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***Review Article***


# Neural Correlates of Mental State Attribution a Scoping Review

Bansal Nupur M[1], Karna Ayushi[2], Emmanuel Gerri Satvik E[3] and Bapu Vigraanth KG

**ABSTRACT**

The paper is a scoping review of Neural Correlates of Mental State Attribution, which explains social cognition, neural correlates, mental state attribution along with the theory of mind. Initially 15 papers were identified and then finally 5 were selected after a screening process. The results of these 5 studies suggest that social cognition and mental state attribution are intricate cognitive processes that engage numerous neural circuits and brain regions. Social cognition refers to the cognitive processes involved in understanding and responding to social information, whereas mental state attribution involves inferring the mental states of others, such as beliefs, desires, and intentions. The ability to infer the mental states of others is linked to increased activity in the medial prefrontal cortex and the temporal-parietal junction, which are responsible for self-referential processing and social perception, respectively. Empathy, on the other hand, is associated with increased activity in the anterior cingulate cortex and the insula, which regulate emotions and interception. Attributing causes to oneself or others activates different brain regions, including the medial prefrontal cortex, precuneus, superior temporal sulcus, and inferior parietal lobule, depending on the target of attribution. Finally, the studies indicate that damage to certain brain regions, such as the ventromedial prefrontal cortex and the superior temporal sulcus, can impair social cognition and mental state attribution, with potential implications for treating social deficits in clinical populations.

**Key Words:** *Prefrontal Cortex, Social perception, Neural Correlates, Mental State Attribution, Temporal Sulcus, Parietal Lobule*

### *Social Cognition*

According to the American Psychological Association (A.P.A,n.d.), "Cognition in which people perceive, think about, interpret, categorize, and judge their own social behaviors and those of others." is social cognition.

Social cognition is the study of how people process, store, and apply information about other people and social situations. It involves understanding how people think about, perceive, interpret, and respond to social information, including the thoughts, feelings, and behaviors of other people.

### *Mental State Attribution*

"Mental State Attribution" has been introduced to describe the cognitive capacity to reflect upon one's own and other persons' mental states such as beliefs, desires, feelings and intentions. Mental state attribution is part of the broader concept of "social cognition" that involves the perception, processing and interpretation of social signals (Adolphs, 2001).

In cognitive neuroscience, mental state refers to the current cognitive and emotional state of an individual, which can be assessed through a variety of measures such as brain activity, behavior, and self-report. Mental states can include a wide range of cognitive processes, such as attention, perception, memory, language, decision-making, and problem-solving. These processes are associated with different neural networks in the brain, and cognitive neuroscience seeks to understand how these networks are organized and how they interact to support mental processes.

Theory of mind (ToM), a phrase created by David Premack and Guy Woodruff of the University of Pennsylvania in 1978, is the capacity to attribute mental experiences to oneself and to others (independent of the processes involved). It is a crucial aspect of social cognition, which refers to the ability to understand and interpret other people's mental states, including beliefs, intentions, and desires. This ability allows us to navigate complex social situations, anticipate others' behavior, and communicate effectively. ToM development typically begins around age 2-3 and continues to develop throughout childhood and adolescence. Researchers have identified various milestones in ToM development, such as the understanding of false beliefs (i.e. the recognition that someone can hold a belief that is not true), which typically emerges around age 4. Theory of mind is basically understood from two major theoretical frameworks which is Simulation Theory and Theory-Theory. According to experience sharing theory (also known as simulation theory), our capacity to copy, or unintentionally duplicate, other people's activities like facial expressions and eye contact, can help us infer some aspects of what they are thinking.

[1] PG Scholar, PG Programme Department of Psychology, Kristu Jayanti College (Autonomous), Bengaluru, India
[2] PG Scholar, PG Programme Department of Psychology, Kristu Jayanti College (Autonomous), Bengaluru, India
[3] PG Scholar, PG Programme Department of Psychology, Kristu Jayanti College (Autonomous), Bengaluru, India
[4] Assistant Professor and PG Programme Department of Psychology, Kristu Jayanti College (Autonomous), Bengaluru, India

There are occasions when mental states diverge from their external clues. There are several occasions where people conceal their genuine feelings and ideas in daily life. Our capacity to spot the discrepancy between outward behavior and inner intents is helpful for identifying persons who shouldn't be trusted in more severe situations. This is what Theory-Theory explains.

The neural basis of ToM has been extensively studied using various neuroimaging techniques, such as functional magnetic resonance imaging (fMRI) and electroencephalography (EEG). Studies have found that ToM involves a network of brain regions, including the prefrontal cortex, the temporal lobes, and the superior temporal sulcus, among others. Furthermore, research suggests that various factors can influence ToM development, including genetics, early social experiences, and cognitive abilities.

