Theory of Mind: Varying Substrates of Social Cognition

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Abstract

In the paper, we firstly provide insight into implicit social brain from multidisciplinary perspective, containing views of psychology, neural substrates and methods of clinical measurement. On the grounds, we outline philosophical consequences. We assess that implicit social brain realization can be as conscious, as unconscious.

Secondly, we focus on a possible altered[1] execution of particular tasks of theory of mind (ToM) in people with autism spectrum disorders (ASD) and Asperger syndrome in particular[2]. Referring to this, we aim to exalt the spectrum of varying possibilities of the cognitive representation of ToM with respect to neurotype.

Finally, we suggest two novel analysis components for effective evaluation of ToM testing tasks, possibly helping us distinguish between particular points within the spectrum of its potential cognitive representations.

1 Definition

Before we expostulate on theory of mind, we stress out the fact that such concept is in literal *a theory*, because we are inquiring into something, that is not directly observable, that is mental states of oneself. By these, we understand for instance intention, knowledge, liking, guessing, pretending, etc. The system inquiring for them as such is important as it can be used to make prediction of behavior of others.

By definition, an individual is said to have a theory of mind if he imputes mental states to himself and others (Premack et al., 1978).

2 Why is it important?

Consider following proposition:

"By means of the theory of mind, one is able to be making instant and continuous assumptions of other people's attitude during interaction,"

and exempt the core principle out of it formally.

[1] with respect to neurotypical expectation

[2] we treat Asperger syndrome as a discrete diagnostic category according to DSM-IV

Suppose we have a group $\mathcal{G}$ of people such that for every person is true that either he or she is a part of the group $\mathcal{G}$, or he or she is not a part of the group $\mathcal{G}$. Name singular components (persons) of this group $\mathcal{P}_i$. Denote $st(\mathcal{P}_i)$ an attribute of mental state of a person $\mathcal{P}_i$. Notice people are dependent upon mental states of each other. Therefore, $\forall i \in \{1, ..., k\}$:

$$st(\mathcal{P}_i) = f(st(\mathcal{P}_1), ..., st(\mathcal{P}_k)). \quad (1)$$

Without attempting to prove, we pronounce following statement.

Statement. Regarding the **group** $G(\mathcal{P}_1, \ldots, \mathcal{P}_k)$ of people instead of merely the bunch of individuals $\mathcal{P}_1, \ldots, \mathcal{P}_k$ of the group, to be working effectively both from the internal perspective (group sustainability) and external perspective (inter-group interactions), it is a necessary condition for the singular people $\mathcal{P}_i$, to have an information of the state of each other, denote $inf(\mathcal{P}_i)$, and if this is not met by default, then to be able to communicate it somehow fluently.

Examples of such principle might be seen in collective adaptation, self-organized construction of social hierarchy or the very origination of intuitive universal languages, as are for example non-verbal communication or art. Charm of this might be seen in the fact that individuals of a community can be represented as nodes of an interconnected system (interconnected by assigning mental states to all of the other individuals), that is subject to changes as a whole network.

As we see that a significant fraction of social phenomena is unconscious (Bacha, 2017), then we can infer that to make above mentioned principles based on **default communication of mental states** between individuals of a community performable, theory of mind is necessary, as it is a tool for that spreading of unconsciously generated information about mental states between its individuals.

3 A (conscious) spick of autism

Ability to spread information unconsciously does not have to be fully present in every individual. It is widely discussed that people with autism spectrum disorders, including Asperger syndrome, show some impairments in ToM (Duverger et al., 2007). Despite of this, there is

empirical evidence that people with Asperger syndrome on the highly functional[3] end still can perform well in ToM tasks, and the explanation for this lies in the *conscious* compensatory learning (Senju et al., 2009).

4 Neural substrates

Assume that there is no impairment in ToM functioning in neurotypical people. According to PET and fMRI neuroimaging studies reviewed by Leblanc (2020) we see that ToM is a very complex cognitive function, if even we could be talking about it as about a *single* function.

