The internal-external dichotomy of social working memory: Evidences from distinct neural correlates and functional roles

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Abstract:

Social working memory (SWM)—the ability to maintain and manipulate social information—plays a crucial role in social interactions. Despite its importance, research on SWM is still in its infancy, and previous researchers perceive SWM as a homogeneous construct. Based on the internal-external dichotomy of social cognition, SWM can be conceptualized as two relatively autonomous components: externally oriented SWM (e-SWM) and internally oriented SWM (i-SWM). The present study examined this view by investigating the neural correlates of the two SWM components and further explored their functional roles in social abilities focusing on empathy. Univariate fMRI analyses revealed greater activation in the left postcentral and right precentral gyri during e-SWM task, whereas the i-SWM task showed greater activation in the precuneus/posterior cingulate cortex and superior frontal gyrus. Moreover, dorsal medial prefrontal cortex exhibits distinct activation patterns for the two SWM tasks. Finally, partial least squares analyses suggested that e-SWM brain activity mainly correlates with affective empathy, while i-SWM brain activity mainly correlates with cognitive empathy. These findings provide novel data on distinguishable neural and behavioral correlates of e-SWM and i-SWM, supporting the external-internal dichotomy of SWM.

Keywords: social working memory; neural substrates; empathy

Introduction

The ability to maintain and manipulate social information, encompassing personal identities, mental states, and traits (Meyer et al., 2012), is known as social working memory (SWM). Despite its crucial role in daily social interactions, SWM remains a nascent field of research with the intrinsic structure of SWM uncharted. Drawing on Lieberman's (2007) internal-external dichotomy of social cognition, SWM can be divided into two distinct components: externally oriented SWM (e-SWM) and internally oriented SWM (i-SWM). e-SWM involves the processing of external, physical, and visual social information in WM, including actions and facial expressions. Meanwhile, i-SWM focuses on internal and mental social information in WM, such as personality traits, emotional experiences, mental states, and interpersonal relationships. To date, no studies have investigated this dichotomy of SWM using a unified paradigm and stimulus set. The present study aims to address this gap by employing both univariate and multivariate neural analyses to explore the neural correlates of e-SWM and i-SWM. Additionally, we seek to investigate whether e-SWM and i-SWM exhibit distinct functional roles in key social abilities, with a particular focus on empathy.

Methods and Results

A modified ranking WM task (Figure 1A) was employed to assess e-SWM, i-SWM, and cognitive working memory (CWM, as baseline) using a block design. In this task, participants (N=35) were asked to memorize two or four facial images depended on load conditions and mentally rank the characters according to specific instruction words that varied across WM conditions (e-SWM: adjectives related to facial expressions; i-SWM: adjectives related to personal traits; CWM: characters' names) while undergoing a 3T fMRI scan.

An empathic accuracy task (EAT; Jospe et al., 2020; Zaki et al., 2008; see Figure 1B) was used to measure individuals' state empathy (N=30, five participants were excluded due to poor quality of physiological data). Participants watched videos where targets narrated stories, and participants continuously inferred the targets' feelings. Meanwhile, the participants' electrocardiogram signals were collected. Empathic accuracy (EA), the correlation between participants' inferences and the targets' feelings, served as an indicator of state cognitive empathy. Heart rate synchrony (HRS), indicating the correlation between participants' and the targets' heart rates, served as an indicator of state affective empathy. The Interpersonal Reactivity Index (IRI) questionnaire, comprising four subscales (perspective-taking, fantasy, empathic concern, and personal distress), was used to assess participants' trait empathy. Specifically, the perspective-taking subscale captures trait cognitive empathy, while the other three subscales encompass trait affective empathy.

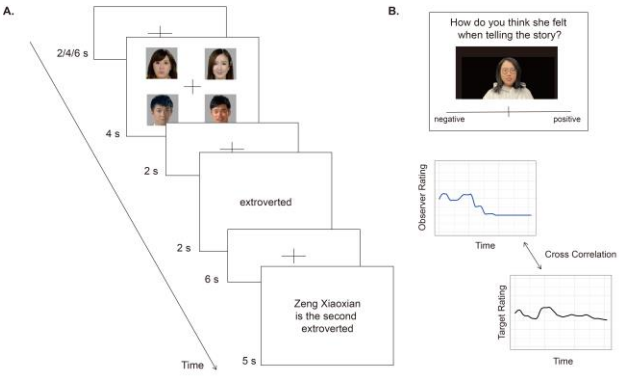

Figure 1. illustrations of the e-SWM condition in SWM task (A) and of the empathic accuracy task (B).

