

# Neural correlates of observing pretend play in which one object is represented as another

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**Observers were scanned while they watched a video of an actor using an object. Three conditions were contrasted in which the same object was used: (i) normally (e.g. using a tennis racket to hit a ball), (ii) in an unusual way (e.g. using a tennis racket to strain spaghetti), (iii) in a pretend play (e.g. playing a tennis racket like a banjo). Observing real and unusual uses of objects activated areas previously seen in studies of tool use including areas associated with a mirror system for action. Observing pretend play activated additional areas previously associated with theory of mind tasks and listening to narrative, including medial prefrontal cortex, posterior superior temporal sulcus and temporal poles. After presentation of each video, observers were asked to name the object as used in the preceding action video (e.g. racket, sieve or banjo). Naming the pretend object elicited activity in medial prefrontal cortex. These results are consistent with proposals that pretend play is a form of communicative narrative, associated with the ability to mentalize. However, this leaves open the question as to whether pretence or mentalizing is the more basic process.**

**Keywords:** pretence; mirror neurons; theory of mind; narrative; medial prefrontal cortex

## INTRODUCTION

### Action observation and the mirror system

Most studies of mirror systems in humans have used tool use or object manipulation as stimuli (Decety and Grezes, 1999; Buccino *et al.*, 2001; Rizzolatti and Craighero, 2004; Dinstein *et al.*, 2007). Social mirror theory (Mead, 1934; Baldwin, 1897; Dilthey, 1976; Whitehead, 2001), however, holds that social displays contribute more to sociality than instrumental actions—two forms of behavior that might become conflated under the rubric of ‘biological motion’. Social mirror theory further suggests that social displays (such as pretend play) are prerequisites for self- and other-awareness (such as theory of mind).

The study of pretend play reported here represents a collaboration between neuroscientists (J.L.M. and C.D.F.) and social anthropologists (D.C. and C.W.). Our aim is to contribute to the knowledge base necessary for further theorizing and research, particularly in relationship to autism and theory of mind, but also to answer some more general questions relating to the social brain. We assume that human culture must depend on implicit displays (such as dance) and mimetic displays (such as pretend play), and that these are the necessary precursors of the conventional displays that characterize and constitute human culture.

Received 8 December 2008; Accepted 22 May 2009

Advance Access publication 17 June 2009

C.D.F. and J.L.M. are supported by the Wellcome Trust. C.D.F. is also supported by the Danish National Research Foundation and Arts and Humanities Research Council. The authors are grateful to Knut Kampe with whom the idea for the experimental paradigm was originally developed.

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### Previous studies of pretend play

Pretend play has been a topic of convergent interest between the psychological and cultural sciences for more than a hundred years, and has been implicated in a number of human abilities and processes. Despite this historic interest and relevance to our understanding of the social brain, however, there have been—to the best of our knowledge—only two previous imaging studies of pretend play (Craik *et al.*, 2000; German *et al.*, 2004).

In the first of these studies, six drama students/recent drama graduates were required to imagine themselves playing the roles of Hamlet and Lady Macbeth in rehearsed extracts from Shakespeare’s plays, cued from a rolling text. The role-play tasks were contrasted with readings from control texts, selected for their apparently uninvolved character. Despite the subjectively greater difficulty of the role-play tasks, we found more brain activity during the control tasks. The contrast of role-play > control showed no significant activity other than a small area in the left occipital lobe. The opposing contrast—control > role-play—showed bilateral activations along the entire length of the intraparietal and intraoccipital sulci.

A possible explanation for this unexpected finding might be that role-play (i.e. imagining social scenarios or ‘day-dreaming’) is the default activity of the brain in awake adults. Such an idea is consistent with evidence that brain areas supporting default activity are involved with thinking about the self and others (D’Argembeau *et al.*, 2005). A pretend-play study incorporating ‘null epochs’ could support or disconfirm this hypothesis.

In the second study (German *et al.*, 2004), participants watched videos in which an actor either performed a real act (e.g. putting a book on a shelf) or a pretend act (e.g. miming putting a book on a shelf). Greater activity when observing pretend *vs* real acts was observed in a number of brain regions including medial prefrontal cortex, temporo-parietal junction and inferior frontal gyrus (BA47). The authors note the overlap with regions associated with mental state reasoning (Gallagher and Frith, 2003) and conclude that, when watching pretend play, observers automatically adopt the intentional stance necessary to understand what the actor is doing (Leslie, 1987). However, it is possible that the extra activity elicited by the pretend actions occurred because pretend actions are simply more novel or unusual.

## THE STUDY

The present study differed from that of German *et al.* in that our volunteers were not watching mimed actions. Instead we followed the examples given by Leslie and showed them videos in which actors used objects in the normal way or pretended that objects were other than what they actually were, e.g. a tennis racket 'played' like a banjo (tennis racket as banjo). As a control for the unfamiliarity of such actions, we included a third condition in which the same object was used in an unusual but functional manner, e.g. a tennis racket used to drain spaghetti (tennis racket as sieve).

