

## Supplementary information

### Midcingulate motor maps and feedback detection: converging data from humans and monkeys

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#### Paracingulate sulcus in humans

70% of brains display a paracingulate sulcus at least in one hemisphere. In the participants (n=15) of the experiment by Amiez et al (2013), 73% of brains (i.e. 11 subjects) contained a paracingulate sulcus in at least one hemisphere, which represented 47% of hemispheres (4 subjects had no paracingulate, 3 subjects had 1 paracingulate in each hemisphere). Yucel et al (1995) reported a paracingulate sulcus in 68% of hemispheres (n=176 brains) and that Paus et al. (1996) reported 85% of brains with a paracingulate sulcus in at least one hemisphere (n=247 brains).

#### Principles of meta-analysis of monkey data

Reconstructions of recording sites were based on the data available in the published articles listed and detailed below (see also Methods in main text).

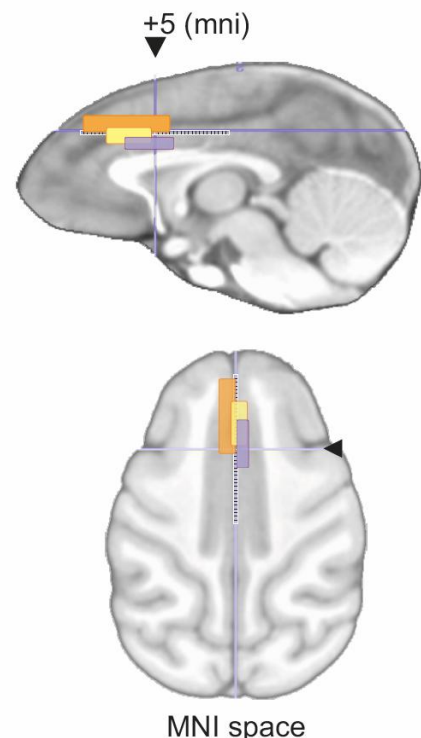
**Co-registration.** In order to co-register the rostro-caudal coordinates reported in all articles examined, we have taken the level of the genu of the arcuate sulcus (ArcGen) as a reference since it is the landmark most frequently reported. When the position of recordings relative to ArcGen was available we aligned data to the ArcGen position. When stereotaxic coordinates were provided but the location of ArcGen was not, we realigned data on the average ArcGen location obtained from a database of 11 monkey MRIs. This average was AP +24 (std 2.6) from interaural zero. The average location for the genu of corpus callosum (32.69mm) was also used in some cases (on average 8.67 mm between ArcGen and Ccgen)

**MNI Space.** For general information, we performed one reconstruction in the MNI monkey atlas (<http://www.bic.mni.mcgill.ca/ServicesAtlases/Rhesus>) (Frey et al., 2011). In this average standard space, the genu of the arcuate sulcus (taken as a rostro-caudal reference -ArcGen) was found at Y = +5. See figure.

#### Outcome-related neural activity

In the list below and in figure 3 (main text), we report the effector used by animals to respond: saccadic eye movement or arm movement. The effector might be a parameter interacting with feedback information during learning or decision tasks in particular in cingulate motor maps. The role of the effectors has also been invoked as a major parameter in the debates comparing human and monkey data (Schall and Emeric, 2010).

**\*(Kennerley and Wallis, 2009).** We used the coordinates for Payoff. The data in reference to the ArcGen were graciously provided by S. Kennerley. Subject A: Genu of arcuate = AP20mm; Genu of corpus collosum = AP30mm; Recordings in dorsal bank of ACC: AP30-34mm, [30;34]-20= [10; 14] from Arc Gen. Subject B: Genu of



arcuate = AP18mm; Genu of corpus collosum = AP31mm; Recordings in dorsal bank of ACC: AP30-37mm, [30; 37]-18= [12; 19] from Arc Gen. We use the min-max of the two monkeys: [10;19]. Note that one monkey responded with arm movements the other with eye movements.

\*(**Luk and Wallis, 2009**). Coordinates of recordings for outcome selective cells were taken from the flat maps presented in figure 9A-B. Note that monkeys responded with arm movements.

