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# Differential Brain Activations between Internal-state Discrimination and Gender Discrimination from Biological Motion

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## I. Introduction

Understanding the internal state of another person is a fundamental socio-cognitive skill which involves sensing and adequately interpreting a number of sophisticated cues from different sensory domains. One of them is visual motion. In everyday life, we can infer whether a walking person is happy or sad or not, even when their facial expression is not visible. Body expressions can be as effective cues as facial expressions for understanding another person's internal states (Atkinson, Dittrich, Gemmell & Young, 2004).

The term 'biological motion' (BM) refers to displays that consist only of a number of small bright dots attached to the principal joints of a person's body (Johansson, 1973). Numerous studies have shown that subjects can recognize various body movements such as locomotory, instrumental and social actions from these

displays (Dittrich, 1993). Although BM is a very degraded representation of body movements, subjects can also use them to recognize others' internal states, such as emotion and intention, personality and gender (Dittrich, Troscianko, Lea & Morgan, 1996; Troje, 2002a).

Previous studies using fMRI and PET revealed that the superior temporal sulcus (STS) is activated when biological motion is perceived (e.g. Bonda, Petrides, Ostry & Evans, 1996). Grossman and Blake (2002) showed that activation in the STS was increased when subjects perceived biological motion stimuli as compared to activation in response to biologically irrelevant motion stimuli, such as scrambled versions of biological motion. Grossman's study, along with others, suggests that the STS is involved in the perception of biological motion.

Although the STS is probably one of the critical regions for the perception of biological motion, the parietal cortex, especially its inferior parts, and the premotor cortex are also considered to be involved in perception of human body movements (Calvo-Merino, Glaser, Grézes, Passingham & Haggard, 2005; Saygin, Wilson, Hagler, Bates & Sereno, 2004). Calvo-Merino et al. (2005) observed higher activations in the STS, in the intraparietal sulcus, and in the premotor cortex when subjects watched videos of performable, familiar whole-body movements than when they watched videos of non-performable whole-body movements. Because these regions, the STS, parietal lobule and premotor cortex, are activated both when perceiving others' body movements and when moving one's own body, it has been suggested that the perception of another person's body movements is based on a kinaesthetic representation of our own body movements (Decety & Grézes, 2006). Similarly, our understanding of another person's internal (or emotional) states may also be based on internal representations of our own body expressions. Grézes, Pichon and de Gelder (2007) observed activations in the parietal, premotor cortex and amygdala when subjects saw videos of a fearful body expression.

In the present study, we attempted to differentiate processes underlying internal-state discrimination (e.g., emotion) from processes involved in discrimination of more external features, such as gender, as derived from biological motion. Because the STS is involved in processing of biological motion, a similar level of activation is expected to be found in the two tasks. In contrast, selective activation should be found in the inferior parietal lobule, in the premotor cortex and also in the amygdala during emotion discrimination, due to the more specific contributions of these regions to the processing of internal states.

## II. Methods

### 1. Subjects

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Fourteen right-handed healthy subjects (8 males and 6 females; mean age =  $22 \pm 1.75$ ) participated in the present study.

### 2. Stimuli

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The experimental stimuli were four types of biological motion (BM) videos and four types of scrambled motion (SM) videos. Video clips (320 x 240 pixels, 20 fps) were created to correspond to exactly one gait cycle. The BM stimuli consisted of 15 white dots, on a black background, attached to the major joints, the pelvis, and chest, of a person walking stationarily, as if on a treadmill. Variations of a neutral walker according to gender and emotional state were derived according to Troje (2002b). In short, the technique is based on motion capture data derived from 80 different individual walkers. A morphable space is constructed that is spanned by these data. Two linear discriminant functions are derived. One was based on the sex of the individual walkers and the other one was based on ratings obtained from naïve observers about the emotional state (happy or sad) of each individual walker. The two functions were then orthogonalized and linearly combined to create the four different walkers: male/happy, male/sad, female/happy and female/sad. Each of the four walkers represents a point in linear walker space at a distance of 6 standard deviations away from the overall average walker. Both the sex of the walker and his or her emotional state can be vividly perceived from these displays (see <http://biomotionlab.ca/Demos/BMLwalker.html> for an example). The SM stimuli consisted of groups of moving dots spatially rearranged from the biological motion.

### 3. Experimental Design

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In two runs, subjects were asked to identify the sex of the walker – in one of them they had to press a key when they saw a male walker, and in the other they had to press the key in response to a female walker. In the other two runs, subjects had to identify the walker's emotional state – again using both key-stimulus assignments. For the fMRI scanning we used a block design, contrasting BM blocks with SM blocks. Each run started with a presentation of 5-s fixation, followed by 16 successive presentations of SM and BM videos presented alternately. The duration of each stimulus presentation was 20 s. One run therefore lasted 325 seconds.