It was inevitable that there would be differences in the precise movements made by the actor in the pretend videos compared to those showing object use, although there is no reason to suppose that these differences would vary systematically across the three different conditions. We, therefore, added a further comparison involving the same stimulus object across the three conditions. Immediately after seeing each video the volunteers were shown the object again and asked to name it in terms of the use they had just seen, e.g. tennis racket, banjo or sieve. As a result of including this final stage in the experiment, our volunteers were not simply observing the actions shown in the video. They also had to recognize what the actor had been doing in order that they could correctly name the object.

## Study hypotheses

*Activity elicited by action observation.* In comparison with the control condition (a blank video), observing normal (NV) and unusual object use (UV) would activate regions associated with complex action observation (see e.g. Molnar-Szakacs *et al.*, 2006), including areas associated with the mirror system for action (e.g. premotor cortex and parietal cortex: Dinstein *et al.*, 2007) We expected that there would be little difference between NV and UV, since the mirror system is primarily concerned with actions, goals and outcomes (Hamilton & Grafton, 2008). From this perspective there is little difference between stirring a cup of tea with a spoon or a pencil.

The pretend videos (PV) would also activate action observation areas, but would activate additional areas to those activated by observation of normal and unusual use. On the basis of the theoretical link between mentalizing and pretend play (Leslie, 1987; Astington *et al.*, 1988; Leslie, 1988; Dunn, 1991; Kavanaugh and Engel, 1998; Lillard, 1998) and the results of a previous imaging study (German *et al.*, 2004), we expected pretend play to activate brain areas associated with mentalizing, including medial prefrontal cortex.

*Activity elicited by preparation to name an object.* The presentation of the objects after the videos would elicit activity in inferior temporal regions concerned with object recognition and naming (Price *et al.*, 2005; Martin, 2007).

This activity would be modified by the preceding context (blank video, NV and UV, PV).

In particular, when the usual name had to be suppressed in the pretend condition, we might expect reduction of activity in traditional object naming areas, and an increase of activity in areas associated with mentalizing.

## Methods

*Subjects.* Fifteen adult participants (seven females, one left-handed, mean age  $24.85 \pm 4.86$  years) with no known neurological history gave written informed consent to take part in the study, which was approved by the Joint Ethics Committee of the National Hospital for Neurology and Neuroscience (UCL NHS Trust) and Institute of Neurology (UCL).

*Stimuli and responses.* A series of videos were filmed in which a professional actor (DC) interacted with a series of objects. Each object was interacted with in three different ways (see Supplementary data): the normal way (e.g. using a pen to write); an unusual way (e.g. using the pen to stir a cup of coffee); and a pretend way (e.g. pretending the pen is a toy aeroplane). Forty objects were first identified as possibilities for generating the three kinds of use. On the basis of pilot studies to ensure that the three different uses of the objects were equally easy to recognize, a subset of 22 objects was chosen to make professional videos of the three kinds of use. From these videos, 18 objects (i.e. 54 videos) were chosen for the experiment. Three additional object videos were used for practice prior to scanning. Participants were shown the videos and then had to verbally report what the object had been used as. Visual stimuli were projected onto a screen located at the back of the magnet and viewed via a 45° angled mirror positioned above the head coil. Responses were recorded using a plastic tube with one end attached to the head coil above the participant's mouth, and the other end connected to a small microphone outside the scan room.

*Experimental paradigm.* Each 12 s task sequence consisted of four parts: First, the cue word 'Ready' appeared on the screen (1 s) followed by a picture of the object to be

featured (1 s). Then there was a 6 s video sequence showing the actor using the object in one of three ways: the normal way (using a pen to write); an unusual way (using the pen to stir a cup of coffee); and a pretend way (pretending the pen is a toy aeroplane). A 'blank' video showing only the studio background was also used as a null action condition. After the video, in half the trials, the picture of the object appeared once more for 4 s with the caption 'Use?', and participants responded by naming the object as it was used in the preceding video (e.g. in the case of the pen, they would say 'pen' after normal use; 'spoon' or 'stirrer' after unusual use; and 'aeroplane' after pretend use). After the blank video they would simply say 'pen'. In the other half of the trials, instead of the object picture a black rectangle appeared, in which case subjects responded with the word 'Use'. For these response tasks, we analyzed imaging data taken only during response preparation—i.e. before subjects actually began to speak. There were 18 objects in all, and so, 144 different trial sequences:

18 objects ×	Four videos : Normal use (NV) Unusual use (UV) Pretend use (PV) Blank background (BV)	×	Two response conditions : Picture of object (NR, UR, PR or BR) Black rectangle (XR)
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Prior to scanning, participants were shown pictures of each of the experimental objects to ensure they were all recognizable and could be named. Three additional objects were used for training to allow task familiarization.

Full details of the study methodology are available as Supplementary data.