Studying the mental states in cognitive neuroscience involves using a range of techniques such as neuroimaging (e.g., fMRI, EEG), behavioral experiments, and computational modeling to investigate how the brain processes information and generates mental states.

It is very important to understand the neural basis of mental states as it provides insights into the underlying mechanisms of cognition and emotion, as well as inform the development of interventions for mental health disorders.

Overall, understanding the neural basis and development of ToM and Mental State attribution is essential for gaining insight into the cognitive processes underlying social interaction and communication. This paper's aim is to find research studies related to Neural Correlates of Mental State Attribution and get a clear picture of the brain areas involved.

## METHODOLOGY

### *Literature Search and Criteria for Paper Selection*

A review of literature was conducted using the methodology framework developed by Arksey and O'Malley (2005), which was further improved by Levac et al. (2010). This framework consists of five stages, which involve identifying research questions, selecting relevant studies, choosing studies, organizing data, and summarizing and reporting the findings.

Initially, we scrutinized various studies by analyzing their titles, abstracts, and keywords that were relevant to our research. During this initial stage, we identified a group of keywords, including "cognitive neuroscience," "theory of mind," "social cognition," "mental state attribution," "neuroimaging techniques," "neural correlates," and "scans." Subsequently, we developed additional keywords by examining the titles, abstracts, and keywords of studies found during the first search phase. This iterative process led us to include keywords such as "MRI," "fMRI," "PET," and "CT" in our search strategy. Finally, we created the following search string to address the variables proposed in our research questions, specifically Cognition, Neuroimaging techniques, and Mental State Attribution

"Theory of Mind and Neural Correlates", "Mental State attribution and imagine techniques", "Neural correlates of mental state attribution", "Social Cognition and Neuroimaging techniques".

Research and articles were gathered from different online journals and sites such as "PubMed" "NCBI", "Science Direct", "Google Scholar", "Online Wiley Library", "Oxford University Press" and etc.

### *Inclusion and Exclusion Criteria*

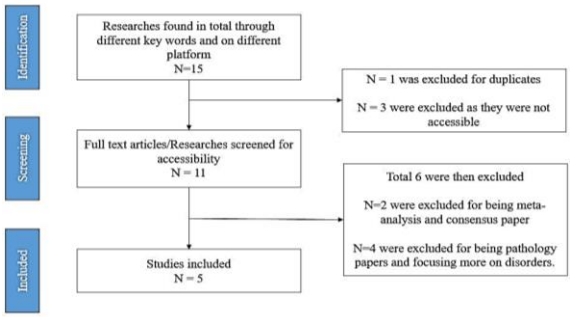
The authors of this paper conducted all the screening stages and resolved discrepancies and citations that partially met the criteria by reaching a consensus. This is because member checking is a well-recognized method for establishing "trustworthiness" in scoping review. The inclusion criteria is as followed:

- Studies related to cognitive neuroscience and mental state attribution only
- Hhad neuroimaging techniques as neural correlate was the main focus
- Studies shall be published in the last 10 years and not before that
- It should be an experimental study or the data collection method should be primary data collection.

### *Researchers found and screened*

Figure 1 summarizes the screening procedure followed where the aforementioned inclusion and exclusion criteria were applied in order to select the key studies. Total of 15 studies were identified from different platforms as mentioned above. Out of which 1 one excluded as it was the same as another study, and then 3 were excluded as they were not accessible and free full access wasn't available. Later 2 were excluded as they were not first hand data collected but rather a meta analysis or was a consensus paper which is a document that reflects the collective agreement or viewpoint of a group of experts or stakeholders on a specific topic which wasn't needed for our paper. 4 more papers were excluded in the screening process as they focused more on pathology in relation to mental state attribution which can be a further scope of study but our paper only aims to focus on the Neural correlates of Mental State attribution.

**Figure 1:** *Screening Procedure of Journals/Articles*




## RESULTS AND DISCUSSION

**Table 1:** *Results of all five researches.*

| Brain Area | Function | Study |
|---|---|---|
| Medial Prefrontal cortex | Attributing causes to self | Kestemont, Baetens, Van Overwalle *et.al* (2015) |
| temporo-parietal junction | Attributing causes to other | |
| Inferior Parietal lobule | Attributing causes to situation | |
| Medial prefrontal cortex | Mental state attribution | Cohen-Zimerman, Khilwani, *et.al* (2021) |
| temporo-parietal junction | | |
| Medial Prefrontal cortex | ability to infer the mental states of others | Birgit Vollm al (2006) |
| The temporal-parietal junction | | |
| anterior cingulate cortex and the insula. | Empathy | |
| Medial prefrontal cortex, temporoparietal junction, and precuneus | Theory of mind | Sarah Carrington & Anthony J Bailey (2009) |
| Temporal pole MPFC | Naturalistic social interactions & social cognitions | L. Deuse et al (2016) |

