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Observing accidental and intentional unusual actions is associated with different subregions of the medial frontal cortex

Charlotte Desmet [a,b,*], Marcel Brass [a,b]

[a] Department of Experimental Psychology, Ghent University, B9000 Ghent, Belgium
[b] Ghent Institute for Functional and Metabolic Imaging of the Brain, Ghent University, B9000 Ghent, Belgium

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ABSTRACT

The literature on action observation revealed contradictory results regarding the activation of different subregions of the medial prefrontal cortex when observing unusual behaviour. Error observation research has shown that the posterior part of the medial prefrontal cortex is more active when observing unusual behaviour compared to usual behaviour while action understanding research has revealed some mixed results concerning the role of the anterior part of the medial prefrontal cortex during the observation of unusual actions. Here, we resolve this discrepancy in the literature by showing that different parts of the medial prefrontal cortex are active depending on whether an observed unusual behaviour is intentional or not. While the posterior medial prefrontal cortex is more active when we observe unusual accidental actions compared to unusual intentional actions, a more anterior part of the medial prefrontal cortex is more active when we observe unusual intentional actions compared to unusual accidental actions.

Introduction

As social creatures we constantly interact with each other. To accomplish these interactions in a smooth manner we continuously interpret each other's behaviour. When we are confronted with actions that are performed in an unusual way, for example someone operating a light switch with the elbow, this interpretative process becomes more difficult. Therefore, examining what happens during the observation of such unusual actions can teach us about the processes related to action understanding.

The observation of unusual actions has been studied in two different experimental contexts based on whether the actor acted accidental or intentional. Assume, for example, someone is operating a light switch with the elbow. This action can be accidental, because the person leans against the wall and happens to touch the light switch, or it can be intentional because the person is holding a glass of wine in each hand and therefore operates the light switch with the elbow. The first (accidental) situation has been investigated in the context of error observation (e.g., Buccino et al., 2007). The second (intentional) situation has been investigated in the context of action understanding (e.g., Brass et al., 2007).

The literature on error observation has shown that similar brain regions are active during error observation as when committing an error (e.g., Shane et al., 2008). In particular, error commission and observation have been associated with the dorsal and posterior part of the medial prefrontal cortex (further called the posterior medial prefrontal cortex, pMPFC) including the presupplementary motor area (preSMA) and the rostral cingulate zone (RCZ) (see Ridderinkhof et al., 2004 for a review on the role of the pMPFC in error commission). See Fig. 1 and Table 1 for an overview of error observation studies with their peak coordinates in the medial prefrontal wall. The literature on action understanding focuses on a more ventral and anterior part of the medial prefrontal cortex, namely the anterior medial prefrontal cortex (aMPFC), a core region of the mentalizing system (Van Overwalle and Baetens, 2009). However, while aMPFC activation has been described when observing unusual actions (Brass et al., 2007), others failed to find aMPFC activation when observing unusual actions (Ampe et al., 2014; de Lange et al., 2008; Jastorff et al., 2010). Some studies even reported more aMPFC activation when observing usual compared to unusual actions (Marsh and Hamilton, 2011; Marsh et al., 2014). See Fig. 1 and Table 1 for an overview of action understanding studies that report aMPFC activation associated with the observation of unusual actions compared to usual actions and action understanding studies reporting aMPFC activation associated with the observation of usual compared to unusual actions.

Thus, the literature on error observation clearly shows that the posterior part of the MPFC is involved in the processing of unusual accidental behaviour (or errors), while the literature on action understanding shows some mixed results concerning the role of the anterior part of the MPFC in the processing of unusual intentional behaviour. The aim of the current study is twofold. First we will investigate if the aMPFC is activated when we observe unusual intentional behaviour. Second, if

* Corresponding author at: Department of Experimental Psychology, Ghent University, Henri Dunantlaan 2, B9000 Ghent, Belgium. Fax: +32 9 2646496.
E-mail address: charlotte.desmet@ugent.be (C. Desmet).

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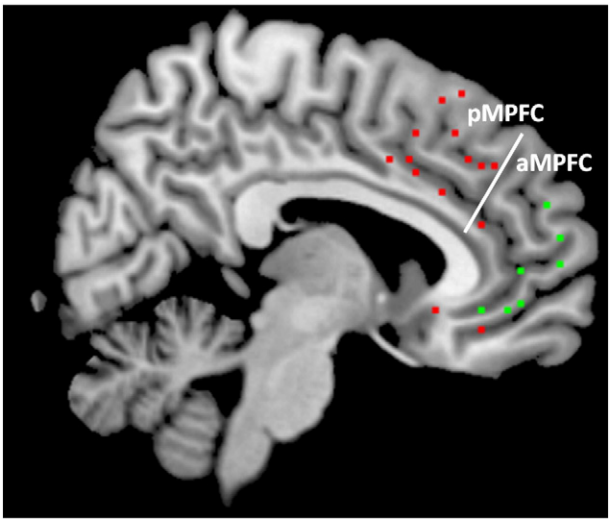