The core lies in that it is not localized to a single critical region, rather it involves activity in multiple brain regions. Particularly, there was established a suggestion (Leblanc et al,. 2020) that the primate social brain is comprised of the "core" regions of orbitofrontal cortex (OFC), superior temporal sulcus (STS) and temporoparietal junction (TPJ) (Fig. 1, 2).

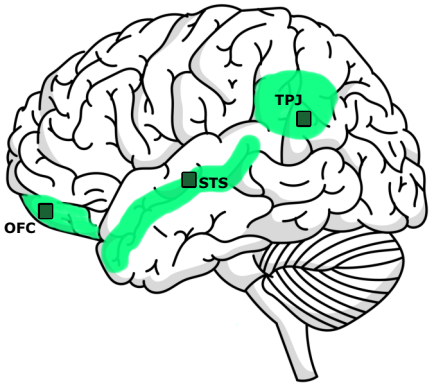

Fig. 1: "core" regions of social brain (lateral view)

Though that some brain regions can be labeled as the most involved, there is still remaining a plurality of constituents undergoing ToM. Also is important to mention explicitly that different ToM tasks activate slightly different brain regions. Moreover, there is not necessarily activated amygdala in every ToM task (Leblanc et al., 2020), out of which we conclude that the role of ToM in navigating social behavior is rather cognitive than affective.

Broadly we make a conclusion that ToM is represented by a specific pattern of communication within a network of interconnected regions, and it is exactly the character of this pattern just as well as the particular network what we are assigning informativeness in regard of observing neural substrates of ToM.

[3]with regard to clinical perspective

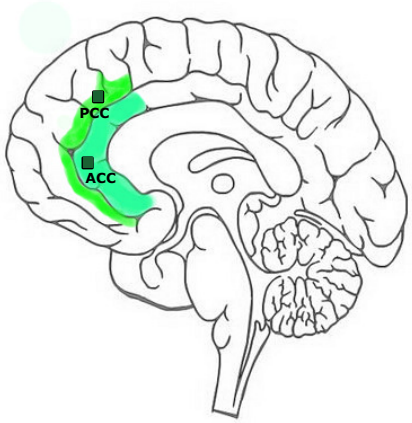

Fig. 2: "core" regions of social brain (sagittal view)

5 Neural substrates in adults with ASD

As mentioned in section (3), ToM mechanism can be also altered, which is particularly a case of people with Asperger syndrome[4]. A recent fMRI study of social animation task performed on 24 people with clinical diagnosis of ASD vs. 24 controls (Chen et al., 2023) suggested that both groups were involved in ToM mechanisms and recruited some shared brain regions during ToM processing (Fig.3),

however there were found additional activations of the middle frontal gyrus (MFG), right superior temporal gyrus (STG) and precuneus in people with ASD (Fig.4).

On the contrary, in control group, there were found additional activations in the left precentral gyrus and right insula (Fig.5).

Both precentral gyrus and right insula have been seen to be the key regions in the *Social Neural Network* (SNN) as well as the human *Mirror Neuron System* (MNS). The precentral gyrus involves the initial step for inferring intentions underlying actions (Gesi et al., 2021). Additionally, the activation of the insula has usually been considered part of the SNN and as a key role in decision making, empathy, and a functional role of social awareness (Hof et al., 2013).

Moreover, as we find concluded by Chen (2023), greater activation of the network of brain regions in ASD group may be attributed to **more effortful processing for adequate task performance**. Particularly on the case of mentalizing, the finding of a positive correlation between greater activation in the right STG and a higher score of the Autism Diagnostic Interview-Revised (ADI-R) in individuals' clinical diagnoses strongly suggests that the poorer the social communication performance in adults with ASD, the more activation in the STG part of their brain. The cor-

[4]in cited study, Chen et al. recruited ASD in general with regard to Diagnostic and statistical manual of mental disorders V (DSM-V®)

