Neural Basis of Working Memory for Social Interactions

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Abstract:

Understanding the social interactions of others is vital for an individual's social adaptation. While the neural basis of observing social interactions has been extensively studied, the memory mechanisms involved remain less understood. This study aims to explore the neural mechanisms of working memory for social interactions employing fMRI experiments. We analyzed neural activity during both the encoding and maintenance periods, comparing responses to interactive versus non-interactive actions. Our findings revealed that during the encoding period, social interactions activate the broad person perception network, mirror network, and mentalizing network, consistent with prior studies on perception. In the maintenance period, activation was predominantly observed in less specific brain regions such as the superior temporal gyrus, supplementary motor area, and basal ganglia. Significantly, the putamen, a part of the basal ganglia, seems to play a crucial role in maintaining social interactions within working memory.

Keywords: social interaction; working memory; fMRI; univariate analyses; multivariate pattern analysis

Instruction

Humans, as inherently social creatures, need to perceive and remember social interactions of others to thrive in society. Research has consistently shown that the human brain is remarkably adept at interpreting these interactions (McMahon & Isik, 2023). Observing social interactions activates specific neural networks, notably the person perception network, mirror network, and the mentalizing network (Arioli & Canessa, 2019; Quadflieg & Koldewyn, 2017), among which the superior temporal sulcus (pSTS) plays a crucial role. On the other hand, researchers have noted that working memory (WM) of social interactions is essential for navigating social behavior as it offers the necessary priors for interpreting others' minds. However, the neural foundations of memorizing social interactions remains largely unknown.

The present study explores the neural mechanisms underlying WM for social interactions. We employed fMRI to measure neural activity in participants while they were memorizing social interactions. Initially, we contrasted neural responses to interactive versus non-interactive actions during both the encoding and maintenance periods. We also utilized classifiers to detect potential differences in activity patterns associated with interactive and non-interactive actions. Lastly, we examined the correlation between the intensity of neural activity and behavioral performance to identify the critical nodes supporting WM for social interactions.

Method

Participants (N=30) were tasked with retaining two pairs of either interactive or non-interactive actions in their working memory (Figure 1). Each trial began with a white fixation cross displayed for 1s to alert participants of the upcoming memory task. Following this, the memory array appeared for 3s. After another fixation cross appeared for 8s, during which participants had to retain the actions. Subsequently, a single action probe was displayed and participants determine whether the action was in the memory array and respond by pressing the corresponding button within 3s.

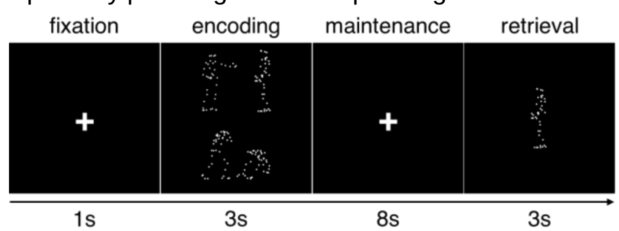

Figure 1. An example trial in experiment

We utilized dynamic point light displays (PLDs) to represent social interactions. From the Motion Capture Database (http://mocap.cs.cmu.edu), we selected seven pairs of interactive actions, including beating, conversing, dashing, dancing, quarreling, drinking, and talking. Prior research has validated these PLDs as effective stimuli for depicting social interactions (Ding et al., 2017). The experiment contained two types of memory arrays: interactive and non-interactive. The non-interactive actions were constructed as mismatched interactive pairs that conveyed minimal interactive information.

Functional imaging data was recorded on a 3-T Siemens Prisma MRI Scanners. All imaging data were preprocessed using DPABI (Yan et al., 2016). Preprocessing steps included the removal of the first 8 volumes, slice-timing, head motion correction, normalization, and smoothing. We performed univariate analyses and multivariate pattern analysis (MVPA) for the imaging preprocessed data. For the univariate analyses, the data were modeled as an event-related design in a general linear model (GLM) framework, employing SPM12. For the MVPA, the decoding was performed on beta weights employing support vector machine classifiers, using CoSMoMVPA (Oosterhof et al., 2016). We also calculated the Pearson correlation between neural activity and behavioral performance.