\*(**Yoshida et al., 2012**): extent from ArcGen is given in the discussion of the paper: "The locations of partner-error neurons in the MFC sulcus covered 7–16 mm anterior to the genu of the arcuate sulcus (Fig. 2a)". Note that monkeys responded with arm movements.

\*(**Matsumoto et al., 2007**): Data shown in figure 2. Two monkeys with recording zones referred to stereotaxic measures and drawing of the ArcGen for both animals. We take the max and min from the two monkeys. Note that monkeys responded with arm movements.

\*(**Cai and Padoa-Schioppa, 2012**). The authors report neurons in the dorsal and ventral banks with activity modulated by juice information. The coordinates were reconstructed from the Corpus Callosum data given in the article (+30 and +31 from Zero ear; see p3792 and figure 1). The arcuate genu is then calculated from our mean difference between the two (8.28 cm from Arc Gen and Ccgen): Thus ArcGen is at  $30.5 - 8.28 = 22.2$ . Figure 1d shows recording sites together with number of cells movement direction related activity. Note that monkeys responded with eye saccades. Interestingly the authors note that rostral dorsal bank recordings were more spatially selective than caudal recordings.

\*(**Amiez et al., 2006**): Data were taken from the map published in the article containing the ArcGen level. Note that monkeys responded with arm movements.

\*(**Procyk et al., 2000**): Data were taken from the map published in the article containing the ArcGen level. Note that monkeys responded with arm movements.

\*(**Quilodran et al., 2008**). Data were taken from the reconstruction provided in the supplementary data with reference the ArcGen. Note that monkeys responded with arm movements.

\*(**Ito et al., 2003**). Figure 4 shows a reconstruction with reference to AP+27 and the position of the ArcGen (+24). Measured from ArcGen the data are over -4 to +8. Note that monkeys responded with saccadic eye movements.

\*(**Seo and Lee, 2009**). The article provides feedback-related activity, i.e. neural activity changes induced by conditioned reinforcers. No stereotaxic coordinates were provided but figure 5 provides a drawing of ArcGen for two monkeys; measures were computed from the drawing of ArcGen and min and max obtained for the two monkeys. Note that monkeys responded with saccades.

\*(**Hayden et al., 2011**). The article provides no coordinates for the arcuate sulcus but range of coordinates where data were acquired in two monkeys. We realigned the extent on our mean arcuate position (+24). Note that monkeys responded with eye movements.

## Connectivity and microstimulation

### Studies informing on face-related representation in MCC

\*(**Wang et al., 2004**). Retrograde diamidino yellow (DY) injection in the frontal eye field (FEF). Retrograde fast blue (FB) injection in forelimb area M1. Injection areas identified by microstimulation. Values taken from figure 3 - one point every 500 $\mu$ m (see methods, p. 1560). The map indicates the ArcGen level. The field projecting to the FEF is observed in the dorsal bank of the cingulate sulcus.

\*(Luppino et al., 2003). Retrograde labeling from F7/SEF. 1 injection with Fast Blue and 1 with WG-HRP; Reconstructions are provided with the level of ArcGen (Figures 3 and 5). We take the max and min of the two monkeys. The fields of projections to F7/SEF are mostly on the dorsal bank and fundus of the cingulate sulcus.

\*(Morecraft et al., 1996). Injection of retrograde tracer FB in electrophysiologically defined M1 orofacial area. Maps in figure 1 shows neurons in the ventral bank of the cingulate sulcus.

\*(Morecraft et al., 2007). Injection in M1 face region (FB) and in M1 arm area (DY) (Figure 12). The figure reports maps and level of ArcGen. Data for rostral face region is mainly in fundus and ventral bank of the cingulate sulcus. A caudal face zone was also found in the ventral bank.

\*(Picard and Strick, 1997). The extent and contour of 2DG labeling was taken from the flat map presented in figure 1A showing relative 2-deoxyglucose uptake while monkeys were licking juice delivered at variable time intervals. Most labeling is found in the dorsal bank of the cingulate sulcus, with a smaller peak in the ventral bank.

\*(Tokuno et al., 1997). This anatomical study examined the distribution of cortical neurons after injections of retrograde tracers (DY, FB) into the electrophysiologically identified orofacial and forelimb region of M1. Data and maps in figure 8.