Reviewing all the 5 studies shows that medial prefrontal cortex (MPFC) is one of the most common brain areas involved in mental state attribution. In the study by Kestemont, Baetens, Van Overwalle *et.al* (2015) on "*Neural correlates of attributing causes to the self, another person and the situation*" they found MPFC to show increased activity while attributing causes to oneself. In another study by Cohen-Zimerman, Khilwani, *et.al* (2021) on "*the neural basis for mental state attribution"* also suggests network of brain regions, including the medial prefrontal cortex is involved in mental state attribution, and that this network was modulated by the complexity of the social situation being perceived. *"Neuronal correlates of theory of mind and empathy: a functional magnetic resonance imaging study in a nonverbal task"* by Birgit Vollm et al (2006) also suggests that the ability to infer the mental states of others is regulated by the medial prefrontal cortex. It is also seen that MPFC was constantly active during ToM tasks and during naturalistic social interactions as seen in the studies by Sarah Carrington & Anthony J Bailey (2009) and L. Deuse et al (2016) respectively.

Another major brain region found is the temporo-parietal junction. Kestemont, Baetens, Van Overwalle *et.al* (2015) found this region to be active when attributing causes to others while Cohen-Zimerman, Khilwani, *et.al* (2021) found it to be associated with mental state attribution.

Birgit Vollm et al (2006) also found temporo-parietal junctions to be associated with the ability to infer the mental states of others and even the study by Sarah Carrington & Anthony J Bailey (2009) found this area to be associated with the theory of mind tasks. L. Deuse et al (2016)'s study also found naturalistic social interaction and social cognition to be associated with the temporal pole.

Kestemont, Baetens, Van Overwalle *et.al* (2015)'s study also found Inferior Parietal lobule to be an important brain area of mental states and is associated with attributing causes to situation. The study by Birgit Vollm et al (2006) also found anterior cingulate cortex and the insula to be associated with empathy while attributing others' mental states. Lastly, precuneus was also found to be a brain associated with theory of mind.

## CONCLUSION

Overall these studies suggest that social cognition and mental state attribution are complex cognitive processes that involve multiple neural circuits and regions of the brain. Social cognition refers to the mental processes involved in perceiving, interpreting, and responding to social information, such as facial expressions, vocal tones, and body language. Mental state attribution, on the other hand, refers to the ability to infer the mental states of others, such as beliefs, desires, and intentions.

The studies indicate that the ability to infer the mental states of others is associated with increased activity in the medial prefrontal cortex and the temporal-parietal junction. The medial prefrontal cortex is involved in self-referential processing, which may help individuals understand and predict the mental states of others by using their own mental states as a reference point. The temporal-parietal junction is involved in social perception and may help individuals integrate social cues and contextual information to infer the mental states of others.

The studies also suggest that empathy, which refers to the ability to share and understand the emotions of others, is associated with increased activity in the anterior cingulate cortex and the insula. The anterior cingulate cortex is involved in emotional regulation and

conflict monitoring, which may help individuals regulate their own emotional responses and empathize with the emotional experiences of others. The insula is involved in interoception, which refers to the perception of internal bodily states, and may help individuals simulate the emotional experiences of others.

The studies further suggest that attributing causes to oneself or others is associated with activation in the medial prefrontal cortex, precuneus, superior temporal sulcus, and inferior parietal lobule, depending on the target of attribution. The medial prefrontal cortex and the precuneus are involved in self-referential processing and may help individuals attribute causes to themselves. The superior temporal sulcus and the inferior parietal lobule are involved in social cognition and may help individuals attribute causes to others by processing social cues and contextual information.

Finally, the studies indicate that damage to certain brain regions, such as the ventromedial prefrontal cortex and the superior temporal sulcus, can impair mental state attribution and social cognition.

## IMPLICATIONS

These findings may have implications for understanding and treating social deficits in clinical populations, such as individuals with autism spectrum disorder, schizophrenia, or traumatic brain injury. By identifying the neural circuits and regions of the brain involved in social cognition and mental state attribution, the studies provide important insights into the neural basis of social interactions and may help develop more targeted interventions for social deficits.

## LIMITATIONS

We have also found a few common limitations of all 5 studies mentioned above and these limitations include Relatively small sample sizes, Potential confounding effects of task difficulty, Limitations of neuroimaging techniques, including low temporal resolution, potential for artifacts, and reliance on blood-oxygen-level-dependent (BOLD) signals, Use of nonverbal stimuli or simplified tasks that may not fully capture the complexity of social cognition, Heterogeneity of studies, including variability in ToM tasks and limited clinical populations studied, and Publication bias and lack of consensus on specific brain regions involved in ToM and empathy processing.

However it is worth noting that these limitations are common across many studies in the field of cognitive neuroscience, and researchers are constantly working to address and overcome them in order to further our understanding of the neural basis of complex cognitive processes like social cognition and empathy.

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