Electrical Microstimulation of the Pulvinar Biases Saccade Choices and Reaction Times in a Time-Dependent Manner

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Supplemental Material

Supplemental material contains:

Supplemental Figure 1.
Target selection and reaction time (RT) microstimulation effects per monkey.

Supplemental Figure 2.
Probability of saccades deferred until after stimulation offset per session per monkey.

Supplemental Figure 3.
Target selection and RT microstimulation effects per target position per monkey.

Supplemental Figure 4.
Eye position trajectories in successful and error memory saccade trials.

Supplemental Figure 5.
Anatomical MRI scans showing dura penetration entry points.

Supplemental figure legends

Supplemental Figure 1. Target selection and reaction time (RT) microstimulation effects per monkey, for the visually-guided saccade task. Effects of dPul stimulation on RTs (all but rightmost column) and target selection (rightmost column) are shown as means and SE across sessions. **A**, monkey C, **B**, monkey L. The top row in each panel shows effects on *all* trials ("All"). In the middle and bottom rows, the data were separated into trials where saccades started either *during* stimulation, or *after* the offset of stimulation period. For RTs, the overall delay (*All* row) was milder in monkey L, especially for the contraversive saccades, however both facilitation and delay were present in both monkeys. Importantly, the separation by the saccade onset in the relationship to the stimulation offset demonstrates that the difference in effect strength in two monkeys is related to a different proportion of trials falling into the two categories, not to a categorical difference of effects between monkeys (see **Suppl. Figure 2**). For target selection, the pattern of stimulation effects was similar in both monkeys. Whenever possible (target selection in *All* and instructed RTs in *All*) a Friedman test followed by Bonferroni-corrected Wilcoxon signed-rank test was performed, *$p<0.05$, **$p<0.01$; otherwise a Kruskal-Wallis followed by Bonferroni-corrected Mann-Whitney-U test, *$p<0.05$, **$p<0.01$ was performed.

Supplemental Figure 2. Probability of saccades deferred until after stimulation offset per session per monkey, in the visually-guided saccade task. Contraversive trials are shown in left column, ipsiversive trials in right column, for stimulation periods starting +40 ms, +80 ms, and +120 ms after the Go signal (upper, middle and lower rows, respectively). Histogram plots show distribution of sessions with a certain fraction of deferred saccades (bin size 10%). Blue and green colors correspond to monkey C and L. In each panel the Spearman correlation coefficient *rho* ("R") and significance (p) are shown for correlation between probability of deferring saccades per session versus 1) depth along the electrode tract and 2) contraversive target selection difference from control ("bias") (NA: not enough data points to perform corre-

lation in that condition). For both monkeys, there was a higher fraction of deferred saccades to the ipsiversive hemispace, which was correlated to the depth (this correlation was significant for all but the +40 ms window in monkey L). This correlation suggests that the occurrence of deferred saccades is site specific (but not monkey specific). In addition, for the +80 ms and +120 ms stimulation periods in monkey L the contraversive target selection correlated with the proportion of deferred saccades to the ipsiversive hemispace, however, for monkey C, showing a larger fraction of deferred saccades, there was no correlation to target selection modulation. Significant correlations ($p<0.05$) are in ***bold italics*** font, p values <0.08 in *italics*.

Supplemental Figure 3. Target selection and RT microstimulation effects per target position per monkey. Effects of dPul stimulation on RTs (all but rightmost column) and target selection (rightmost column) are shown as means and SE across sessions. In each session, trials were sorted according to the target vertical position (top schematic, upper, horizontal, lower corresponding to light-, medium- or dark-shade blue (monkey C) and green (monkey L) colors), to demonstrate the consistency of stimulation effects on RTs and target selection. As in **Suppl. Figure 1**, the top row shows effects on *all* trials ("All"). In the middle and bottom rows, the data were separated into trials where saccades started either *during* stimulation, or *after* the offset of stimulation period. Dashed lines in the middle row denote lack of saccades that started during stimulation in the two early stimulation periods. Both monkey displayed similar delay/facilitation of RTs and target selection modulation patterns regardless of the vertical target position.

