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THE NEURAL CORRELATES OF THEORY OF MIND AND THEIR ROLE DURING EMPATHY AND THE GAME OF CHESS: A FUNCTIONAL MAGNETIC RESONANCE IMAGING STUDY

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Abstract—Chess involves the capacity to reason iteratively about potential intentional choices of an opponent and therefore involves high levels of explicit theory of mind [ToM] (i.e. ability to infer mental states of others) alongside clear, strategic rule-based decision-making. Functional magnetic resonance imaging was used on 12 healthy male novice chess players to identify cortical regions associated with chess, ToM and empathizing. The blood-oxygenation-level-dependent (BOLD) response for chess and empathizing tasks was extracted from each ToM region. Results showed neural overlap between ToM, chess and empathizing tasks in right-hemisphere temporo-parietal junction (TPJ) [BA40], left-hemisphere superior temporal gyrus [BA22] and posterior cingulate gyrus [BA23/31]. TPJ is suggested to underlie the capacity to reason iteratively about another's internal state in a range of tasks. Areas activated by ToM and empathy included right-hemisphere orbitofrontal cortex and bilateral middle temporal gyrus: areas that become active when there is need to inhibit one's own experience when considering the internal state of another and for visual evaluation of action rationality. Results support previous findings, that ToM recruits a neural network with each region sub-serving a supporting role depending on the nature of the task itself. In contrast, a network of cortical regions primarily located within right- and left-hemisphere medial-frontal and parietal cortex, outside the internal representational network, was selectively recruited during the chess task. We hypothesize that in our cohort of novice chess players the strategy was to employ an iterative thinking pattern which in part involved mentalizing processes and recruited core ToM-related regions.

Key words: theory of mind, chess, empathizing, temporo-parietal junction, fMRI.

INTRODUCTION

Theory of Mind (ToM), also referred to as intentionality and mentalizing (Frith and Frith, 1999; Völlm et al., 2006), is the ability to infer the intentions, beliefs or mental states of others in order to explain and predict behavior (Powell et al., 2010, 2014; Stiller and Dunbar, 2007). Neuroimaging literature suggests that ToM is associated with a distributed network of cortical regions (reviewed by Carrington and Bailey, 2009, and Lieberman, 2007). Regions most commonly reported include, medial frontal gyrus [MFG: BA8/9], inferior frontal gyrus [IFG: BA47], ventromedial and ventrolateral prefrontal cortex (PFC) [both of which partially overlap orbital PFC and include BA11], temporoparietal junction [TPJ: BA40], superior temporal sulcus [STS: BA21] and precuneus [BA7] (see Powell et al., 2014). The extent to which these different regions are involved depends on the nature of the social cognitive task being used (Lieberman, 2007; Powell et al., 2014). A 'core-network' for ToM has been proposed, which includes medial PFC (mPFC) and bilateral TPJ (Amodio and Frith, 2006; Frith and Frith, 2006; Mitchell, 2009; Schurz et al., 2014). These regions are consistently engaged whenever we reason about the mental states of others, regardless of task and stimuli (Schurz et al., 2014). Empathizing, while important for inferring the emotional states of others and for successful social interaction (Baron-Cohen et al., 2001; Baron-Cohen and Wheelwright, 2004), is different to ToM: it is the capacity to comprehend, infer, judge and share the emotional experiences of another (Gallese, 2003). Using functional magnetic resonance imaging (fMRI), Völlm et al. (2006) showed that ToM and empathy are associated with overlapping but distinct neural networks.

Knowing how another person thinks and 'thinks you think' etc. is critical to predicting behavior in strategic interaction games (Camerer et al., 2005). Iterated strategic thinking consumes working memory and requires the ability to metaphorically 'put ourselves in another player's mind' (Camerer et al., 2005). It seems then that ToM and

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Abbreviations: BOLD, blood-oxygen-level-dependent; FDR, false discover rate; fMRI, functional magnetic resonance imaging; HRF, hemodynamic response function; IMT, imposing memory task; IPL, inferior parietal lobule; PET, positron emission tomography; PFC, prefrontal cortex; ToM, theory of mind; TPJ, temporo-parietal junction.

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strategic interactions both require similar cognitive processes. However, while strategic interactions require iterative reasoning about another's mind state from a purely strategic perspective (where the potential moves are predefined and based on a set of structured rules, as is the case during strategic interactions), ToM requires iterative reasoning about another's mind state within social contexts (where rules are much less well defined, ambiguity is pervasive and decisions are based on prior experience and expectations which might be culturally and contextually embedded).