\*(Mitz and Wise, 1987). This intracortical microstimulation study provide a mapping for various effector movements. The extent of upper limb and orofacial movements zones were taken from figure 4 on which the position of ArcGen was reported. These data were obtained from the dorsal bank of the cingulate sulcus (Figure 4).

#### **Studies informing on arm/hand-related representations in MCC**

\*(Akkal et al., 2002). Microstimulation maps shown on figure 4 for 2 monkeys together with the level of the ArcGen. Extent of the rostral area where upper limb movements were evoked: -1 to +8. Data were obtained in the dorsal and ventral banks of the cingulate sulcus.

\*(Hoshi et al., 2005). Maps for microstimulation evoking forelimb movements in one animal. The reconstruction shows the ArcGen position that allowed for realignment of data. Movements are evoked after stimulation in the dorsal and ventral banks close to the fundus of the cingulate sulcus.

\*(Dum and Strick, 1991). The extent of labeling in the dorsal rostral part of the cingulate sulcus are taken from the flats maps (Figures 11 and 18) that reported labeled neuron density after injections into M1 arm area and into in spinal segments C4-T2. These two extents are reported separately in our analysis.

\*(Morecraft et al., 2007). See above. Labeled neurons after injection in the arm representation in M1 were in both the dorsal and ventral banks of the cingulate sulcus.

\*(Shima et al., 1991). The authors performed an HRP injection into the digit area of M1. Data and map reported in figure 11.

\*(He et al., 1995). The authors report labeled neuron density after injections in spinal segments C7-T1 (monkeys H1 and H2, maps figure 5-6) and C2-C4 (monkey H3, maps figure 12-13). Two extents are reported separately in our analysis, one for C2-C4 and one for C7-T1 taken from the above mentioned figures (figure 12 top and figure 5 top) for which data covers the entire extent observed in the study for the upper limb representation. Data used here are from the fundus and the dorsal banks of the cingulate sulcus, but labeling was found also in the ventral bank.

\*(Richardson et al., 2008). This single unit recording study reports also intracortical microstimulation flat maps for arm and leg representation. Only arm related data close to the ArcGen (reported on maps, Figure 4) were used to calculate the extent. They were obtained from both the dorsal and ventral banks

**\*(Tokuno et al., 1997).** See above.

**\*(Wang et al., 2004).** See above. The field projecting to M1 hand is observed in the dorsal bank and fundus of the cingulate sulcus partly extending into the ventral bank.

**\*(Mitz and Wise, 1987).** See above

**\*(Dum and Strick, 2002).** (from Holsapple JW, Preston JB, Strick PL. *The origin of thalamic inputs to the "hand" representation in the primary motor cortex. J Neurosci 1991;11:2644– 54*). WGA–HRP into the physiologically identified digit representation of M1 in the macaque monkey. The rostro-caudal extent is taken from figure 1A. CMAr projections to M1 digit are from the ventral bank, and projections to C7T1 segments of the spinal cord are mostly from the dorsal bank.

### Notes on some articles excluded from the meta-analysis

**\*(Shima et al., 1991; Shima and Tanji, 1998).** The recording data presented in these two articles are not in the meta-analysis for the following reasons:

- the Shima and Tanji 1991 J Neurophysiol article presents maps of recordings in two monkeys. The coordinates are +5;+13 and +2;+10 relative to the level of the ArcGen. However, the report does not concern outcome-related activity.

- In Shima and Tanji (1998), the authors report outcome-related activity, but no stereotaxic coordinates are provided nor a map of the recordings and, therefore, reconstruction was impossible. Note, however, that the authors report that "The neurons described here were recorded at sites in the CMAs that (i) project to the primary motor cortex and (ii), when stimulated, evoke limb movements" (p. 1336). These indications suggest that neurons were not recorded in the face area.

**\*(Gong et al., 2005)** report cortical neuronal labeling after injection of a transsynaptic tracer (rabies virus) into the orbitularis oculi motoneurons (controlling the eye lid). Data were reported on reconstructed global maps with no scale. However, the data clearly show (Fig. 8-11) labeling in the cingulate sulcus with a particularly dense spot close to the level of the genu of the corpus callosum. Precise reconstruction was, however, not possible. The figures indicate labeling in both the dorsal and ventral banks.

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