**MRI data acquisition.** A 1.5-T Siemens Sonata MRI scanner (Erlanger, Germany) was used to acquire T<sub>2</sub>-weighted gradient echo, echo-planar images with Blood Oxygenation Level-Dependent contrast. Whole brain coverage was achieved using 35 axial slices of 2 mm thickness with a 2 mm gap and a TR of 3.15 s. There were three functional imaging runs of 200 volumes and the first 6 volumes were discarded to allow for effects of T<sub>1</sub> equilibrium. An 8-min T<sub>1</sub>-weighted structural MRI scan was acquired for each subject, using a hybrid sequence.

**MRI statistical analysis.** Image processing was carried out using Statistical Parametric Mapping software (SPM2; Wellcome Department of Imaging Neuroscience, www.fil.ion.ucl.ac.uk/spm), implemented in MATLAB 6.5.1. EPI images were realigned to correct for movements, unwarped, spatially normalized to standard space, using the Montreal Neurological Institute template (voxel size of 2 × 2 × 2 mm<sup>3</sup>) and spatially smoothed with an 8 mm full-width half maximum Gaussian kernel.

First-level fixed-effect analysis was conducted for each subject using the general linear model with the haemodynamic response modeled as boxcars: a 6 s boxcar across the video duration for each observation condition; a reaction-time dependent (mean 1 s) boxcar for each response condition commencing at cue onset and ending just prior

to speech onset. In addition to these 12 experimental regressors, six movement parameters were modeled. Incorrect or no response trials were removed from analysis.

Contrasts of interest were calculated for each subject using *T*-tests and introduced to a second-level random-effect analysis for population inference. Main effects were calculated for each contrast using a one-sample *t*-test to include all subject contrasts. The maps were thresholded at *P* < 0.05 false detection rate corrected at the voxel level, and a human brain atlas (Duvernoy, 1999) was used to localize clusters of cortical activity.

## Results

**Action observation.** The only difference in activity elicited by observation of UV in comparison to NV was observed in left inferior frontal cortex. However, this difference was only significant at the cluster level and failed to reach an acceptable level of significance at the voxel level (FDR corrected). These two conditions were therefore combined (as object use) in subsequent analyses.

**Object use > blank video:** locations of activity for this comparison are shown in Table 1. Consistent with previous studies of action observation (e.g. Molnar-Szakacs *et al.*, 2006), activity was seen in dorsolateral prefrontal cortex (DLPFC), ventral premotor cortex (vPMC) and parietal cortex. The activity in vPMC and parietal cortex is in locations identified as part of a mirror system for action by Dinstein *et al.* (2007). Activity was also seen in fusiform gyrus and extra-striate cortex, in regions associated with object recognition (e.g. Martin, 2007) and visual motion detection (e.g. Bundo *et al.*, 2000), respectively.

**Pretend > object use:** a number of regions were more active for observing pretend than for NV and UV (see Table 2 and Figure 1). The activity was in regions similar to those reported by German *et al.* (2004), including medial prefrontal cortex, DLPFC, temporal poles and right superior temporal sulcus (STS).

**Object use > pretend:** unexpectedly, some regions were also more active when observing object use in contrast to pretend. These included the postcentral gyrus and the parietal operculum (Table 3).

**Blank video > Action observation:** when watching the blank video greater activation was seen in the inferior parietal lobule (angular gyrus and supramarginal gyrus) as well as posterior medial areas (posterior cingulate and precuneus). There were no striking differences between blank > normal & unusual (Table 4) and blank > pretend (Table 5).

**Naming object use: behavioral analysis of vocal responses.** Accuracy: the number of erroneous responses for each subject was very low (2.5%), ranging from 0–11 across the 144 stimuli, with a mean of 3.7 (±0.7 S.E.). Erroneous responses included those in which inappropriate or no answers were given and when excessive head

**Table 1** Brain activation results for [(Real + Unusual) vs Null] action observation ( $P < 0.001$ ,  $n > 30$ )

		LEFT				RIGHT			
		<i>x</i>	<i>y</i>	<i>z</i>	<i>z</i> -value	<i>x</i>	<i>y</i>	<i>z</i>	<i>z</i> -value
IFG	BA46	-52	42	4	4.26				
IFG opercularis	BA44	-42	6	22	4.42				
Postcentral gyrus, SI	BA2	-64	-24	38	3.93	60	-20	44	3.86
IPL	BA40	-52	-28	24	3.77	62	-26	24	4.34
IPS	BA40	-46	-34	44	4.88	30	-42	52	4.45
SPL	BA7					24	-62	58	4.55
Temporal pole	BA38	-26	10	-26	3.86	44	24	-32	4.00
ITG	BA20					34	-4	-44	4.08
Posterior STS	BA22					56	-50	10	3.94
Fusiform gyrus	BA37	-44	-68	-20	6.30	38	-62	-16	6.63
MOG (LO/V5)	BA19	-36	-86	6	6.25	38	-86	2	6.67
Substantia nigra		-10	-30	-4	4.32				
Cerebellum (VIII)		-10	-78	-44	4.88	26	-60	-50	3.74

BA, Brodmann area; IFG, inferior frontal gyrus; SI, primary somatosensory cortex; IPL, inferior parietal lobe; IPS, intraparietal sulcus; SPL, superior parietal lobe; ITG, inferior temporal gyrus; STS, superior temporal sulcus; MOG, middle occipital gyrus.