Fig. 1. Overview of MPFC activation in error observation and action understanding literature. Peak activations (in MNI coordinates) in the MPFC from error observation literature (in red) and action understanding literature (in green). For visual presentation we plotted all coordinates at X-coordinate 5. For an overview of all studies with their respective peak coordinates see Table 1. The white line marks the boundary between the pMPFC and the aMPFC. MNI coordinates of the endpoints connecting this line are 5 40 41 and 5 30 15, as indicated by Steele and Lawrie (2004) and also applied in the meta-analysis of Amodio and Frith (2006).

this is the case, we will investigate if there is an anterior–posterior dissociation in the medial prefrontal wall based on the perceived intentionality of the unusual behaviour. To this end, we presented video clips of unusual actions that were intentionally or accidentally performed. While the outcome of the action was the same for the intentional and the accidental actions (for example switching on a light), the way in which this outcome was accomplished differed for the two situations. During the intentional actions the action was performed intentionally but in an extraordinary way. For example, a person walks to a light switch but operates it with the elbow. During the accidental actions the outcome was established by means of an accident. For example, a person leans against the wall and pushes accidentally against the light switch. If two distinct parts of the medial prefrontal wall are involved in the processing of unusual behaviour, depending on the attributed intentionality, we expect stronger activation in the pMPFC for observing unusual accidental behaviour compared to unusual intentional behaviour while we expect stronger aMPFC activation for observing unusual intentional behaviour compared to unusual accidental behaviour.

Materials and methods

Participants

Twenty participants (14 females) with normal or corrected-to-normal vision participated in this study (mean age = 22.8 years, SD = 2.4 years). They were all right handed as measured by the Edinburgh Handedness Inventory (Oldfield, 1971) and had no history of neurological disorders. Written informed consent was given before participation and all participants were paid 31 euro after the experiment. Ethical approval was given by the Medical Ethical Review Board of the Ghent University hospital.

Stimuli and design

The experiment was conducted using presentation software (Neurobehavioral Systems, Albany, NY). Forty different movie clips were shown during the experiment. These forty clips were generated by constructing four conditions of ten daily life situations. The four conditions comprised two conditions of interest that depicted unusual actions and two control conditions that depicted usual actions. The unusual actions were further divided into actions that were caused accidentally (ACCIDENTAL) and actions that were performed in an intentional way (INTENTIONAL). For example, one out of the ten daily life situations illustrated a woman placing a chair under a table. In the ACCIDENTAL condition the woman bumps into the chair and as a result the chair is placed under the table. In the INTENTIONAL condition the woman places the chair under the table in an extraordinary way (i.e., by using her leg). In addition two control conditions were included. These control conditions showed usual actions and were included to control for participants' expectations about the content of the clips. This resembles error observation research and action observation research where typically half the trials feature correct actions (e.g., Buccino et al., 2007) and plausible actions (Brass et al., 2007) respectively. Half of the usual actions were thus CORRECT actions. In our example of the chair, this condition showed the woman placing the chair under the table in a correct way (i.e., with her hands). The other half of the trials were plausible actions (PLAUSIBLE). This latter condition resembles the method used by Brass et al. (2007). In particular, the plausible condition showed the same behaviour as in the INTENTIONAL condition but in a context that makes the behaviour plausible. In our example this condition showed the woman placing the chair under the table with her leg while her hands are occupied. See http://users.ugent.be/~cdesmet/materials.html for the four video clips related to the example of the chair. For a complete description of our stimulus material see Table 2. The timing of the clips differed somewhat dependent on the situation (range between 4.6 and 13 s, mean duration = 8 s, SD = 2.3 s). However for a particular situation the duration of the four conditions was equally long. In this way the average timing of the clips between the four conditions was kept equal. On average, the onset of the actions started 4.9 s after the onset of the video (range between 1 s and 9 s, SD = 1.98 s). This did not differ significantly between the four conditions, $F < 1$ (ACCIDENTAL: 5.05 s, CORRECT: 4.80 s, INTENTIONAL: 4.75 s, PLAUSIBLE: 5.10 s).

Procedure

The experiment consisted of two runs in which every movie was repeated two times. This resulted in a total of 160 trials (40 video clips × 2 runs × 2 repetitions). The order of the movie clips was pseudo-randomized so that the same video clip was never successively presented. Between the two runs a short break was inserted. Participants were instructed to watch the videos attentively. To make sure participants were attentive, question trials were inserted in 10% of all trials. Participants were informed about this at the start of the experiment. In each run 8 videos were randomly selected to be followed by a question. The question always related to what happened during the video that was previously shown and appeared immediately after the end of the particular video. The questions were constructed in the following way: 'What is correct?' followed by four possibilities. For example, in the chair situation the question was 'What is correct:' (1) The woman's hands are free and the chair is moved by the leg. (2) The woman's hands are free and the chair is moved by the hands. (3) The woman's hands are occupied and the chair is moved by the leg. (4) The woman's hands are occupied and the chair is moved by the hands. Participants had to indicate which of the four sentences was a correct description of the video clip that they had just watched. For example, when participants had seen the CORRECT video the correct answer would be (2), whereas after viewing the INTENTIONAL video the correct response would be (1).

Dependent on the chosen answer, participants responded with their index or middle finger of their right or left hand by means of two response boxes placed on their upper legs. The mapping of the response buttons to a particular response was indicated on the screen. Movies shown prior to a question were discarded for further analyses. This resulted in 144 experimental trials.