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The Neuroscience of Cognitive Theory

Dr Debopriya Ghosh¹, Dr Ekta Verma², Mr. Romel Kumar Ghosh³

Department of Physiology, University College of Medical Sciences. Delhi, India.

Department of Paediatrics, All India Institute of medical Sciences, Gorakhpur, India.

University of Calcutta, Kolkata, India.

ABSTRACT: The biology of Cognitive processes or Theory of Mind (ToM), For a Special Issue Since the seminal publication of the study by Wimmer and Perner in 1983, developmental psychologists have extensively studied ToM; nevertheless, the neuroscience of this critical ability—which is arguably what distinguishes humans from all other animals (Saxe, 2006)—has only lately started to get considerable attention. It occurred to us as guest researchers and the journal research board that this topic because there are now more researchers producing high-caliber work on it. Additionally, the studies that have already been conducted are frequently dispersed, so there was an opportunity to invite top researchers in this field to present their work in one location with the hope of connecting the major threads. In this mini review, we give some background information and offer our own analysis of the outstanding collection of articles we were thrilled to review.

KEYWORDS: Neuroscience, Cognitive Ability, Neurocognitive Functions, Autism, Theory of Mind.

I. INTRODUCTION

The well-known "false belief" task has been the method of choice used to test ToM. (Wellman, Cross, & Watson, 2001; Wimmer & Perner, 1983). Young infants witness an object being transferred covertly in one common variation (the "object transfer" dilemma). The youngster must focus on the character's belief in addition to the actual location of the thing in order to accurately predict or explain the character's subsequent action (Dennett, 1978). The false belief task has been employed in literally hundreds of research, but it is still debatable whether or not the employment of a "special" domain-specific mechanism for thinking about other minds is necessary for success on this task. This issue's Stone and Gerrans offer a helpful summary of this argument. They point out that passing false belief tasks might not be possible using a domain-specific method (Bloom & German, 2000). Children must use their general cognitive abilities, such as general perceptual and linguistic representations of the story, working memory (to track all the moving parts of the story), and motor representations of their own responses, in order to recognise and rationalise about someone else's false beliefs. Therefore, the question is whether it is required to postulate a special, devoted domain-specific mechanism for reasoning about beliefs and wants in addition to domain-general processes. In the past, the discussion of domain-specificity has taken into account data from typically developing and autistic children (Baron-Cohen, Leslie, & Frith 1985; Baron-Cohen, Tager-Flusberg, & Cohen, 2000). In particular, developing success on false belief tasks may depend not on conceptual shifts in ToM but rather on children's capacity to balance two opposing representations of reality (the actual state of affairs vs. the world as imagined by the character) and to prevent a false but persuasive answer (the true location of the object). Numerous studies have shown that these inhibitory control elements (a) develop at around the same age as success on false belief tasks and (b) are related to each child's performance on these tasks individually (e.g., Carlson & Moses, 2001; but see Sabbagh et al., 2006, for intriguing recent evidence that differences in inhibitory control across cultures do not produce differences in false belief performance). The performance of typically developing youngsters on false belief tests closely resembles that on logically identical issues involving non-mental false representations (Perner, Aichhorn, 1990). It's possible that what emerges instead of a particular concept of belief is a broad awareness of representational relationships, or the ability to engage in meta-representation. The research on autism have provided the most convincing evidence of domain specificity to date. Although they frequently perform well on false photograph or false drawing tasks (Charman & Baron-Cohen, 1992), children with autism consistently demonstrate delays or deficits in passing false belief tests (see Baron-Cohen et al., 2000), which suggests a domain-specific problem with representing mental states as attitudes rather than a general meta-representational issue. However, the current evidence does not persuade Stone and Gerrans. These authors come to the conclusion that although the execution of false belief tasks does depend on domain-general inhibitory control and meta-representation processes, there is currently no need to propose an extra domain-specific mechanism for belief attribution. Stone and Gerrans support the parsimony argument, which holds that scientists shouldn't propose an additional mechanism when

