Encyclopedia of Neuroscience
Springer-Verlag GmbH Berlin Heidelberg 2009
10.1007/978-3-540-29678-2_1039
Marc D. Binder, Nobutaka Hirokawa and Uwe Windhorst

Cingulate Cortex – Role in Eye Movements

Jeffrey D. Schall[4]

(4) Department of Psychology, Center for Integrative and Cognitive Neuroscience, Vanderbilt Vision Research Center, Vanderbilt University, Nashville, TN, USA

Without Abstract

Definition

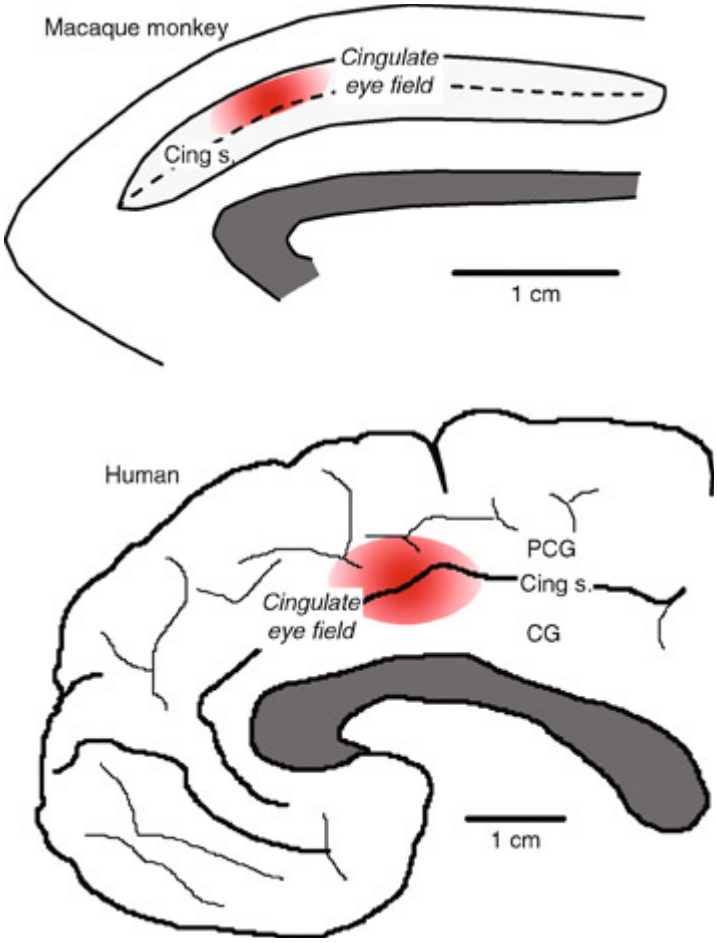
Cingulate cortex, occupying the gyrus and surrounding cortex encompassing the corpus callosum includes a variety of areas with diverse functions.

Characteristics

Higher Level Structures and Lower Level Components

Traditionally regarded as part of the limbic system, the cingulate cortex is a large and heterogeneous part of the cerebral cortex that can be partitioned based on architecture, connectivity and functional properties [*1*,*2*]. First, cingulate cortex is divided into a posterior part (Brodmann's area 23) and an anterior part. The anterior cingulate cortex can be divided into a ventral zone (occupying the surface of the cingulate gyrus, containing Brodmann's areas 24a, 24b and the subcallosal area 25) and a dorsal zone (mainly in the cingulate sulcus, containing Brodmann's areas 24c and 32). In humans, this functional area often extends into the surrounding paracingulate gyrus.

A putative cingulate eye field has been described in the caudal portion of anterior cingulate cortex (Fig. 1), and visual and saccade-related activity has been described in a portion of posterior cingulate cortex (not shown). Anterior cingulate cortex can contribute indirectly to ocular motor function through dense, reciprocal connectivity with the supplementary eye field and a weaker linkage with the frontal eye field, superior colliculus and ocular motor thalamic nuclei [*3*].