**Table 2** Brain activation results for [(Real + Unusual) vs Pretend] action observation ( $P < 0.001$ ,  $n > 30$ )

		LEFT				RIGHT			
		<i>x</i>	<i>y</i>	<i>z</i>	<i>z</i> -value	<i>x</i>	<i>y</i>	<i>z</i>	<i>z</i> -value
Premotor cortex	BA6	-22	-2	64	4.43				
Postcentral gyrus, SI	BA2	-60	-28	42	4.71	54	-22	42	4.46
IPL	BA40	-62	-20	20	4.12	64	-18	28	5.31
Fusiform gyrus	BA37	-30	-48	-14	4.08	26	-54	-10	4.00
Lingual gyrus	BA18	-6	-80	-10	4.06				

IPL, inferior parietal lobe; SI, primary somatosensory cortex.

movements were made. Synonyms for the object (e.g. spoon for stirrer, guitar for banjo) were not considered errors.

Reaction times: a repeated measures  $4 \times 2$  ANOVA (video  $\times$  response type) showed there was no significant effect of preceding video type upon vocal response reaction times. The overall mean reaction time across all conditions was 1.11 s. However, reaction times were significantly faster when participants said 'use' after a blank image stimulus was shown when compared to stating the object's use when a picture of the object was presented. There was no interaction between video and response type.

**Naming object use: fMRI analysis.** (i) Stating the use of the objects in contrast to saying 'use' when no object was presented. Presentation of an object, whatever the preceding video, elicited activity in areas previously associated with object recognition and object naming (see Martin, 2007 for a review): most notably inferior frontal gyrus (on the left), temporal poles and the ventral visual stream (including fusiform gyrus and inferior occipital gyrus: see Table 6). (ii) Stating a pretend use in contrast to a normal or unusual use. This analysis revealed a subset of the same areas activated when watching the PV, the strongest activation

being observed in anterior rostral medial prefrontal cortex (see Table 7 and Figure 2).

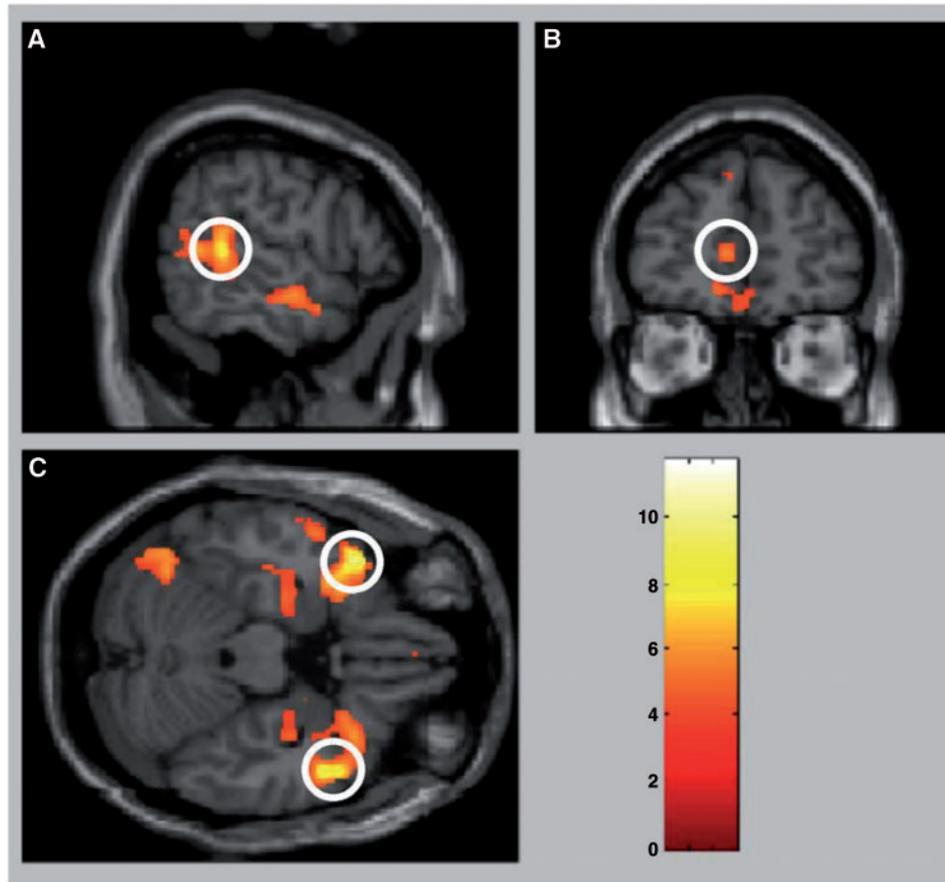
## DISCUSSION

### Recognizing actions

In comparison to watching a blank video, it is not surprising that observing actions activated a great many brain regions (Table 1). There was activity in extrastriate cortex associated with visual motion (e.g. Bundo *et al.*, 2000), in inferior temporal cortex (including fusiform gyrus) associated with object recognition (e.g. Martin, 2007) and in DLPFC, vPMC and parietal cortex associated with action observation (e.g. Molnar-Szakacs *et al.*, 2006). The activity in vPMC and parietal cortex was in locations identified as part of the mirror system for action (Dinstein *et al.*, 2007).