fewer entities would, in theory, be sufficient. For social neuroscientists, this theoretical perspective offers an ideal starting point. To explicitly test the concept that different neurological pathways are required for reasoning about other minds, neuroscientific approaches can be used to get beyond observed correlations in behaviour. In three pieces in the current issue, claims of domain-specificity are examined using fMRI. The problem posed by Stone and Gerrans (this issue) is directly addressed by Perner and colleagues (this issue). Both groups of authors concur that in order to be specifically implicated in re-presenting beliefs, a mechanism must satisfy at least three requirements: (1) a robust and repeatable response to stories that do require belief attribution; (2) a significantly lower response to closely matched control stories that only require representing non-mental representations; and (3) no difference between non-mental stories that demand meta-representation or do not. The right temporo-parietal junction is the only part of the brain that fits all three of these requirements, according to Perner and colleagues (current issue) (RTPJ). First, they confirm the result that readers of short tales about characters' views are more likely to engage with the RTPJ than readers of stories about images like pictures (Saxe & Kanwisher, 2003). More importantly, the RTPJ is not activated when readers of stories involving maps and signs, which are more analogous to beliefs (and better correlated with the development of belief-reasoning), because, like beliefs, maps and signs are intended to represent the current reality, and as a result, they may be genuinely false. Last but not least, the RTPJ failed to distinguish between control tales about temporal change that do not need meta-representation and stories about false maps that do depend on such understanding. The RTPJ does seem to indicate the operation of a specialised, domain-specific mechanism for reasoning about beliefs, which is a clear answer from these data to Stone and Gerrans' (this issue) challenge. Perner and colleagues (current issue) discovered a distinct pattern in the left TPJ, which was recruited for both mental and non-mental meta-representational activities, which is also consistent with prior evidence (Aperly, Samson, Chiavarino, Bickerton, & Humphreys, 2006; Aichorn, Perner, Kronbichler, Staffen, & Ladurner, 2006). The study by Saxe and colleagues provides more proof that reasoning about beliefs rely on both domain-general and domain-specific procedures (this issue). The initial step taken by these authors is to pinpoint the brain areas involved in (a) belief reasoning and (b) domain-general response selection and inhibitory regulation. They then go on to demonstrate that while reasoning about beliefs does trigger strong activity in domain-general systems, reasoning about misleading images also produces an equivalent reaction. That is, both false belief and false photograph tales attract domain-general mechanisms for inhibitory control, response selection, etc., but there are additional brain areas that are uniquely recruited for beliefs. These findings imply that reading about misleading photos depends exclusively on domain-general processes, but reasoning about beliefs rely on both domain-general and domain-specific mechanisms. Next, Saxe and colleagues created a non-verbal task where participants may observe the same stimuli and provide the same responses while either reasoning about beliefs or according to domain-specific rules. Saxe and colleagues discovered that the right TPJ provided the strongest evidence for a domain-specific response, which is consistent with the findings of Perner and colleagues (same issue). Saxe and colleagues also note that human adults responded more quickly to stimuli when they reasoned about their views than when they followed default-general norms. These findings are consistent with a long history of evolutionary psychology study. For logically equivalent "if-then" reasoning issues, Cosmides & Tooby (1997) shown, for instance, that individuals are generally quicker and more accurate when the difficulties are framed in terms of social duties as opposed to generic abstract ones. Ermer and colleagues support their major thesis in the present issue, which is that social thinking is a domain for which humans possess domain-specific mechanisms. In contrast to logically equivalent, equally well-known precautionary guidelines (such as "If you deal with TB patients, then you must wear a surgical mask"), they discover that brain areas are differently engaged when people complete the Wason selection task for social contracts. Social contracts may not seem to entail ToM, but they do since they imply that both parties expect the other to adhere by the terms of the agreement. In this way, they also imply that both parties have similar views on the nature of the social responsibility. In all of these studies, fMRI is a helpful tool for identifying the functional profile of brain areas, which are ultimately psychological functions. However, fMRI can never describe the linkages that are required; it can only describe the brain areas that are connected to a psychological task. Social neuroscientists use alternative approaches to investigate if one cognitive skill, like language, is a prerequisite for another, like belief attribution.