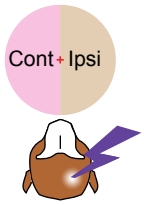
Supplemental Figure 4. Eye position trajectories in successful and error memory-guides saccade trials. Top schematic: task timing and four stimulation periods as shown in **Figure 9A**. Trajectories are colored according to the period in which stimulation occurred; trials in which no stimulation was delivered are colored gray. **A**, Successful instructed trials. Monkey L showed some blinks at the start of few saccades,

this however happened in any stimulation period as well as in non-stimulated trials. **B**, Error instructed trials, similar to **Figure 9E**. **C**, Error choice trials. Similar to error instructed trials, both ipsiversive aborts after the offset of "-80 ms to Cue" stimulation period, and contraversive undershooting in "+80 ms after Go" stimulation period were present for also choice trials.

Supplemental Figure 5. Anatomical MRI scans showing dura penetration guide-tube entry points. Left: T1-weighted transversal MR images showing the region for future penetrations in monkey C and L, upper and lower panels respectively. The cross-hair shows future penetration location, red dashed circle outline is centered on the location. Estimated borders of the lateral intraparietal area (LIP) and the area AIP are shown. Right: similar MR images taken after multiple penetrations, with matching red dashed circle outlines centered on the penetration. Red insert, outlined region magnification. Superficial focal lesions close to area AIP are visible in both monkeys. However, no hand-related or oculomotor deficits were observed during or after the experimental period.

Suppl. Figure 1

Target selection and reaction time
All, **during** and **after** stimulation offset



A Monkey C

Reaction time

Target selection

Instructed contra | Choice contra | Instructed ipsi | Choice ipsi

All | During stimulation | After stimulation

Reaction time [ms]

Contraversive target selection [%]

Stimulation onset [ms]

B Monkey L

Reaction time

Target selection

Instructed contra | Choice contra | Instructed ipsi | Choice ipsi

All | During stimulation | After stimulation

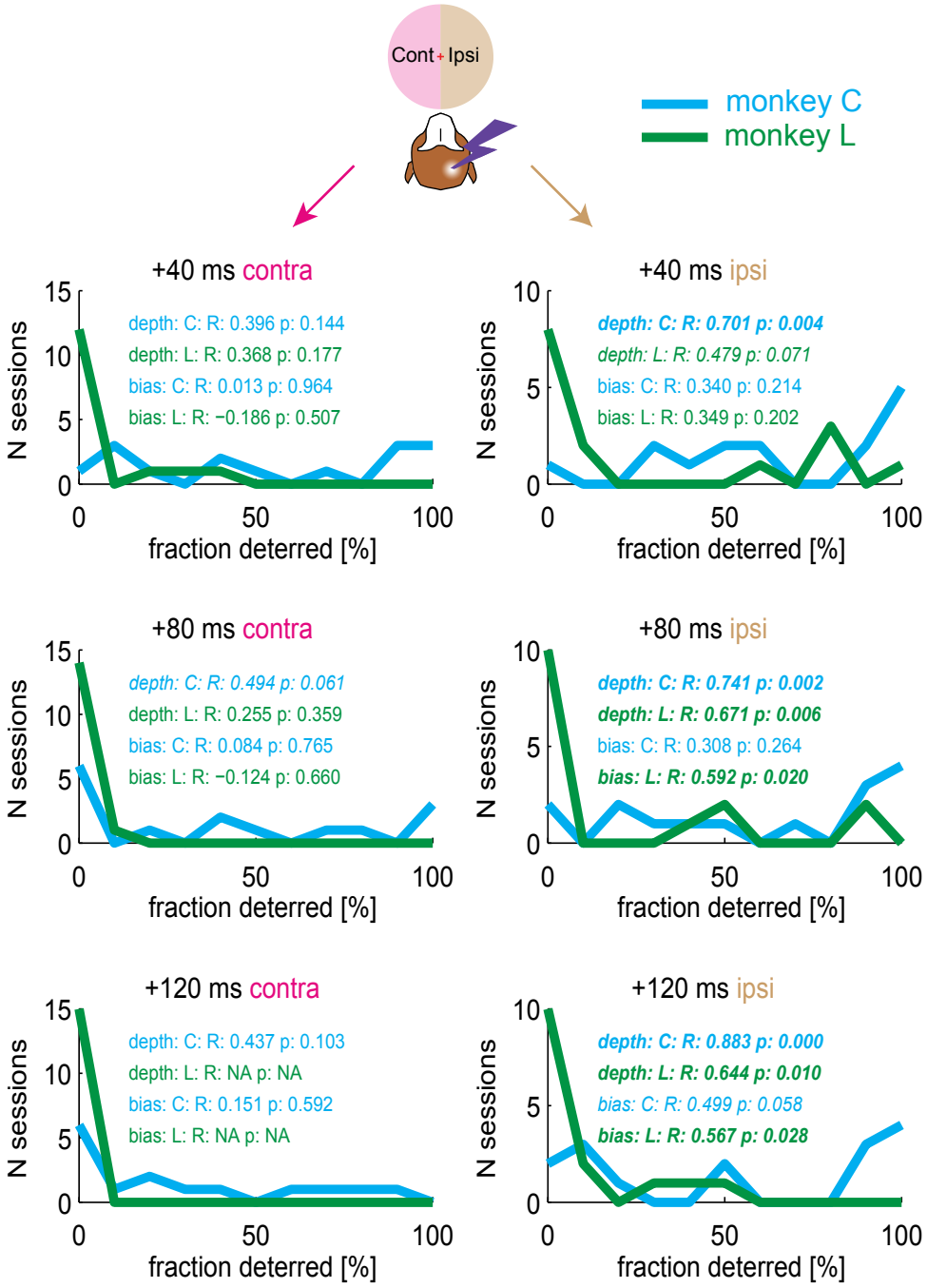
Reaction time [ms]