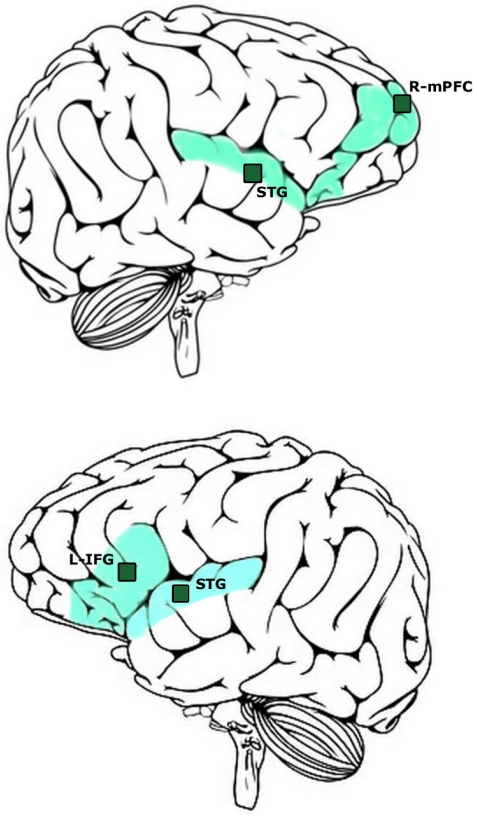

Fig. 3: Social animation task: conjunction of activations

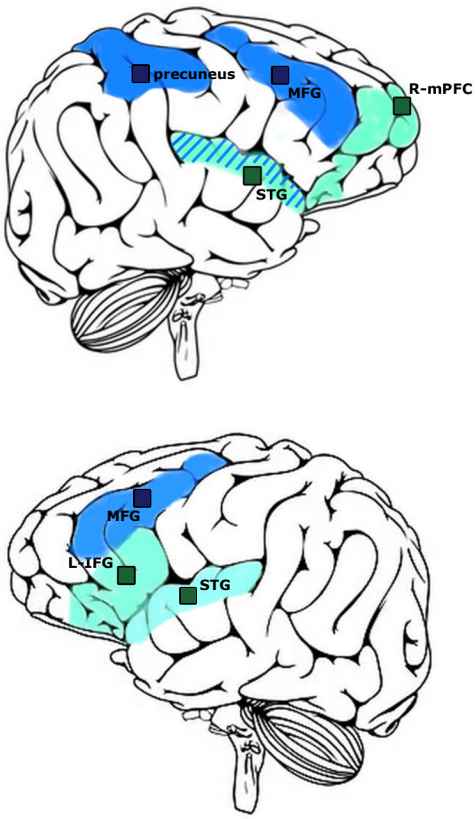

Fig. 4: Social animation task: additional activations in ASD group

relation consistently supports the notion that adults with ASD might spend **excessive effort** on the intentional detecting processing during mentalizing.

6 ToM tasks and measures

Impending to clinical experience, we stress on proper measurement of ToM with an aim to help distinguish between the possible alternative neural substrates of the function. Leblanc et al. (2020) provided a systematic review, screening peer-reviewed literature and relevant test publishers' catalogs, in order to generate an inventory of existing ToM measures that have been used with children under 6 years of age. Note that age is not a limitation in order to measure ToM abilities, yet in younger children less complex testing methods might suffice as we expect an increase in complexity of ToM with age. Importance of development of complex ToM testing methods can be for example seen directly in the need for relevant testing methods for late diagnosis of Asperger syndrome, which is especially frequent in females (Bagriela et al., 2016; Gesi et al., 2021). On the grounds, we suggest following novel analysis components for ToM testing evaluation, potentially helpful specially within the issue of Asperger syndrome diagnostics in females.

1. **Measurement of cognitive fatigue.**

   This is an *objective* approach. According to above conclusions, we assume that on the continuum between thought extremes of fully present ToM and fully compensated ToM, cognitive fatigue will be increasing with growing compensation of ToM, indicating present neurodiversity.