II. THEORY OF MIND & LANGUAGE

Beliefs and wants are imperceptible, abstract concepts, whereas mental processes are difficult to physically examine. Additionally, there is no direct link between conduct and mental states. For instance, there is no observable action that reliably indicates whether someone believes it is Tuesday at the moment (Baldwin & Saylor, 2005). Therefore, listening to other people discuss the mind is a priceless approach to get knowledge about the enigmatic contents of the mind. Research in developmental psychology suggests that verbal interaction is crucial for the formation of a theory of mind (Astington & Baird, 2005). The first study to show that linguistic skill predicts performance on the false belief task,

regardless of age, was conducted by Dunn and colleagues (e.g., Dunn & Brophy, 2005). Both samples of healthy kids and kids with autism and other developmental difficulties show a similar association (Astington & Jenkins, 1999; Peterson & Siegal, 1999). The direction of the association between communication and ToM is unclear. Most likely, there is a two-way link here: Since language is a "print out" of someone else's mind, having good language skills gives you better access to that person's mental states and allows you to understand more of their thoughts, intentions, and feelings. However, ToM may also aid in the learning of new languages (Baron-Cohen, Baldwin, & Crowson, 1997; Bloom, 2000), for instance, by instructing the growing kid to look for the speaker's purpose while deciphering unfamiliar words. The discovery that deaf infants whose parents are non-native signers are selectively delayed in passing the false belief test provides compelling evidence that limited language input inhibits the development of ToM. (Peterson & Siegal, 1999). Even nonverbal tests of false belief understanding are challenging for these kids, indicating that the linguistic demands of the activities are not the cause of their delay (e.g., Figueras-Costa & Harris, 2001). Furthermore, even after taking into consideration the child's own language abilities, the mother's competency with sign language, notably her use of mental state terms, independently predicts the child's success on the false belief test (Moeller & Schick, 2006). The age at which a child first learned sign language, rather than the length of time they have been using it, appears to be a better predictor of performance on non-verbal false belief tasks in a recent study of Nicaraguan Sign Language. Children who first joined the sign language community before the age of 8 perform significantly better than those who did so later in life. Children of native signers who are deaf and who start learning sign language at infancy do not exhibit any delays at all (deVilliers, 2005). Clearly, language exposure has a considerable impact on the development of ToM; nonverbal social information, which is accessible to all deaf groups, is clearly insufficient. To find out how language and ToM are related, Ronald and Plomin conducted a thorough investigation on 9-year-old twins in the current issue. The authors distinguish between the impacts of shared and non-shared environments and genetic factors on development by comparing monozygotic and same-sex dizygotic twin pairs. ToM task performance in late childhood is reported to be modestly heritable, but also exhibits a large influence of shared environment, according to Ronald and Plomin. Given the preceding statement of ToM deficiencies in autism and the fact that autism is a highly hereditary condition, the heritable element is crucial (Folstein & Rutter, 1988). Another crucial part of ToM is the environment, which may show how language functions. On three scales—social skills, linguistic skills, and repetitive behavior—Ronald and Plomin gathered assessments of the kids from parents, teachers, and the kids themselves. It's interesting to note that the only factor significantly predicting children's success on false belief tests was their verbal abilities. These findings underline how closely verbal communication and ToM are related. The desire to belong to a social group, on the other hand, could be less reliant on ToM and instead represent social desires shared by many primate species. Finally, even if both measures characteristics that are uncommon in autism, ToM may be somewhat independent of "repetitive behaviour." Thus, the domain-specific understanding of ToM that results from the fMRI investigations matches well with this particular pattern of relationships in the Ronald and Plomin study. Even yet, there is debate concerning the causal mechanism behind the apparent developmental link between language and ToM. One perspective holds that linguistic representations of mental state notions are inherent to language. The parasitic hypothesis holds that if sophisticated grammatical structures are required even for the formulation of ideas about mental states, then the development of ToM would be dependent on linguistic competence. The syntax of sentential complements is the special feature of language that is frequently implicated in representing another person's views (de Villiers, 2000; de Villiers & de Villiers, 2000; de Villiers & Pyers, 2002). In both correlational and training experiments, children's production and understanding of this syntactic structure precede and predict performance on the false belief test (de Villiers & de Villiers, 2000; de Villiers & Pyers, 2002; Hale & Tager-Flusberg, 2003). The way adults talk about the mind, on the other hand, could be a significant piece of evidence that kids rely on when they're building ideas about what a person's mental state is like. Using the same mental state verbs repeatedly can help kids notice the subtle parallels between radically dissimilar acts or circumstances and between various subjective points of view. By doing so, verbal communication might aid in the formation of ToM without contributing to mental state representations (Baldwin & Saylor, 2005; Harris, 2005). The association between language and ToM in adults is predicted by these two theories in two different ways (and in adult brains). The parasite theory states that grammatical constructions provide the representational substrate for thoughts about other minds, and that ToM should be parasitically dependent on language in both adults and children. Contrarily, the communicative theory recognises the potential that language may aid in the formation of mental state conceptions. Once these ideas are developed, a mature ToM may be able to function without the use of language. Therefore, the crucial test is to look at the effects of late-onset aphasia (particularly loss of grammatical abilities) on an already developed Theory of Mind. In the current issue, two publications give unambiguous proof that the parasite hypothesis is false. The first writers to document spared ToM competency in two patients with "dense" aphasia were Siegal and Varley (Varley & Siegal, 2000). According to their current evaluation (this issue), the data to date supports their claim that, once developed,



