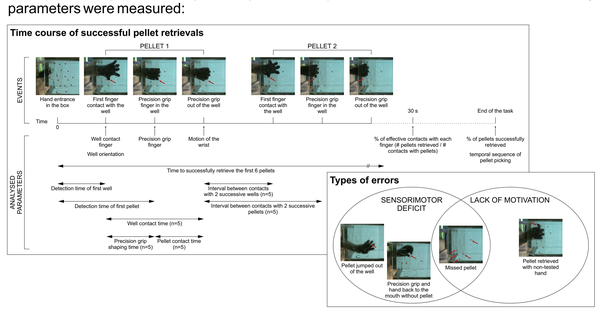
At behavioural plateau in manual dexterity tests, unilateral permanent cortical lesion of the hand representation of M1 by microinfusions of ibotenic acid



Projection of the grey matter lesioned area on lateral view of the brains, based on consecutive coronal histological sections (Nissl and SMI-32 stainings).

Data analysis

BB data **with** and **without vision** obtained from the **contralesional hand** and the **ipsilesional hand** were analysed frame by frame (25 frames/s) with the software Kinovea. The following parameters were measured:



Pre and post-lesion mean plateaux were computed for each parameter. The **percentage of recovery** was defined for appropriate parameters as (mean post-lesion plateau/mean pre-lesion plateau)*100 when a higher plateau value means a better performance and as 1/(mean post-lesion plateau/mean pre-lesion plateau)*100 when a lower plateau value represents a better performance.

Simple linear regressions and Pearson's correlation coefficients were computed.