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Synchronous brain activity across individuals underlies shared psychological perspectives

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ABSTRACT

For successful communication, we need to understand the external world consistently with others. This task requires sufficiently similar cognitive schemas or *psychological perspectives* that act as filters to guide the selection, interpretation and storage of sensory information, perceptual objects and events. Here we show that when individuals adopt a similar psychological perspective during natural viewing, their brain activity becomes synchronized in specific brain regions. We measured brain activity with functional magnetic resonance imaging (fMRI) from 33 healthy participants who viewed a 10-min movie twice, assuming once a 'social' (detective) and once a 'non-social' (interior decorator) perspective to the movie events. Pearson's correlation coefficient was used to derive multisubject voxelwise similarity measures (inter-subject correlations; ISCs) of functional MRI data. We used k-nearest-neighbor and support vector machine classifiers as well as a Mantel test on the ISC matrices to reveal brain areas wherein ISC predicted the participants' current perspective. ISC was stronger in several brain regions—most robustly in the parahippocampal gyrus, posterior parietal cortex and lateral occipital cortex—when the participants viewed the movie with similar rather than different perspectives. Synchronization was not explained by differences in visual sampling of the movies, as estimated by eye gaze. We propose that synchronous brain activity across individuals adopting similar psychological perspectives could be an important neural mechanism supporting shared understanding of the environment.

Introduction

Shared understanding between people requires a certain degree of similarity in perception and interpretation of external events, both related to social situations and to physical environment. Top-down cognitive processing modes or *psychological perspectives* adopted toward external events greatly influence how we interpret the world (Moll and Meltzoff, 2011). For example, a referee calling a last-minute penalty kick in the Champions League final may be perceived as unfair and incompetent by supporters of the penalized team, while the supporters of the opposing team will praise the referee's accurate reading of the game (see, e.g., Hastorf and Cantril, 1954). In behavioral studies, sharing psychological perspectives enhances the similarity of interpretation of simple visual scenes (Kaakinen et al., 2011) and recall of expository text (Kaakinen et al., 2002, 2003) across individuals. However, the neural mechanisms supporting shared psychological perspectives across individuals have remained poorly specified.

Psychological perspective-taking involves building an internal model or schema, which helps to select task-relevant objects and events from the external world, thereby aiding the interpretation of the experienced events and the selection of appropriate actions. Accordingly, the interpretation of a scene and the corresponding brain activity go hand-in-hand. For example, activity in the fusiform face area is stronger when the ambiguous Rubin's vase–face illusion is perceived as opposing faces rather than a vase (Andrews et al., 2002; Hasson et al., 2001). Moreover, directing attention to specific objects in dynamic visual scenes shapes both brain responses to those objects and the related semantic categories (Çukur et al., 2013). Similar mechanisms may underlie directing of attention to task-relevant sensory information during psychological perspective taking. However, it remains unclear to what extent the shifts in sensitivity to various objects and features in the incoming sensory streams are shared among individuals during perception of naturalistic scenes.

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During prolonged naturalistic stimulation, such as movie viewing, brain activity becomes synchronized across individuals in the time scale of a few seconds, both in early sensory cortices and in brain areas involved in higher-order vision and attention (Hasson et al., 2004; Jääskeläinen et al., 2008; Malinen et al., 2007; Wilson et al., 2008). Such brain-region specific inter-subject synchronization of hemodynamic activity could be an important neural mechanism that supports sharing of psychological perspectives with others, as it may reflect the similarity of information processing across individuals. Recent evidence supports this notion by showing that mental action simulation increases the across-participants synchrony of brain activity in the action–observation network (Nummenmaa et al., 2014).

In the present study, we directly tested the hypothesis that sharing a psychological perspective with others enhances synchronization of brain activity across subjects, and that the degree of brain synchronization between two individuals could be used to predict the perspective they are taking. Participants viewed a 10-min movie segment twice, assuming a different psychological perspective on the two runs. We replicated the results in two experiments using independent subject populations and different functional magnetic resonance imaging (fMRI) scanners. We show that inter-subject synchronization of brain activity, particularly in the lateral occipital cortex, parahippocampal gyrus and posterior parietal cortex, allows classifying whether two participants viewed the movie from the same or different perspectives. The results thus suggest that synchronous brain activation across individuals supports shared understanding of the environment.

Material and methods

Participants

The study protocol was approved by the Ethics Committee of the Hospital District of Helsinki–Uusimaa, and each subject signed an ethics-committee-approved informed consent form prior to participation. In Experiment 1 twenty healthy volunteers (13 males, 7 females; 3 left-handed; mean age 27 years, range 21–38) participated in the experiment. One additional participant was scanned but the data were removed from the analysis due to excessive head motion (relative displacement > voxel size) during fMRI scanning. Eye-movements were recorded in a separate session outside of the scanner from independent subjects. To control for potential differences in viewing behavior inside vs. outside of the fMRI scanner and to be able to directly model the effects of subject-specific eye movements on brain activation, we ran Experiment 2 with 13 additional subjects (8 females; 1 left-handed; mean age 27 years, range 22–34) whose eye gaze was tracked during the fMRI. One additional subject was scanned but was excluded from the analyses due to misunderstanding of the instructions. None of the participants reported a history of neurological or psychiatric disease and they were not currently taking medication affecting the central nervous system.