ToM is independent of language. In this issue, Apperly and colleagues offer compelling fresh support for the same theory. The results of PH's performance on a battery of language and TOM tests are reported. PH is a young guy who had a left hemisphere stroke. PH displays no deficits on non-verbal measures of ToM, such as second-order inferences, but being highly impaired on tests of syntax, particularly the syntax of embedded clauses (what X thinks that Y thinks). Together, these two investigations offer convincing evidence that even in the presence of significant grammatical errors, adults with a developed ToM may create ideas about other people's thoughts. These findings support the idea that, rather than being parasitic, the relationship between language and the development of ToM is essentially communicative.

There is little doubt that language is not a developing ToM's only source of knowledge. Subtle configurations of human facial and body motions may be used to decipher a lot of information about another person's intentions, perceptions, and feelings (Sabbagh et al., this issue). Key visual cognitive "precursors" of ToM, such as those that recognise and represent the visual signals that others use to convey their intentions and emotions, may thus interpret this information. There are still unanswered issues with these predecessors. For instance, are the primary perceptual or motor systems involved in social perception? Do they appear before attributions of full-blown mental states? New information and fresh viewpoints on these important theoretical issues are presented in three pieces in the current issue. The right posterior superior temporal sulcus is a brain area connected to the perception of both purposeful action and gaze direction (pSTS; e.g., Allison, Puce, & McCarthy, 2000). When adults see biological motion as opposed to non-biological motion, the pSTS has been demonstrated to have a greater BOLD response (Pelphrey et al., 2003). Additionally, the pSTS distinguishes between human body motions depending on whether the movement is initiated by the actor or compelled by the physical surroundings (Morris, Pelphrey, & McCarthy, 2006). The STS responds differently depending on the relationship between the biological motion and the context of the action when the visible biological motion is exactly matched, which is perhaps most intriguing. Three studies have discovered an enhanced response in the STS when a hand, body, or eye movement is unexpected given the environmental context (Pelphrey, Singerman, Allison, & McCarthy, 2003; Pelphrey, Morris, & McCarthy, 2004; Saxe, Xiao, Kovacs, Perrett, & Kanwisher, 2004). This issue's work by Senju and others provide convergent evidence for this characteristic of perceptual representations of deliberate behaviour. They employ stimuli from earlier fMRI research (Pelphrey, Viola, & McCarthy, 2004), but they also discover an ERP component that has the similar functional profile as the pSTS. In other words, it is improved when a character is viewed and their gaze direction is unexpected or incongruent with the environment. After that, the authors are able to spot an identical ERP component in the brains of 9-month-old babies. These findings are significant in three fundamental ways: This study (1) uses a novel method, EEG, which has much higher temporal resolution than fMRI, and (2) provides converging evidence for a perceptual mechanism for processing intentional action that shows an enhanced response for unexpected actions. It also (2) provides evidence that this mechanism is very early developing and constant from infancy to adulthood. In this issue, Kaplan and Iacoboni look at the right inferior frontal gyrus, another part of the brain associated with representations of purposeful activities (IFG). The right IFG is a pre-motor area, in contrast to the pSTS, which is typically assumed to create perceptual representations of other people's activities. It may have interesting functional ramifications to distinguish between perceptual and motor representations of other people's behaviours. According to findings presented by Kaplan and Iacoboni, the IFG representation of activities in context follows a different pattern than that which is often seen in the pSTS. The reaction in the IFG was actually larger for one environmental component (a breakfast table) when the action was expected in the context (a precise hold on a mug's handle, compatible with drinking), as opposed to an unexpected action (a whole-hand power grip on the body of the mug). The contrast between the functional profiles of the IFG and pSTS may offer significant suggestions for the distinct roles of perceptual and motor representations in comprehending others' actions, even though these findings still need to be confirmed (since the response to precision grips in the IFG is higher across all contexts). Senju and colleagues' other main argument is that the pSTS's perceptual processes are constant throughout development and are already fully formed in infancy. It's interesting to note that Carter and Pelphrey (this issue) reach a somewhat different conclusion on the pSTS's developmental course. Carter and Pelphrey identified the pSTS in a juvenile fMRI research by its response preference for biological versus non-biological motion. These researchers discovered that although they could identify the pSTS in children aged 7 to 10, the region's selectivity for biological motion changed considerably throughout this time period. In fact, there was absolutely no biological motion impact among the pSTS in the youngest research participants. Given the rarity of the youngest infants and the difficulties in paediatric neuroimaging, this result will be repeatable. All in all, these investigations indicate to important new social neuroscience research areas that focus on the evolution of specific brain systems for social awareness.