Studies exploring strategic interactions during gaming situations (e.g. the Prisoners Dilemma, Dictator and Ultimatum games) suggest that the ability to infer the mental states of one's opponent is beneficial to making the best choice (McCabe et al., 2001; Sally and Hill, 2006; Behrens et al., 2009). The game of chess involves facets of high-level cognition and problem-solving abilities (Atherton et al., 2003) and, at least in novice chess players, the capacity to reason iteratively about the potential moves of the opponent. It provides a simple environment, using chess pieces that have a finite number of moves but through which an immense number of possibilities can be generated (2^{143}, see de Groot and Gobet, 1996). Games like the prisoners' dilemma and ultimatum game have a social motive or empathizing component which occurs during a strategic interaction (for example, altruism, fairness, reciprocity, and cooperation), which is not present in the game of chess. The strategies of novice chess players differ from those employed by expert chess players. Expert chess players are thought to automatically call to memory perceptual patterns of game play (known as 'chunks') when perceiving familiar positions (Chase and Simon, 1973; Gobet, 1998) and use them for carrying out look-ahead search (Gobet, 1997), whereas novice chess players proceed only using an iterative strategic thinking pattern. This would suggest that in novice chess players there is a large degree of neural overlap when the chess players are considering potential moves on a chess board and tasks that involve assigning mental states to others (i.e. ToM-related tasks), and this is the primary aim of the present study.

To explore the underlying mechanisms of social cognition, some neurocognitive studies have used a game theory approach (e.g. King-Casas et al., 2008; Behrens et al., 2009; Tayama et al., 2012). During games that involve strategic interactions, fMRI and positron emission tomography (PET) studies show that playing humans versus computers activates ToM areas (Gallagher et al., 2002; Camerer, 2009). This suggests that strategic interactions during games that require an iterative component are not purely based on a computational task, but do require some degree of social cognition such as the understanding that the other player holds a mind state that is different from one's own. Few studies have looked at the neural correlates of chess, but those that have, show neural regions associated with chess in bilateral frontal lobes, parietal lobes and occipital lobes (Atherton et al., 2003; Campitelli et al., 2005). This study will investigate the neural network associated with ToM, using a well-established ToM task (Völlm et al., 2006) and identify whether a significant blood-oxygenation-level-dependent (BOLD) response for the processing of a chess task and empathizing task is significant within those pre-defined regions identified using the ToM task.

METHODS AND MATERIALS

Participants

Participants were 12 males, all right-handed, aged 20–58 years (mean age = 36.42yrs, SD = 13.91yrs). All are chess players with different levels of experience, who know the rules of chess and have at some point belonged to a chess club. Years playing chess ranged from 4 to 48 years (mean years playing chess = 26.33yrs, SD = 13.75yrs). Participants learned to play chess between 6 and 17 years of age (mean age learned to play chess = 10.17yrs, SD = 3.22yrs). Intensity of play refers to the frequency of chess play. For the individual to qualify as having played chess with intense periods of play, they must have played regularly at a chess club for a period of 6 months and report playing the game at least three times a week. Participants were recruited from University of Liverpool and Merseyside Chess clubs. All participants gave signed informed consent, and the study had the approval of the local research ethics committee.

Neuropsychological protocol

Participants completed an imposing memory task (IMT) used previously (Lewis et al., 2011; Powell et al., 2010, 2012a, 2014). The IMT provides a measure of the individuals' ability to infer the mental states of others. The task involves reading five short stories twice, each approximately 200 words in length. Stories depict a social situation (e.g. an employee trying to decipher, from a work colleague, whether a different colleague might be interested in him). Following each story, the participant answers a set of 20 true/false questions containing an equal number of intentionality questions and factual (short-term memory) questions to distinguish between intentionality capacity and ability to remember factual information. Intentionality questions require complex mentalizing about a character's perspective within a social situation. The questions vary in complexity and require the individual to represent the mind states of others, up to and including level six intentionality and short-term memory. Further details of the IMT, including an example story and questions, as well as the equation for calculating intentionality and short-term memory scores, are provided in Powell et al. (2014).

fMRI activation tasks

Participants completed three experimental tasks in the scanner: a Theory of Mind (ToM) task, an empathizing task and a chess task. Task stimuli were presented using 'Presentation' software (https://nbs.neuro-bs.com). All stimuli were presented in blocks. The ToM task and empathizing task have been used previously (Brunet et al., 2000; Völlm et al., 2006). With these two tasks, the participant is first presented with a short comic strip consisting of three images. A further two images are then