Contraversive target selection [%]

Stimulation onset [ms]

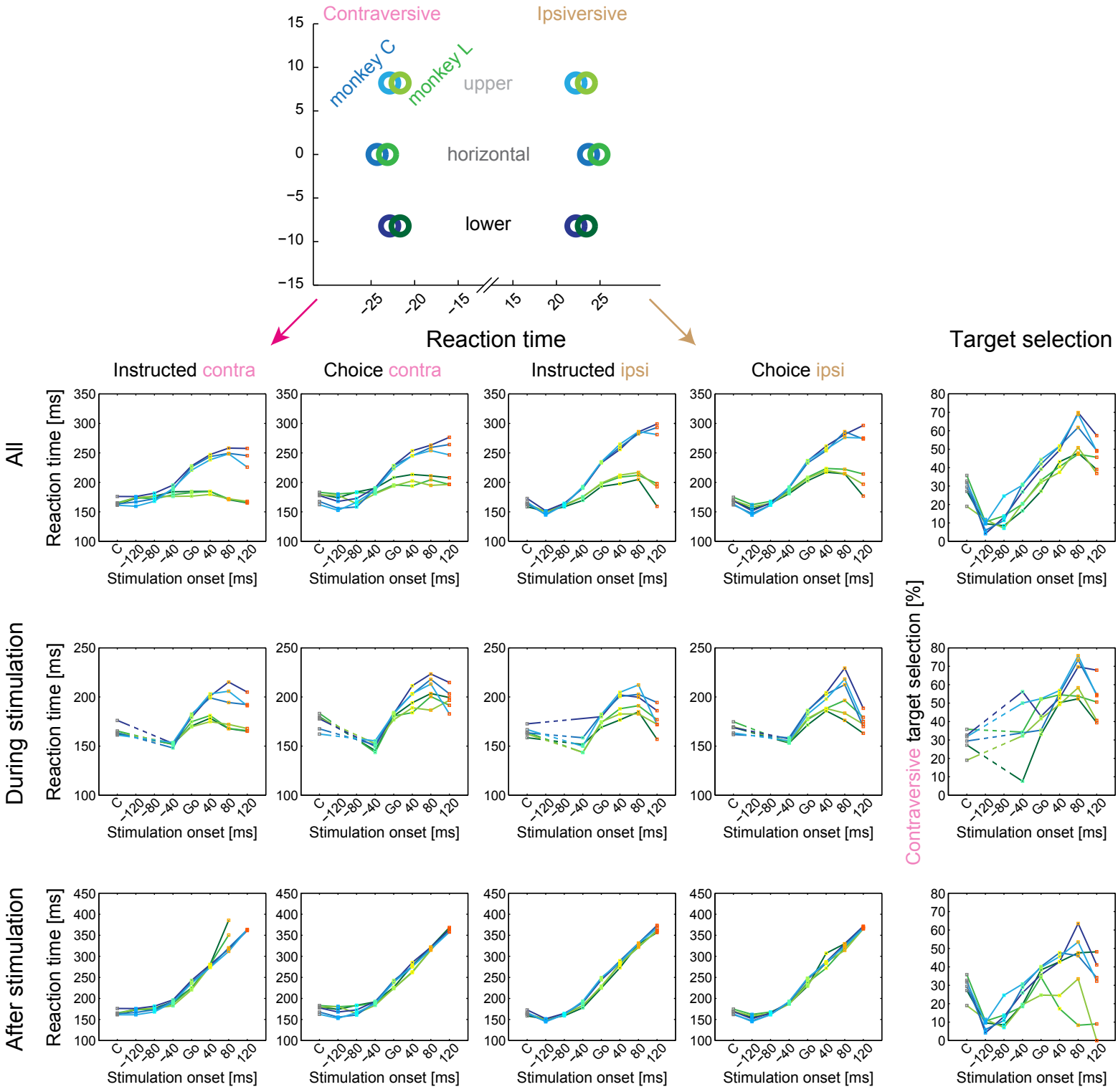
Suppl. Figure 2

Fraction of saccades deterred until after stimulation offset



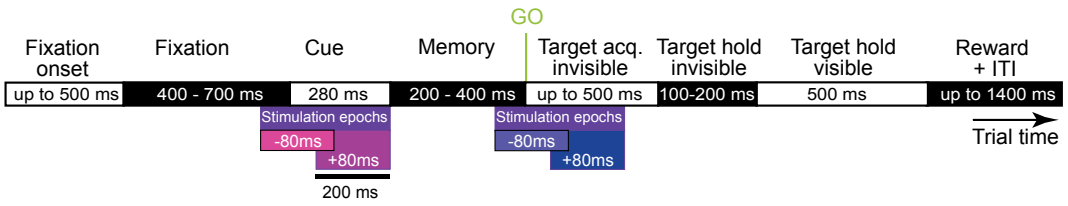