## 4. Image Acquisition and Analysis

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Subjects were scanned in an Allegra fMRI scanner (Siemens, Germany) with a standard head coil operating at 3 Tesla. After initial localizer images had been obtained, T1-weighted anatomical images were obtained with inversion recovery-prepared magnetization-prepared rapid acquisition with gradient echo (MP-RAGE). For functional imaging, we used single-shot gradient-echo, echo planar imaging with a repetition time of 1000 ms, echo time of 20 ms, flip angle of 70 degree, field of view of 210–230 mm, matrix size of 64 x 64, and slice thickness of 5 mm with a 0.8 mm gap. We acquired 325 volumes of 21 slices parallel to the AC-PC for each run. Data analysis was carried out using SPM2 (Wellcome Department of Cognitive Neurology, University College London) implemented in Matlab (Mathworks Inc., USA).

## III. Results

### 1. Behavioral Results

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Two-sample t-tests showed that there was no significant behavioral difference between the emotion discrimination task and the gender discrimination task in terms of either response time or response accuracy ( $t_{14} = 1.28$  and  $t_{14} = 1.94$ , respectively,  $p > 0.05$ ).

### 2. Imaging Results

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In the emotion discrimination, we find activations in the right rostral prefrontal cortex (BA10), particularly in the middle frontal gyrus, in the left inferior parietal lobule (which includes parts of intraparietal gyrus), and in the right lingual gyrus. For the gender discrimination task, we observed activations in the right and left middle occipital gyrus.

## IV. Discussion

In the present study, we attempted to differentiate processes underlying internal-state discrimination from processes underlying discrimination of external features within the context of biological motion perception. We observed activations in the right middle frontal gyrus and left inferior parietal lobule for emotion discrimina-

tion, and activation in the visual cortex for gender discrimination. No significant behavioral difference was found between the two tasks.

As we expected, the left inferior parietal lobule was activated in the emotion discrimination task. Calvo-Merino et al. (2005) observed increased activation in the left intraparietal sulcus when subjects perceived performable movements. The activation in the left inferior parietal lobule in the present study is consistent with these findings and suggests that this region is involved in the perception of body movements.

We expected activation in the premotor cortex when subjects discriminated emotion from biological motion, but no activation was observed in this region. The results in the present study seem to be inconsistent with those of Saygin et al. (2004), who reported that the premotor cortex was activated in perception of biological motion. The difference might be due to the number of stimuli and the types of action being used in the two studies. Whereas Saygin et al. (2004) used six different actions in each stimulus presentation block, we used different styles of one single, stereotypic action (walking) in the present study. Subjects in our study did not have to recognize an action and therefore we would not expect them to ‘simulate’ the action covertly with their motor system. Rather, the emphasis here was on the particular style of the action. It is unlikely that a male observer needs to ‘simulate’ female walking style in order to understand it, and the same is probably true for the understanding of emotion in movement patterns as well. It is worth noting that only the right middle frontal cortex (which also involves a part of the rostral prefrontal cortex) was activated in the emotions discrimination task in the present study. The results in the present study seem to be inconsistent with those in other studies (Calvo-Merino et al., 2005). However, previous studies have suggested that this region is involved in reasoning and judgement (Christoff, Ream, Geddes & Gabrieli, 2003). We found activation in the right middle frontal cortex, and this may be because subjects inferred and evaluated others’ internal states while performing the task.

In contrast to our expectation, no activation was observed in the STS in the two tasks. For the emotion discrimination task, there was no activation in the amygdala. This may be because the present experimental design was not suitable to detect activation in the STS region. BOLD signals in the STS when processing biological motion tend to have very sharp response curve. In the present study, the stimulation duration was 20 s, which may have dampened the BOLD signal in the STS. To understand how patterns of activation in cortical regions change as a function of stimulus duration, it will be necessary to conduct further analyses comparing transient and sustained responses.

In conclusion, we found dissociation between two different processes involved in style recognition from biological motion. While recognition of the internal state

of the walker seems to be mediated by the left inferior parietal lobule and right middle frontal cortex, our data do not reveal a brain area specific for gender classification from biological motion. Differential activity in the visual cortex depending on whether the point-lights formed a coherent figure or a scrambled, meaningless cloud was not specific to the task. Nevertheless, it demonstrates that complex visual discrimination is already processed at this level.

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