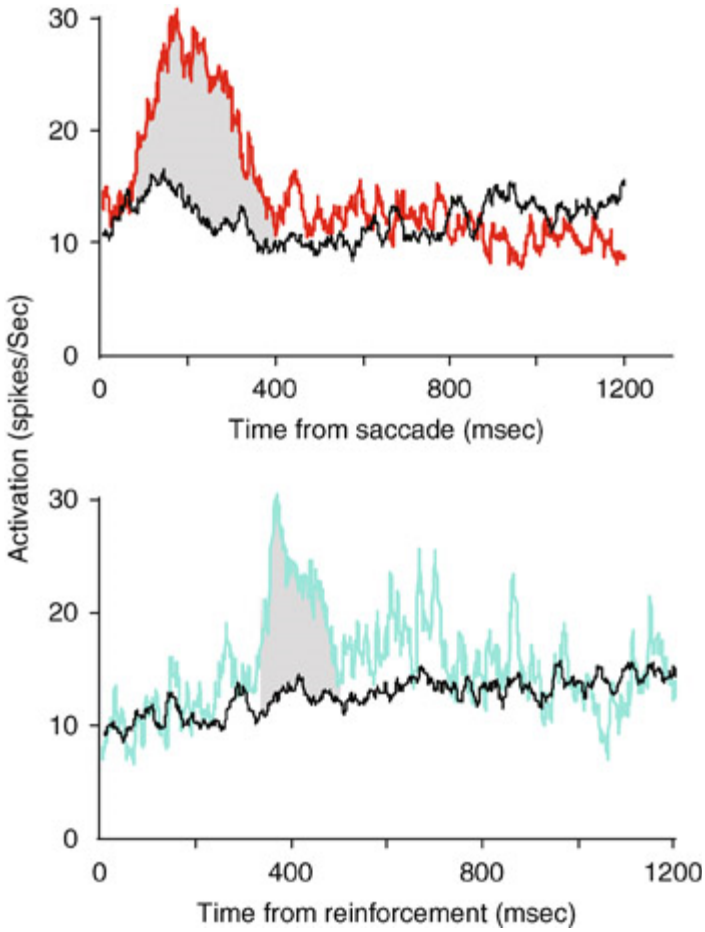


Cingulate Cortex – Role in Eye Movements. Figure 1 Medial view of macaque monkey (*top*) and human (*bottom*) brains showing estimated location of zone in cingulated cortex related to movements of the eyes. Abbreviations: *CG*, cingulated gyrus; *cing s*, cingulate sulcus; *PCG*, paracingulate gyrus.

Higher Level Processes and Lower Level Processes

Neurons in posterior cingulate cortex of macaque monkeys discharge in response to visual stimuli and following saccadic eye movements [4], and functional imaging in humans has described activation in posterior cingulate cortex associated with visually guided saccades [5]. However, more evidence indicates a role in gaze control for a caudal zone in anterior cingulate cortex. Saccadic eye movements can be evoked by electrical microstimulation of a region in the upper bank of the cingulate sulcus directly ventral to the SEF, in area 24c [6]. Functional brain imaging studies have reported activation in anterior cingulate cortex during production of self-generated saccades guided by arbitrary cues [7].

In macaque monkeys performing a task that requires inhibition of a partially prepared movement in response to an imperative stop signal, neurons in anterior cingulate cortex were modulated following errors or when reinforcement was earned but not delivered (Fig. 2) [8]. This signal from single neurons corresponds to a scalp potential referred to as the error-related negativity, which may originate from a single dipole in anterior cingulate cortex. In addition, a diversity of neurons in anterior cingulate cortex signal when reinforcement is earned and received, earned and not received, or delivered but not earned. The activation of these neurons can guide adjustments of performance, probably derived from signals arriving from brainstem dopamine neurons, the ventral striatum or orbital frontal cortex. These results are consistent with a body of research indicating that anterior cingulate cortex monitors performance for executive control.



Cingulate Cortex – Role in Eye Movements. Figure 2 Monitoring signals in anterior cingulate cortex. Activity of a single neuron is shown aligned on the time of a saccade (*top*) or time of reinforcement (*bottom*) on trials when the saccade was correct and earned reinforcement (black), when the saccade was an error and received no reinforcement (red), and when the saccade was correct but reinforcement was not delivered (blue). This representative neuron signaled the unexpected absence of reinforcement.

Function

Three general perspectives have framed hypotheses about the function of cingulate cortex: motor control, performance monitoring and motivation. Cingulate cortex seems to contribute indirectly to gaze control through mediating the influence of motivation derived from the consequences of previous actions.

Pathology

Damage to cingulate cortex in humans results in diverse disorders. Lesions focused in a limited part of anterior cingulate cortex result in impairments in producing memory-guided saccades and antisaccades [9]. These deficits involved impaired suppression of reflexive saccades as well as increased latency of visually guided saccades.

References

1. Paus T (2001) Primate anterior cingulate cortex: where motor control, drive and cognition interface. Nat Rev

Neurosci 2:417–424
PubMed ChemPort crossref

2. Dum RP, Strick PL (2002) Motor areas in the frontal lobe of the primate. Physiol Behav 77:677–682
PubMed ChemPort crossref

3. Luppino G, Rozzi S, Calzavara R, Matelli M (2003) Prefrontal and agranular cingulate projections to the dorsal premotor areas F2 and F7 in the macaque monkey. Eur J Neurosci 17:559–578
PubMed crossref

4. Olson CR, Musil SY, Goldberg ME (1996) Single neurons in posterior cingulate cortex of behaving macaque: eye movement signals. J Neurophysiol 76:3285–3300
PubMed ChemPort

5. Mort DJ, Perry RJ, Mannan SK, Hodgson TL, Anderson E, Quest R, McRobbie D, McBride A, Husain M, Kennard C (2003) Differential cortical activation during voluntary and reflexive saccades in man. NeuroImage 18:231–246
PubMed crossref

6. Mitz AR, Godschalk M (1989) Eye-movement representation in the frontal lobe of rhesus monkeys. Neurosci Lett 106:157–162
PubMed ChemPort crossref

7. Paus T, Petrides M, Evans AC, Meyer E (1993) Role of the human anterior cingulate cortex in the control of oculomotor, manual, and speech responses: a positron emission tomography study. J Neurophysiol 70:453–469
PubMed ChemPort

8. Ito S, Stuphorn V, Brown JW, Schall JD (2003) Performance monitoring by the anterior cingulate cortex during saccade countermanding. Science 302:120–122
PubMed ChemPort crossref

9. Gaymard B, Rivaud S, Cassarini JF, Dubard T, Rancurel G, Agid Y, Pierrot-Deseilligny C (1998) Effects of anterior cingulate cortex lesions on ocular saccades in humans. Exp Brain Res 120:173–183
PubMed ChemPort SpringerLink