### Recognizing particular actions

There were no significant differences in activity elicited when observing unusual vs standard uses of objects. This lack of difference is consistent with the idea that the action



**Fig. 1** Brain regions (circled) showing greater activity when observing pretend rather than normal or unusual object use. (A) Posterior superior temporal sulcus ( $x = -54$ ). (B) Anterior rostral medial prefrontal cortex ( $y = 50$ ). (C) Temporal poles ( $z = -20$ ).

**Table 3** Brain activation results for [Pretend vs (Real + Unusual)] action observation ( $P < 0.001, n > 30$ )

		LEFT				RIGHT			
		<i>x</i>	<i>y</i>	<i>z</i>	<i>z</i> -value	<i>x</i>	<i>y</i>	<i>z</i>	<i>z</i> -value
arMPFC	BA 32	-8	50	6	3.91				
oMPFC*	BA 11	0	46	-18	3.88				
IFG orbitalis	BA 47	-42	34	4	4.23	44	32	-4	4.93
IFG triangularis	BA 45					46	22	16	4.32
IFG opercularis	BA 44	-40	12	18	3.84				
pre-SMA	BA 6					10	6	72	4.00
Temporal Pole	BA 38	-44	24	-20	5.61	36	18	-26	4.35
anterior STS	BA 22					54	8	-18	5.47
posterior STS	BA 22					52	-40	4	5.10
Amygdala/hippocampus		-16	-8	-18	4.30	28	-4	-28	3.80
Fusiform gyrus	BA 37	-46	-66	-24	4.37	42	-48	-30	4.39
MOG (LO/V5)	BA 19	-40	-86	-8	4.46	56	-70	-2	3.92
Cuneus	BA 18	-6	-98	12	5.68	12	-100	18	4.61
Thalamus		-2	-8	2	3.45	8	-10	10	3.71
Sustantia Nigra		-8	-26	-12	3.74				
Cerebellum (X)		-14	-40	-42	3.70				

\*Bilateral activation, maximal peak reported. arMPFC, anterorostral medial prefrontal cortex; BA, Brodmann area; IFG, inferior frontal gyrus; MOG, middle occipital gyrus; oMPFC, medio-orbitofrontal cortex; pre-SMA, pre-supplementary motor area; STS, superior temporal sulcus.

**Table 4** Brain activation results for [Blank vs (Real + Unusual)] action observation ( $P < 0.001$ ,  $n > 30$ )

		LEFT				RIGHT			
		x	y	z	z-value	x	y	z	z-value
MFG	BA 10	-34	46	0	4.26				
MFG	BA 9					34	28	26	4.98
MTG	BA 21					66	-22	-6	4.50
IPL/angular gyrus	BA 39	-52	-58	42	5.29	60	-54	40	5.77
PL/supramarginal gyrus	BA 40					64	-54	28	5.03
PCC	BA 32/31	-26	-62	6	4.71	4	-44	44	3.85
Cerebellum						<b>4</b>	<b>-56</b>	<b>-22</b>	<b>3.97</b>

BA, Brodmann area; IPL, inferior parietal lobule; MFG, middle frontal gyrus; MTG, medial temporal gyrus; PCC, posterior cingulate cortex; PL, parietal lobe.

**Table 5** Brain activation results for (Blank vs Pretend) action observation ( $P < 0.001$ ,  $n > 30$ )

		LEFT				RIGHT			
		x	y	z	z-value	x	y	z	z-value
STG	BA 21					56	2	-2	4.81
IPL/angular gyrus	BA 39	-52	-60	46	4.67	62	-56	34	5.15
Precuneus	BA 7	-8	-70	34	5.05				

BA, Brodmann area; IPL, inferior parietal lobule; STG, superior temporal gyrus.

