



## Viewing a forelimb induces widespread cortical activations



Vassilis Raos<sup>\*</sup>, Marina Kilintari, Helen E. Savaki

Institute of Applied and Computational Mathematics, Foundation for Research and Technology Hellas, School of Health Sciences, University of Crete, Greece  
Department of Basic Sciences, Faculty of Medicine, School of Health Sciences, University of Crete, Greece

### ARTICLE INFO

#### Article history:

Accepted 8 December 2013

Available online 18 December 2013

### ABSTRACT

Given that prerequisite of activating the mirror neuron system is the preshaping of the hand and its interaction with the object during observation of a reaching-to-grasp-an-object action, the effects of viewing the object, the reaching forelimb and the static hand may obscure the effects of observing the grasping action per se. To disentangle these effects, we employed the <sup>14</sup>C-deoxyglucose quantitative autoradiographic method to map the functional activity in the entire cortex of monkeys (*Macaca mulatta*) which observed the experimenter performing non-goal-directed (purposeless) forelimb movements towards an object that was previously presented but no longer visible. Thus, our monkeys were exposed to the view of an object, a moving arm and a static hand with extended wrist and fingers. The distribution of metabolic activity was analyzed in 20 μm thick brain sections, and two dimensional maps were reconstructed in the occipital operculum, the temporal, the lateral and medial parietal, the lateral and medial frontal, the lateral prefrontal and orbitofrontal cortices, including the cortex within the lunate, superior temporal, lateral, parietoccipital, intraparietal, central, arcuate and principal sulci. Increased metabolic activity, as compared to fixation-control monkeys, was measured in the forelimb representation of the primary motor and somatosensory cortices, the premotor cortices F2 and F5, cingulate motor areas, the secondary somatosensory cortex SII, the posterior intraparietal area 5 and areas TPOc and FST, in the hemisphere contralateral to the moving arm. Moreover, bilateral activations were elicited in areas pre-SMA, 8 m, SSA and the somaterecipient area VS, the retroinsula, the auditory belt area CM, motion areas MT, MST, LOP/CIP, area 31, visual areas TEO, V6, V6Av and the parafoveal and peripheral visual representations of areas V1 and V2, respectively. Few parietal, auditory and visual areas were bilaterally depressed. In brief, a surprisingly wide cortical network is recruited even by mere observation of an arm executing goalless movements, which partially overlaps with the cortical network supporting the execution and observation of goal-directed forelimb actions. Interestingly, this overlap concerns mainly lower order sensory-motor rather than higher order association prefrontal and parietal cortices. Our results demonstrate that in order to reveal the net effects specifically induced by observation of a purposeful reaching-to-grasp action, the use of an appropriate control taking into account the effects of viewing the object to be grasped, the reaching arm and the static hand is crucial.

© 2013 Elsevier Inc. All rights reserved.

### Introduction

The view of static images of bodies and body parts was reported to activate specific occipitotemporal cortical areas in macaque monkeys (Pinsk et al., 2005, 2009) and humans (Bracci et al., 2010; Downing et al., 2001; Op de Beeck et al., 2010; Peelen and Downing, 2005a,b; Schwarzlose et al., 2005; Spiridon et al., 2006; Weiner and Grill-Spector, 2010). Actually, the selective involvement of the extrastriate body area (EBA, in the inferior temporal sulcus) and the fusiform body area (FBA, in the posterior fusiform gyrus) in the visual processing of human body forms is widely accepted (Berlucchi and Aglioti, 2010; Minnebusch and Daum, 2009; Peelen and Downing, 2007; Weiner and Grill-Spector, 2013). The body detection network was also suggested to include areas

in the inferior parietal lobe (Hodzic et al., 2009). Similarly, viewing 3D objects activates consistently a large region, known as the lateral occipital complex (LOC) in humans, which extends between the inferior occipital and the temporal cortex (Haxby et al., 2001; Kanwisher et al., 1997; Malach et al., 1995; Spiridon and Kanwisher, 2002; Spiridon et al., 2006), and which may correspond to areas TEO-TE in monkeys (Grill-Spector et al., 1998; Malach et al., 1995; Tanaka, 1997).