Suppl. Figure 3

Microstimulation effects per target position and monkey

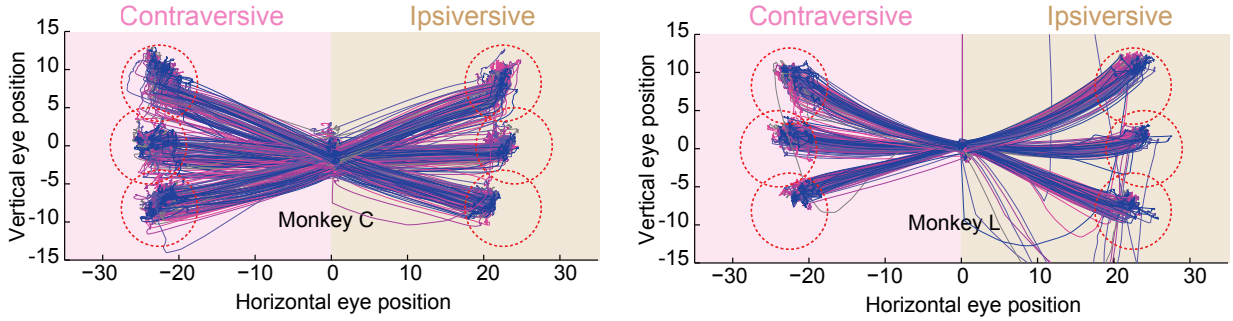


Suppl. Figure 4

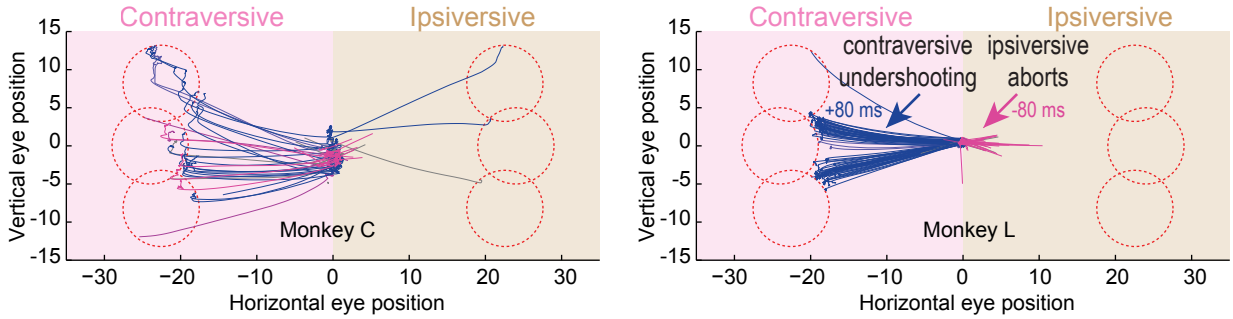
Eye position trajectories in memory saccade trials