Dissociable brain activations involved in e-SWM and i-SWM

Both e-SWM and i-SWM exhibited parametric increases in the dorsal medial prefrontal cortex (DMPFC), bilateral inferior frontal gyrus (IFG), and middle temporal gyrus (MTG) along with the WM load,

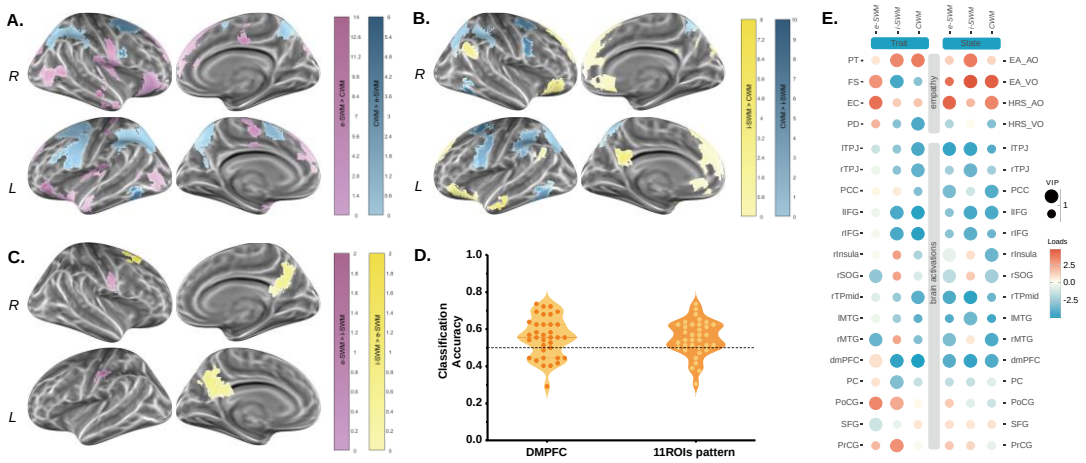

Figure 2. (A). the contrast between e-SWM and CWM. (B). the contrast between i-SWM and CWM. (C). the contrast between e-SWM and i-SWM. (D). the accuracy of the multivoxel pattern analysis. (E). the results of partial least squares analyses.

indicating common activation within the default mode network. Different areas emerged when contrasting the two components of SWM with CWM. In e-SWM, greater activations were observed in regions involved in processing visual, motor, and emotional information, including the bilateral insula, supplementary motor area (SMA), and postcentral gyrus(PoCG) (Figure 2A). Conversely, i-SWM showed significant increases in activation in typical mentalizing regions, such as the bilateral temporoparietal junction (TPJ) and precuneus/posterior cingulate cortex (PC/PCC) (Figure 2B). Contrasting the load effects in e-SWM and i-SWM revealed that the left PoCG and right precentral gyrus exhibited greater activation with increasing e-SWM load, while activation in the PC/PCC and superior frontal gyrus (SFG) increased with increasing i-SWM load (Figure 2C). These regions were functionally corresponding to the two components of social information processing.

To further investigate the neural patterns, we conducted a multivoxel pattern analysis using 11 regions of interest (ROIs) derived from the contrast between SWM and CWM. Among these ROIs, only DMPFC exhibited a distinguishable activation pattern between the e-SWM and i-SWM conditions (Figure 2D left). Additionally, we combined the mean activation intensities of each of the 11 ROIs to create a pattern representing multiple SWM-related ROIs, and found that the combined pattern was distinct between the two SWM tasks (Figure 2D right). These findings provide direct evidences of distinct brain regions involved in the two components of SWM.

Distinguishable relationship of e-SWM and i-SWM with social ability

We conducted two sets of partial least squares analyses to investigate the brain-behavioral associations between WM-related brain activation and the two empathy components (i.e., cognitive and affective empathy) in two empathy domains (i.e., state empathy and trait empathy) by focusing on the variable importance in projection. Regarding state empathy, HRS showed most contribution to the relationship with e-SWM-related activation, while both EA and HRS mostly contributed to the association with i-SWM-related activation (see Figure 2E right). In terms of trait empathy, the scores of the empathic concern and fantasy subscales showed most contribution to the relationship with e-SWM-related activation, while the scores of the fantasy and perspective-taking subscales mostly contributed to the association with i-SWM-related activation (see Figure 2E left). Together, these findings suggest distinct relationships between empathy for the two SWM components. Specifically, e-SWM brain activity was mainly correlated with individual differences in affective empathy, while i-SWM brain activity was mainly correlated with cognitive empathy.

Conclusion

This study examined, for the first time, the external-internal structure of SWM by showing the distinct neural activations of the two SWM components and their unique relationships with individuals' social performance in empathy. we provide valuable evidence supporting the feasibility of the external-internal dichotomy in fundamental social cognitive abilities, and thus offers a clearer perspective on the field of SWM.

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