**Table 6** Brain activation results for [stating object's use vs repeating the word 'use' (no object)] ( $P < 0.001$ ,  $n > 30$ )

		LEFT				RIGHT			
		x	y	z	z-value	x	y	z	z-value
IFG orbitalis	BA 47	-38	42	-14	5.31	58	26	-4	4.11
IFG triangularis	BA 45	-42	34	4	5.24				
ACC	BA 24	-8	26	40	4.67				
Caudate						20	6	18	4.35
Temporal pole	BA 38	-52	10	-6	4.86	20	12	-20	3.90
Precentral gyrus	BA 4					48	-10	40	4.20
STG	BA 22					58	-10	2	4.60
Ant STS	BA 22	-46	-10	-18	4.32				
mid STS	BA 22	-62	-28	2	4.14				
fusiform	BA 37	-48	-58	-20	5.22	42	-50	-17	3.94
IOG	BA 19	-44	-78	-14	5.27	42	-82	-11	4.45
V1/V2	BA 17/18	-16	-102	-10	4.53	16	-102	-6	4.95
Cerebellum	(VI)					28	-64	-28	5.68
Cerebellum	(VIII)					20	-72	-48	4.90

ACC, anterior cingulate cortex; BA, Brodmann area; IFG, inferior frontal gyrus; STG, superior temporal gyrus; STS, superior temporal sulcus; IOG, inferior occipital gyrus.

observation system in the brain is primarily concerned with actions, goals and outcomes. What the brain represents is 'stirring' rather than 'stirring with a spoon' (Hamilton & Grafton, 2008).

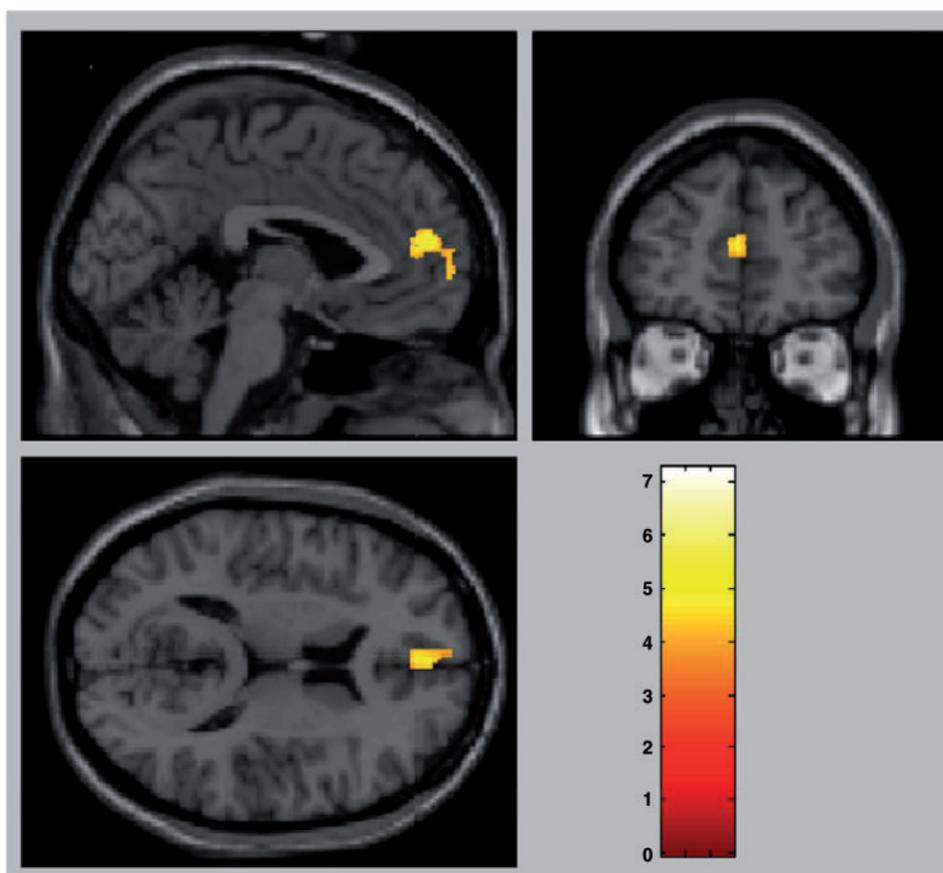
Contrary to our expectations, we observed regions where there was greater activity for observation of object use than for observation of pretend play (see Tables 2 and 3). Observation of object use (vs pretend play) elicited

activation in sensory-motor regions (BA6, BA2 and BA40). We can only speculate at this stage, but the location of this activity might relate to subjects imagining what it is like to use the object in terms of movement and touch. When watching the video of pretend play, there is a conflict between what it would feel like to play a banjo and what it feels like to the actor pretending with his tennis racket, so that activity in sensory-motor regions might be reduced.

**Table 7** Brain activation results for Stating object's use after different action videos, ((Pretend vs [(Real + Unusual)]) $P < 0.001$ ,  $n > 30$ )

		LEFT				RIGHT			
		<i>x</i>	<i>y</i>	<i>z</i>	<i>z</i> -value	<i>x</i>	<i>y</i>	<i>z</i>	<i>z</i> -value
arMPFC	BA 32/10	-2	52	16	3.94				
SFG	BA 46	-20	54	20	3.79				
Post central gyrus	BA 43	-58	-16	18	3.51				
<b>V1/V2</b>	<b>BA 17/18</b>	<b>-16</b>	<b>-94</b>	<b>-2</b>	<b>3.63</b>				

BA, Brodmann area; arMPFC, anterior rostral medial prefrontal cortex; SFG, superior frontal gyrus



**Fig. 2** Activity in anterior rostral medial prefrontal cortex (-2, 52, 16) elicited when naming an object used in a pretend action. The region is shown in a sagittal, coronal and horizontal slice.