III. COGNITIVE EMPATHY

The difference between cognitive and affective empathy, or between assigning thinking vs feelings, is another distinction that is important in many publications. Similar to the classic core of ToM, affective empathy entails both understanding what another person is thinking or experiencing and reacting to that emotion with one's own appropriate emotional state. Even yet, there are two factors that suggest that different systems from the core ToM may be necessary for emotion perception. First, unlike other people's views, which are not easily represented in straightforward behavioural patterns, other people's sentiments are rather plainly signalled by their facial expressions. Second, seeing someone acting on a belief may be more likely to cause "contagion" than seeing someone experience a powerful emotion. In other words, witnessing someone else desperately look for something missing is less likely to make an informed observer "catch" the other's incorrect belief. An extreme expression of delight, anxiety, or grief could make an observer experience a corresponding feeling. The neurological underpinnings of ToM and emotional empathy are just now being understood, despite the fact that these considerations make it conceivable that they depend on at least partially separate systems. The current issue contains four papers that add to this body of work. Dissociations that have been seen in patients with brain injury to the ventral medial prefrontal cortex provide the strongest evidence yet for a separation between the cognitive and emotional components of empathy (VMPFC). By varying whether participants were asked to infer a character's belief or her emotions, Shamay-Tsoory and colleagues (current issue) created a fresh battery of tasks that were matched for difficulty. Only individuals with VMPFC lesions demonstrated a selective impairment, performing worse on tasks requiring assessments of emotion compared to patients with a variety of other lesion locations. Additionally, the performance of these patients was negatively linked with both their own scores on the Interpersonal Receptivity Index's "Empathic Concern" part and independent assessments of the emotional intensity of each scenario. According to Shamay-Tsoory and colleagues, knowing another person's feelings requires different brain mechanisms than comprehending another person's thinking, and that mechanism is found in the VMPFC. Based on their analysis of social deficits in frontal-variant fronto-temporal dementia, a progressive neural degenerative condition that disproportionately affects the ventro-medial frontal cortices, Kipps and colleagues (current issue) reach nearly identical results. The similar conclusion is reached by Mojzisch and colleagues in this issue as well. They deepen and enhance a prior fMRI study in their present research by utilising a variety of psychophysiological measures. According to their findings, the VMPFC is active during online interactions when social and emotional responsiveness is present. Chakrabarti and colleagues (this issue) give evidence that various brain systems react to various emotional expressions, in contrast to the findings mentioned above which see affective empathy as a single cohesive entity. The researchers then go on to pinpoint the parts of the brain where there was a connection between individual variations in empathy quotient (EQ) and neuronal reaction to particular emotional facial expressions. Chakrabarti and colleagues (current issue) expect that empathy scores and brain activity in response to emotions would converge on the same neural mechanism across emotions if a single, unifying psychological mechanism were responsible for empathy. Although they also discovered some evidence for a shared substrate of empathy across the fundamental emotions, in the left inferior frontal gyrus, Chakrabarti and colleagues (current issue) revealed that unique brain areas were connected with EQ during the experience of each individual emotion. When compared to Kaplan and Iacoboni's findings, these findings offer an intriguing difference (this issue). Both teams looked into the relationship between the brain's activity while seeing a human action and a gauge of personal empathy variances. The IFG has been identified in both investigations as the source of this association. However, Kaplan and Iacoboni find a right lateralized impact, whereas Chakrabarti and colleagues observe the association in the left IFG (see also Minio-Paluello et al., this issue). All things considered, however, Chakrabarti et al.'s research indicates that the neurological basis of empathy is complicated, since it seems to govern how many brain areas are employed when each particular emotion is seen.