On the other hand, viewing body parts in motion [two hands and arms moving in front of an actor's torso (Engel et al., 2008) an arm with extended fingers and wrist reaching toward an object (Di Dio et al., 2013), smooth curvilinear hand and arm movements of a human subject (Casile et al., 2010)] induces activation of parietal and frontal cortical areas. Even non-biological moving stimuli such as artificial effectors [slow movements of constant velocity of a robotic arm and claw (Gazzola et al., 2007), an arrow moving from a fixed point towards a red cross (Di Dio et al., 2013)], objects [two moving spheres following sinusoidal trajectory (Engel et al., 2008)] and a cloud of dots rigidly moving along elliptical paths with velocity profiles complying or

<sup>\*</sup> Corresponding author at: Department of Basic Sciences, Faculty of Medicine, School of Health Sciences, University of Crete, P.O. Box 2208, GR-71003, Iraklion, Crete, Greece. Fax: +30 2810 394806.

E-mail address: [vraos@med.uoc.gr](mailto:vraos@med.uoc.gr) (V. Raos).

opposing to the 2/3 power law (Dayan et al., 2007) activate parietal and frontal areas. Accordingly, the circuit involved in motion analysis seems to extend beyond the widely accepted temporal and occipital cortical areas (Allison et al., 2000; Beauchamp et al., 2003; Blakemore and Decety, 2001; Bonda et al., 1996; Carter et al., 2011; Grezes et al., 2001; Grossman et al., 2000; Jellema et al., 2004; Pelphrey et al., 2005; Perrett et al., 1989; Puce and Perrett, 2003; Rizzolatti et al., 1996b; Vaina et al., 2001) encompassing frontal and parietal areas.

Cortical areas of the parietal and frontal lobes are also activated by the observation of goal-directed forelimb actions (Rizzolatti and Sinigaglia, 2010; Rizzolatti et al., 2001). In a plethora of neuroimaging studies, the effects of observing purposeful reaching-to-grasp actions were contrasted to the effects of viewing scrambled images, hand or object pictures (Biagi et al., 2010; Buccino et al., 2001; Gazzola and Keysers, 2009; Gazzola et al., 2007; Grosbras and Paus, 2006; Kaplan and Iacoboni, 2006; Molnar-Szakacs et al., 2006; Nedelko et al., 2010; Ohnishi et al., 2004; Perani et al., 2001; Pierno et al., 2006; Shmuelof and Zohary, 2005, 2006; Tai et al., 2004; Turella et al., 2009), thus leaving open the confounding possibility that at least some of the reported effects might have resulted merely from observation of a moving forelimb.

Accordingly, the aim of the present study was to reveal the cortical network recruited in the monkey brain by observation of non-goal-directed (purposeless) forelimb movements and compare it with the cortical circuits so far reported to support execution and observation of purposeful goal-directed forelimb actions. To this end, we used the quantitative  $^{14}\text{C}$ -deoxyglucose ( $^{14}\text{C}$ -DG) method (Savaki et al., 1980; Sokoloff et al., 1977) which allows for spatial analysis of 20  $\mu\text{m}$ , and we reconstructed two-dimensional maps of functional activity throughout the entire primate cortex.

## Methods

### Subjects and behavioral tasks

Seven hemispheres from four adult female monkeys (*Macaca mulatta*) weighing between 4 and 5 kg were analyzed. Animals were purpose-bred by authorized suppliers within the European Union (Deutsches Primatenzentrum, Göttingen, Germany). Experiments were approved by the institutional animal use committee in accordance with European Union regulations concerning biosafety and the use of live animals in research (directive 2010/63/EU and its amendments) as well as with the National Institutes of Health's *Principles of Laboratory Animal Care*. For immobilization of the monkeys, a metal bolt was surgically implanted on their head with the use of mandibular plates secured on the bone by titanium screws (Synthes, Bettlach, Switzerland). Surgical procedures were performed under general anesthesia and aseptic conditions. Monkeys were trained to perform their tasks continuously for at least 1 h per day for several months before the  $^{14}\text{C}$ -DG experiment. They had a water delivery tube attached close to their mouth and were rewarded for all correct responses. On the day of the experiment monkeys performed their tasks during the entire experimental period of 45 min. Eye movements were recorded with an infrared oculometer. A detailed description of the surgical procedures and the eye-position recording was previously reported (Raos et al., 2004).