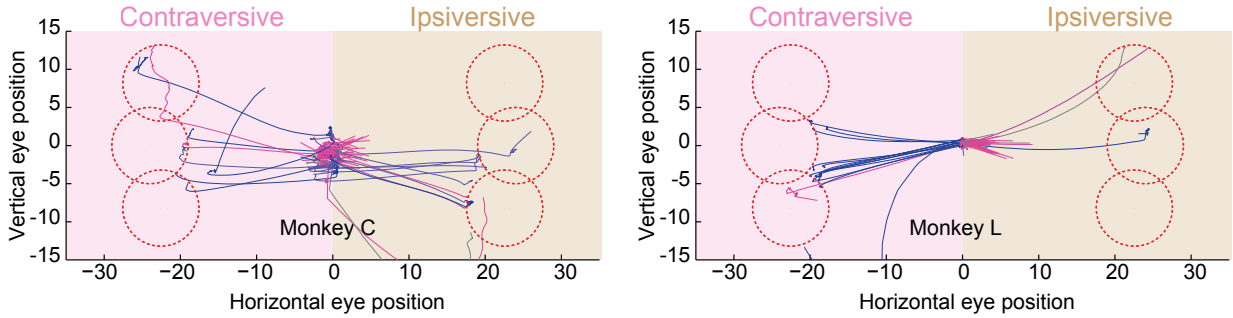
A Successful trials in memory sessions, instructed trials



B Error trials in memory sessions, instructed trials (from Figure 9E, for comparison)



C Error trials in memory sessions, choice trials



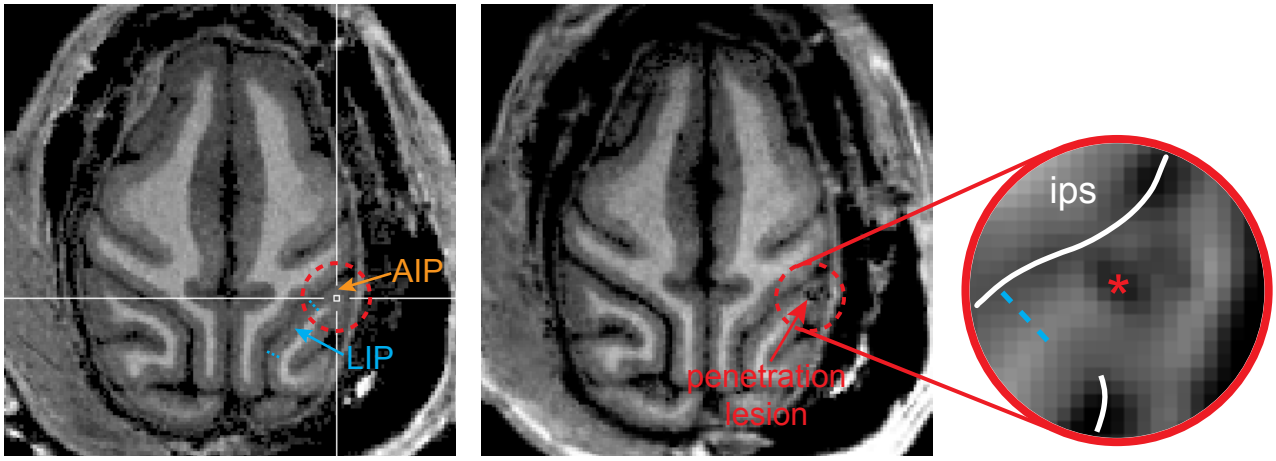
Suppl. Figure 5

Penetration entry points

Monkey C

pre-penetration scan (20130627)

post-penetration scan (20140828)



Monkey L

pre-penetration scan (20130614)

post-penetration scan (20150619)