Experimental design

The participants watched the first 10 min of an episode of the television series Desperate Housewives (Season 1, Episode 15, Cherry Alley Productions, 2005; original English soundtrack with no subtitles) twice during fMRI. All participants of the two experiments were fluent in English and understood the dialog without subtitles. In the fMRI experiment, the stimuli were delivered using the Presentation software (Neurobehavioral Systems Inc., Albany, California, USA). The video was back-projected on a semitransparent screen using a 3-micromirror data projector (Christie X3, Christie Digital Systems Ltd., Mönchengladbach, Germany), and from there via a mirror to the subject. In Experiment 2 the setup was otherwise similar except that the projector was replaced by a Panasonic PT-DZ110X projector (Panasonic Corporation, Osaka, Japan). Auditory stimulation was delivered using the UNIDES ADU2a audio system (Unides Design, Helsinki, Finland) via plastic tubes through porous EAR-tip (Etymotic Research, ER3, IL, USA) earplugs. For the last 10 subjects of Experiment 2, the auditory stimuli were delivered through Sensimetrics S14 insert earphones (Sensimetrics Corporation, Malden, Massachusetts, USA) due to equipment update at the imaging site. Sound intensity was adjusted individually to be comfortable but loud enough to be heard over the scanner noise.

Prior to watching the episode, the participants were given written instructions regarding the psychological perspective they should adopt while watching the movie for the first time (see Fig. 1A). Initially, half of the subjects were instructed to assume a 'social' perspective of a *forensic detective* whose task was to solve which one of the persons appearing in the movie was the murderer. In contrast, the other half

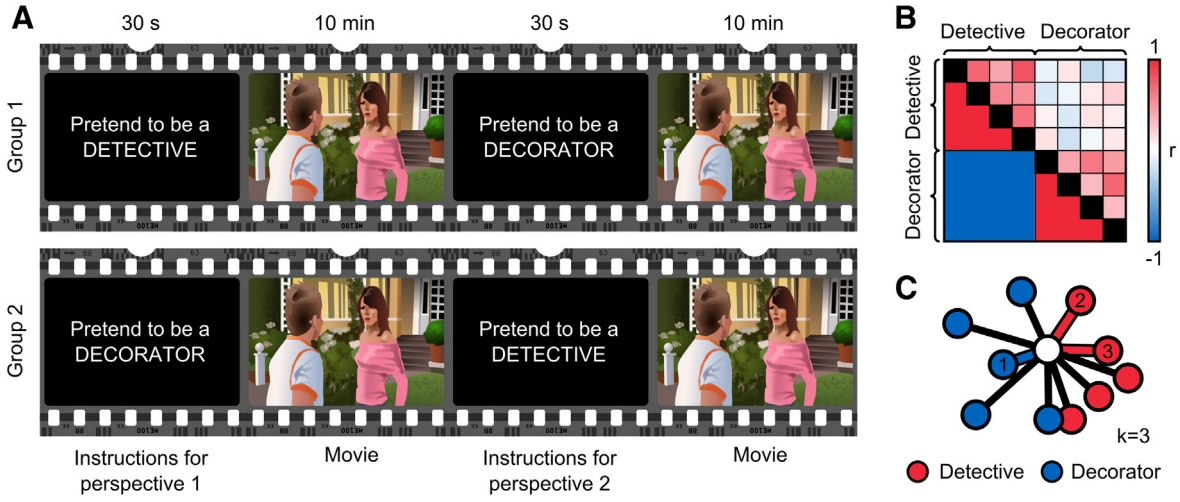

Fig. 1. Experimental design and analyses. A: Participants watched the same movie clip twice, once from the detective and another time from the interior decorator perspective, with the starting perspective counterbalanced across participants. B: Mantel test was used to compare the pairwise ISC values (upper triangle entries) to a correlation matrix template (lower triangle entries) where ISC in same-perspective pairs (red) was higher than different-perspective pairs (blue). C: Subjects were classified according to the labels of the training subjects (detective — red, decorator — blue) with whom their ISC was highest. Proximity between two dots reflects the strength of the ISC between those subjects. The nearest three neighbors are indexed according to their proximity to the current subject, and the links are highlighted with the color corresponding to their class. For k = 3 the current subject (white dot) would be classified as a detective because two of the three nearest neighbors (neighbors 2 and 3) are detectives.