Observing pretend play (*vs* object use) elicited activity in a number of regions. These included areas consistently activated during performance of theory of mind tasks (reviewed in Frith and Frith, 2003): antero-rostral medial prefrontal cortex (BA32), right posterior superior temporal sulcus (STS: BA22), with a large cluster extending into parietotemporal areas, and bilateral temporal poles (BA38). We also observed bilateral activations in the amygdala extending caudally into the hippocampal head. The amygdala has also been implicated in some (e.g. Castelli *et al.*, 2000), but by no means all, ToM studies. In addition to these areas,

we observed activity in orbitomedial prefrontal cortex, inferior frontal gyrus (BA44, 45 and 47) as well as anterior STS and some regions of extrastriate cortex.

### Naming objects

As expected, subsequent naming of the objects, in terms of how they were used in the preceding video, activated areas previously associated with object recognition and object naming (Martin, 2007). The critical result concerns the naming of objects after they have been involved in pretence. In this comparison, the stimulus that elicits the activity

(the picture of the object) is identical. Any difference in activity must be due to the attitude towards the object that has been created by the preceding video. Naming objects in the pretend condition elicited activity in medial prefrontal cortex in the same location as the activity observed when subjects were watching the pretend video. This is strong evidence that MPFC has a role in the understanding of pretence. The inclusion of the condition of novel object use confirms that this activity associated with pretend play is not simply a result of novelty. The lack of difference in RT for naming the objects in the three conditions is not sufficient to prove that the conditions were equally difficult, since the name could be retrieved well in advance while watching the preceding video. However, the very low error rate in naming the objects suggests that none of the conditions presented any great problem for our volunteers.

### Pretence and theory of mind

The findings of German *et al.* (2004) were very similar to ours. Watching videos of pretence in both studies activated areas associated with ToM (MPFC, posterior STS and amygdala) as well as lateral prefrontal cortex (BA44, 47). These results provide evidence at the neural level for an intimate relationship between pretence and theory of mind. This is consistent with social mirror theory and Angeline Lillard's (2001) 'twin earth' model, which both assume that pretend play is causally necessary for the development of ToM. However, the results are also consistent with Leslie's (1987) view that pretend play is 'a primitive manifestation of the ability to conceptualize mental states'. Evidence of common patterns of neural activity when confronted with pretence or with theory of mind tasks cannot address the question as to which of these views about the relation between pretence and ToM is correct.

However, we may get clues from the many different kinds of task that activate MPFC (see Amodio and Frith, 2006 for a review). In addition to tasks involving ToM, MPFC is activated by tasks requiring knowledge about psychological aspects of the self (e.g. Kelley *et al.*, 2002; Ochsner *et al.*, 2004) or of other people (e.g. Mitchell *et al.*, 2005). This is clearly not a region that is specific to ToM. It is also possible to make finer distinctions within the region of anterior dorsal MPFC where these activations are observed. For example, Walter *et al.* (2004) make an important distinction between making inferences about private intentions (e.g. inferring that someone is replacing a light bulb in order to read a book) and making inferences about communicative/social intentions (e.g. inferring that someone is showing someone else a map in order to get directions). Activity associated with inferring communicative intentions occurred in regions more anterior and inferior to activity associated with inferring private intentions, close to the activations observed in the present study (Walter *et al.* exp. 1: 0 54 12; present study: -8 50 6). Another relevant study is one in which communicative actions were observed.

Gallagher & Frith (2004) report activity elicited by observation and recognition of communicative gestures. Two kinds of gesture were included in this study: instrumental gestures telling people what to do (e.g. beckoning; 'come here') and expressive gestures indicating the emotional state of the gesturer (e.g. thumbs up; 'I am pleased'). In comparison to instrumental gestures, recognition of emotional gestures elicited activation in a similar region of MPFC (-12 54 0), as well as temporal poles and posterior STS.

One possible implication of the commonalities revealed by these studies is that, when we observe pretend play, we experience this as a communicative activity. While a young child may indulge in pretence without any audience being present, pretend activity is much more typically a group activity with one or more actors in front of an audience. Furthermore, pretence is expressive rather than instrumental communication. The actor is telling us something about himself. There is no obvious communicative component when observing object use (unless we are being taught), even when the object is used in an unusual manner. On this view, pretend play is a form of story-telling. We might therefore expect to find similar patterns of brain activity associated with narrative.