IV. NEUROCOGNITIVE CONDITIONS

Social neuroscience is beginning to paint a clear picture of the many cognitive processes required for effective social thinking. The application of this theoretical environment to comprehend illnesses impacting social cognition, such as autism, may be the next step. Historically, it has been believed that autism, in particular, is characterised by difficulties assigning cognitive rather than affective emotions (e.g., Blair 2005). In contrast, Ashwin and colleagues (current issue) report that a group of people with autism demonstrated selective abnormalities in the identification of negative fundamental emotions, particularly dread, when compared to matched controls. The identical individuals found it significantly easier to identify the more "cognitive" emotion of surprise. The authors draw the conclusion that functional anomalies in the amygdala may contribute to autism. Turner's syndrome is the subject of a comparable assertion by Mazzola and colleagues. The purpose of these two publications is not to determine what features are

unique to the autistic brain. But the method for identifying social reasoning components that are not damaged is just as crucial for describing the social deficits in autism. According to Leslie and colleagues, whereas autistic youngsters struggle with false belief tasks, they succeed on straightforward moral reasoning assessments. Children with autism, in instance, performed equally well as typically developing 4-year-olds in understanding that eating one's own cookie is OK even if another person (who selfishly wants two cookies) begins to cry is stealing it from them. This conclusion supports common clinical accounts that people with high functioning autism or Asperger syndrome may care deeply about moral concerns like social justice despite having weaknesses on sophisticated ToM tests (Baron-Cohen, 1997; Baron-Cohen et al., 2000). In this way, their lack of empathy does not result in psychopathy. Even if they have trouble understanding the other's mind or emotional emotions on their faces, they rarely intentionally injure or are unkind to others, and they have a strong sense of right and wrong. The neuroscience of moral development may out to be a crucial tool for distinguishing between the two empathy disorders, autism and psychiatric illness.

V. CONCLUSIONS

The variety of approaches that have just lately been used to study the neurological and psychological underpinnings of ToM has astounded us as researchers. We have included studies that explore ToM in twins, Turner's syndrome patients, patients with acute lesions, and patients with neurodegenerative illnesses in this single issue. These publications also employ TMS, EEG, psychophysiology, eye-tracking, and fMRI. Despite this, we are conscious that the studies we have selected for this Special Issue cannot adequately represent the breadth and depth of the neuro-science of ToM. If ToM, for instance, has a hereditary component, molecular genetic research will be necessary to determine which candidate genes may be functionally connected to the onset of ToM. Future study in this area will be crucial. Second, there is strong evidence to suggest that androgens, in addition to genes, may play a significant role in the development of TOM and empathy (Baron-Cohen, 2003; Mazzola et al., this issue). The abundance of androgen receptors in the brain areas linked to ToM may prove to be a significant source of diversity in individual variations in ToM development. Last but not least, research into how the early environment influences the development of empathy will be crucial for creating an integrated model of the development of ToM. This idea was initially put out by Bowlby (1969). The gaps in this discipline that a new generation of social neuroscientists will fill are highlighted in this Special Issue, along with the advancements being made in our knowledge of ToM.

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