Two experimental monkeys (FV, forelimb viewing) were trained to maintain their gaze straight ahead, while the experimenter (standing on the right side of the monkey and using the right arm) executed an out-reaching non-goal-directed (purposeless) movement with extended wrist and fingers in front of the monkey and from its peripheral to its central visual field where a 3D-object was previously displayed. Although filmed actions are typically used in fMRI studies, in our experiments here we used real actions executed by the experimenter because we know from electrophysiological studies that real actions evoke stronger stimulation and consequently result in better signal-to-noise ratio than video-clips. For example, it is known that the population of neurons responding to naturalistic actions is two-fold the population of neurons

responding to filmed ones (Caggiano et al., 2011) and that the median of the distribution of the peak activities computed over the whole grasping period of naturalistic stimuli is significantly higher than that for filmed stimuli (Caggiano et al., 2011, Supplemental Information). Besides, monkey and human movements share striking kinesiological similarities (Roy et al., 2000). Explicitly, each FV monkey had both hands restricted, had no previous grasping training, and was trained to maintain its gaze straight ahead (within the 8 degree diameter circular window of the behavioral apparatus) during the opening of the window, the presentation of the illuminated object behind the opened window, the closure of the window, while the experimenter was reaching with extended wrist toward the closed window and while the experimenter was keeping her hand with extended fingers at final reaching position i.e. in front of the closed window (total period of 2.7–3 s per trial). This way, the FV monkeys, while fixating straight ahead, were exposed to the view of the object, the moving arm and the static hand, sequentially. Both hemispheres of these two monkeys (total of four FV hemispheres) were used to evaluate glucose consumption in the cortex.

To disambiguate the effect caused by plain fixation, the activations of the cortex of the FV monkeys were compared with those of 3 hemispheres of fixation-control (Cf) monkeys. A detailed description of the behavioral apparatus for visual fixation was reported previously (Savaki et al., 2010). In brief, the behavioral apparatus was a video monitor placed in front of the monkey. The visual targets for fixation were red circles, 1.5° in diameter, and the monkeys were required to hold eye position within a circular window 2.5° in diameter around the fixation target. The first monkey had to maintain fixation on a visual target straight ahead for the entire duration of the trial (4 s), and was allowed to move its eyes outside the window only during the intertrial period. This monkey maintained fixation for 75% of the  $^{14}\text{C}$ -DG experimental time, and both its hemispheres were used to evaluate glucose consumption in the entire cortex. In our effort to sacrifice the minimum number of monkeys, we used as an additional control hemisphere the left hemisphere of a monkey required to execute up-left saccades (of 20° amplitude and 135° direction from the central starting position) and to maintain fixation on each target for 0.5–1.0 s. The return saccades of this animal were distributed quite homogeneously in its right oculomotor space, therefore its left hemisphere could be used as a control hemisphere. Indeed, cortical areas are known to participate in the execution of contraversive saccades (Bakola et al., 2006; Bakola et al., 2007; Blatt et al., 1990; Bruce and Goldberg, 1985; Desimone and Ungerleider, 1986; Gnadt and Andersen, 1988; Maunsell and Van Essen, 1987; Robinson and Fuchs, 1969; Savaki et al., 2010). Moreover, in a previous study we demonstrated that the lateral intraparietal area (LIP) is not affected by ipsiversive saccades (Savaki et al., 2010), and in a different study we report that the activity in the frontal eye field (FEF) is not influenced by ipsiversive saccades (Savaki HE, Gregoriou G, Bakola S, Moschovakis AK, unpublished data). More specifically, in the latter study we demonstrate that the number of executed contraversive saccades is significantly correlated with the degree of activation in the contralateral FEF, in contrast to the lack of correlation between the number of ipsiversive saccades and the activity of the ipsilateral FEF.

### $^{14}\text{C}$ -DG experiments

On the day of the  $^{14}\text{C}$ -DG experiment, monkeys were subjected to femoral vein and artery catheterization under general anesthesia. About 5 h after catheterization, plasma glucose concentration, blood pressure and hematocrit were measured to range within normal values in all monkeys. Five minutes after the monkeys started performing their tasks, a pulse of 100 mCi/kg of 2-deoxy-D-[1- $^{14}\text{C}$ ] glucose (specific activity 55 mCi/mmol, ARC) was delivered intravenously. Arterial samples were collected from the catheterized femoral artery during the succeeding 45 min, and the plasma  $^{14}\text{C}$ -DG and glucose concentrations were measured. At the end of the experimental period, monkeys were killed by intravenous injection of sodium thiopental followed by saturated

Download English Version:

<https://daneshyari.com/en/article/6027988>

Download Persian Version:

<https://daneshyari.com/article/6027988>

[Daneshyari.com](https://daneshyari.com)