### Pretence and narrative

Whether fictional or supposedly factual, the human appetite for narrative is large and seems to be continuous with social fantasy and pretend play (Whitehead, 2001; Mar, 2004). The study of this topic has been primarily the domain of social psychology and anthropology, but, more recently, neuroscientists have begun to investigate the brain correlates of narrative (Mar, 2004).

There is a considerable overlap between studies of narrative and studies of theory of mind. Many ToM studies use narrative stimuli—whether in words or pictures—and ToM is implicated in most cognitive models of narrative comprehension and production (Mar, 2004). However, the ventrolateral prefrontal areas (IFG *pars orbitalis*, *triangularis* and *opercularis*), which were activated in all three studies of pretence, are not typical ToM areas, but have been reported in four studies of narrative (Mazoyer *et al.*, 1993; Nichelli *et al.*, 1995; Partiot *et al.*, 1996; Schmithorst *et al.*, 2006). The study by Schmithorst *et al.* was unusually large, involving 307 children aged 5 to 18. Other non-ToM areas seen in our study have also been implicated in narrative. Bilateral activation of orbitomedial prefrontal cortex (BA11) has been associated with 'creating a narrative representation' (Maguire *et al.*, 1999), and preSMA (BA6) with 'story script ordering' (Crozier *et al.*, 1999), although this was in the left hemisphere, and not the right as in our study.

In a review of narrative theory and research, Mar (2004) identifies five main areas associated with narrative processes: (i) bilateral medial frontal; (ii) lateral frontal, more on the right than the left; (iii) bilateral temporoparietal (in which he includes the inferior parietal lobule); (iv) bilateral anterior

temporal, including the temporal poles; and (v) bilateral posterior cingulate.

Mar makes clear that the controls used in the studies confirm that all the implicated areas were specific to narrative and could not be attributed to the processing of words, sentences or syntax. Narrative is not essentially dependent on language, and a story can be told in pantomime or pictures.

Not all of the areas identified by Mar were activated in our study, or in the study by German *et al.* (2004). The narrative areas not activated by observing pretence were dorsolateral prefrontal, inferior parietal lobule and posterior cingulate. Interestingly, these same areas *were* activated in the role-to-control switch in our earlier study of role-play (Craik *et al.*, 2000). Whilst this pilot study cannot be regarded as definitive, it is provocative, and suggests that further research is needed specifically to study role-play as distinct from pretend play using objects as toys.

Whether or not the neural correlates of role-play prove to be the same or similar to those of narrative, on the basis of the evidence reviewed above, it would appear that observing pretence activates a subset of the areas involved in narrative, and that ToM activates a subset of the areas involved in observing pretence.

#### Pretend play and 'deactivation areas' of the brain

Imaging studies have revealed that certain areas of the brain are tonically active during 'rest' or 'null epochs', and that these areas show reduced activity during a wide range of laboratory tasks designed to investigate cognitive processes. In debriefing sessions, participants in such studies have reported autobiographical thoughts or memories during rest epochs, suggesting daydream activity or social fantasy (Kennedy *et al.*, 2006). Indeed, all of these 'deactivation areas' have been reported as activated in imaging studies of narrative, further suggesting their involvement in social imagination or 'theatre of mind'.

Daydreaming is closely related to pretence. So we might expect the pattern of activity associated with pretend play to resemble that seen during 'rest'. We did find some resemblance between pretend-play activations in our study and typical deactivation areas, but the match was not perfect. Furthermore the pattern of activity associated with rest in our study (i.e. blank video > observing object use) did not overlap with the pattern associated with observing pretend play and was not typical of the default state. During observation of the blank video, the strongest activity was seen in the angular gyrus bilaterally, and this was the case whether the comparison was made against observing object use or pretend play (see Table 4). Further research will be needed to explain why we did not see the usual pattern of default activity during rest. Perhaps mental activity during rest depends upon the context in which this rest occurs.

#### SUMMARY AND CONCLUSIONS

We have reported an fMRI study of the observation of pretend play in which one object was represented as another.

- (i) Observing instrumental actions—i.e. watching video sequences showing an actor using objects in a normal or an unusual (but still instrumental) way—elicited activity in many regions seen previously in studies of action observation and object recognition, including the mirror system for action.
- (ii) Observing pretend play (in contrast to instrumental actions) activated major ToM areas, which are also commonly reported in studies of narrative, and also some non-ToM areas, which have likewise been reported in narrative. Naming an object as a 'toy', after having seen a pretend action, also activated one major ToM area—ventromedial prefrontal cortex. Interestingly, typical narrative areas that were not activated in two studies of pretence—posterior cingulate, inferior parietal and dorsolateral frontal—were activated in an earlier study of role-play. We postulate that this may reveal a functional difference between introjective play (role-play) and projective play (playing with toys). We further postulate that role-play will prove substantially similar to narrative, whereas projective pretend play activates fewer cortical structures as shown in two studies of observing pretence. A more definitive study of role-play, as distinct from pretend play with representational toys, is needed to resolve this issue.

#### SUPPLEMENTARY DATA

Supplementary data available at SCAN online.

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