Results

Behavioral performance

The WM capacity for actions (Figure 2) was estimated employing Cowan's formula (Cowan et al, 2014): $K = S \times (H - F)/H$, where K is WM capacity, S is the number of displayed action stimuli, H is the hit rate that refers to the successful detection of a new BM, and F is the false alarm rate that refers to an incorrect new action response. The WM capacity was 2.60 (SD = 0.87) and 1.90 (SD = 0.88) under the interactive and non-interactive conditions, respectively. A paired t-test revealed that the accuracy for interactive action was significantly higher than that for non-interactive action, [$t(29) = 3.39$, $p = 0.002$, Cohen's $d = 0.62$].

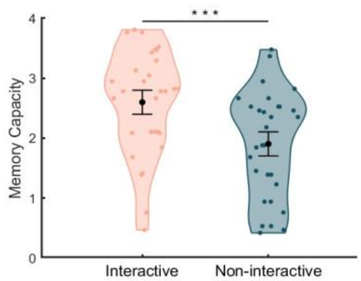

Figure 2. Working memory capacity for actions.

Brain regions involved in encoding and maintaining social interactions

The whole-brain analysis with contrast of interactive verses non-interactive conditions revealed a significant difference in activity. During the encoding period, certain areas of the mirror neuron system, mentalizing network showed stronger activation for interactive actions, including bilateral inferior frontal gyrus (IFG), superior frontal gyrus (SFG), inferior parietal lobule (IPL), insula, and superior temporal sulcus (STS). During the maintenance period, the activation was confined to superior temporal gyrus (STG), supplementary motor area (SMA), and basal ganglia (BG). The searchlight analysis using MVPA demonstrated revealed that the activity patterns in the occipital lobe during the encoding period effectively distinguished between the two types of actions. The aforementioned networks also exhibited some ability to discriminate between these actions, although their capacity is relatively limited.

The differences in activation (interactive minus non-interactive) in the right basal ganglia (BG) during the maintenance period predicted the enhancement effect in behavioral performance. However, no activation differences in any ROI during the encoding period were found to correlate with enhancement in behavioral performance.

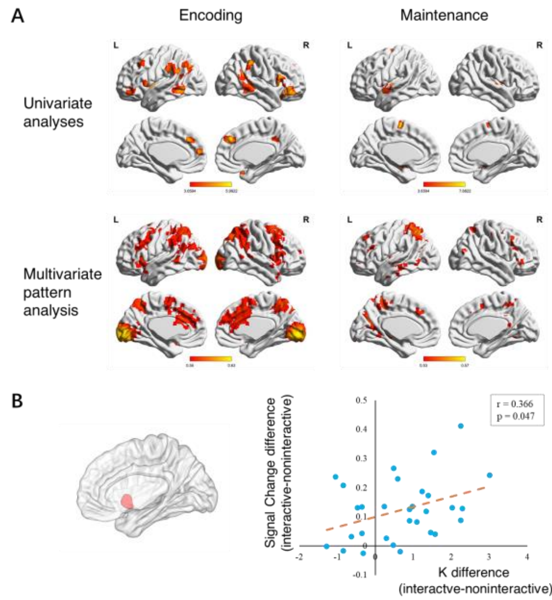

Figure 3. (A) Brain regions involved in encoding and maintaining interactions. (B) The correlation between right basal ganglia activity and working memory capacity.

Discussion

Combining behavioral and fMRI data, we discovered that the WM performance for interactive actions exceeded that for non-interactive actions, and this enhancement may be attributed to the stronger activation of multiple brain networks during both the encoding and maintenance periods. During the encoding period, the involved brain regions are similar to those identified in previous perceptual studies. In contrast, during the maintenance period, there are fewer brain regions specifically activated by interactive actions, notably only the STG, STS and SMA. Recent research by Lee Masson et al. (2024) also pinpointed the STS as a critical node that supports both the perception and recall of social interactions.

Our findings indicate that the brain regions engaged in encoding and maintaining social interactions do not completely overlap. In particular, the BG are critical for maintaining social interactions in WM, yet they play a minimal role during the encoding period. Intriguingly, Interestingly, research involving macaques has demonstrated activation of the BG when observing social interactions (Sliwa et al., 2017). We propose that the BG may be pivotal in the deeper processing of social interactions and could also be significant for other types of social computation.

Acknowledgments

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