2. **Approach analysis.**

   This is a *subjective* approach. Suppose a participant undergoes a particular ToM testing task, as encapsulated by Leblanc (2020). According to the functional distinction between ToM task execution in neurotypical people, that can be concluded to be predominantly unconscious, and neurodiverse people, where the task execution can be altered into a form of conscious[5] analysis aiming for the making of optimal decision, we suppose there will be present qualitatively different approaches toward the task execution in respective groups of participants.

[5] or possibly automatized by learning

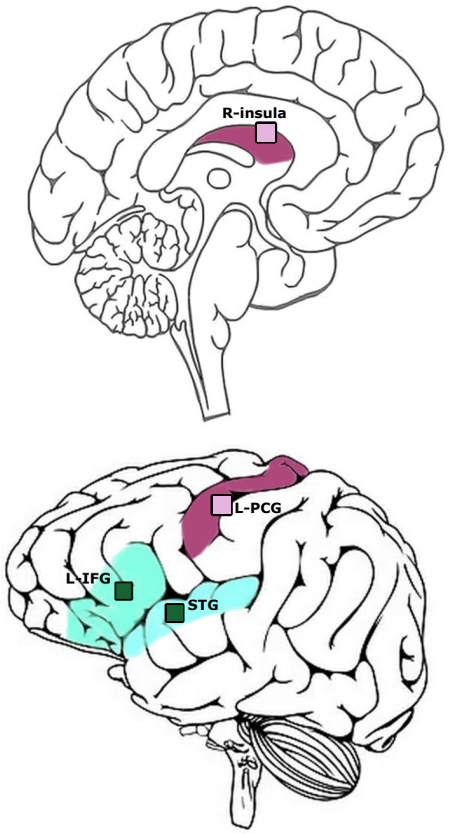

Fig. 5: Social animation task: additional activations in TD group

A method used for above explained analysis is an observed dialogue focused on

(a) presence of participant's need to explain the choice,

(b) presence of an automatic assumption that the interviewer knows the correct answer,

(c) length of answer report.

For successful performing of such analysis, we suppose it is further necessary to devise a manual for evaluation of above-mentioned dialogue, as well as to test it on empirical data. Within this study, we are reducing our attention to the correct frame of theoretical basis.

7 Conclusion

We are pointing to the difference between well-known unconscious realization of ToM tasks in comparison with an option of this functional process to be also conscious, which we can observe in individuals with Asperger syndrome.

On the grounds we conclude there is no single way of how ToM tasks can be executed, which we illustrate in the Neural Substrates sections ((4) and (5)).

We refer that according to neuroimaging studies (sections (4) and (5)), there is enhanced cognitive load in people with autism spectrum disorders affiliated with ToM tasks execution, particularly with mentalizing, that leads to faster and more intense development of cognitive fatigue in these individuals.

We evaluate that the feasibility of execution of a ToM task by means of multiple neural pathways (sections (4) and (5)) might provide partial answer on the nature of apparent behavioral invisibility of Asperger syndrome in people on its highly-functional end resulting in numerous misdiagnoses. We propose to broaden our focus from examining only the functional presence of particular ToM task execution in observed individuals to the probability of a particular pathway being involved.

Picking up on such, we suggest a novel analysis approach for evaluation of the measure of 'typicalness' of ToM task execution in tested individuals (section (6)). Desire of such approach is to help decrease the error tendency in diagnoses of Asperger syndrome in individuals whose execution of ToM tasks is present, but the process of its realization is altered.

Note that our suggestion relates merely to the theoretical basis of the problem, without any direct aim for a particular design to be drawn. Possible continuation of this study we propose would comprise of assigning and testing particular models.

Simultaneously, our study introduces a conceptual view on what theory of mind is (sections (1) and (2)) and conjectures a starting point on how we could access the unconscious communication between members of one society by the means of a mathematical model (section (2)).

Acknowledgement

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