

Introduction to Brain & Behaviour
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Lecture 38
Neural Correlates of Mental State Attribution

Hello and welcome to the course Introduction to Brain and Behaviour. I am Dr. Ark Verma from IIT Kanpur. This is week 8 of the course and now we will talk about the Neural Correlates of Mental State Attribution.

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Mental State Attribution

- We are often faced with situations when it becomes difficult to understand the feelings and intentions of others as evidenced by their overt behavior.
- Moreover, it also happens a lot of times that there is a mismatch between a person's actual intentions and the displayed behavior.
- Individuals have the ability to gauge the mismatch between people's actual intentions and their outward behaviors which can be used to recognize people who can or cannot be trusted.
- Most tasks investigating the brain regions that are involved with inferring mental states from unobservable cues, and their activity draw from tasks used to investigate the developmental milestones of children as they develop the theory of mind.

Now, we are often faced with situations when it becomes difficult to understand the feelings and intentions of others as evidenced by their overt behaviour. So, people might be you know behaving in a certain way and they are being very nice to you but in their head probably they are very uncomfortable. They do not like hanging out with you, sometimes people are showing a lot of pain, disappointment etc.

But, inside they are happy that you have suffered some misfortune. Sometimes, people are just in awkward spots, you know you are continuously talking about something with other individual who is not enjoying the conversation at all. But, it is because of considerations of propriety and anxiety. You know, it is about being forced to go on with the communication. So, these kind of things happen quite a lot, where individuals are faced with these situations.

Individuals are faced with these situations when it becomes very difficult to actually correctly understand what the other person actually feels because, their outward behaviour is not only clearly showing that.

It also happens as I was just saying that a lot of times there is a mismatch between a person's actual intentions and the displayed behaviour. You wanted to say something, but your behaviour is completely in the opposite manner. Now, as people and as social animals we have this ability to gauge the mismatch between people's actual intention and their outward behaviours.

This can be used to recognize people who can or cannot be trusted. Who would like to trust the person in who's behaviour and actions there is least mismatch. You will feel very uncomfortable trusting a person who's actual behaviour and whatever they are saying are very very different from each other. Now, most tasks investigating the brain regions that are involved in making these judgements in inferring this mental states from these unobservable and nonverbal sort of queues.

So, most hours basically are used in investigating the developmental mindstones of children as they are developing their theory of mind. So, most of the theory of mind development that are used to so these things as well.

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- These paradigms often proceed by asking participants to make inferences about the beliefs, knowledge, intentions, and emotions of others based on written narratives or pictures.
- Regions of brain that are commonly engaged in a variety of tasks wherein participants are making inferences about the thoughts and beliefs of others include the medial prefrontal cortex (MPFC), temporoparietal junction (TPJ), superior temporal sulcus (STS), and the temporal poles.

These paradigms often proceed by asking participants to make inferences about the beliefs, knowledge, intentions, and emotions of others based on written narratives or pictures.

Regions of brain that are commonly engaged in a variety of task wherein the participants are making inferences about the thoughts and beliefs of others include the medial prefrontal cortex, temporoparietal junction, the superior temporal sulcus the temporal poles.

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The medial prefrontal cortex

- Mitchell and colleagues (2004) compared the brain activity of participants engaged in two conditions: forming an impression of another person and a sequencing task.
- Participants were asked to view pictures of people paired with statements about their personality, such as, "At the party, he was the first to start dancing at the table."
- A cue indicated how the participants should think about the faces and statements.
- In the impression formation task, the cue would indicate the participants to make an inference about the personality of the person in the picture, whereas in the sequencing task, the cue prompted participants to remember the order in which specific statements were presented in relation to a particular face.

Now, the medial prefrontal cortex, Mitchell and colleagues the brain activity of participants engaged in two conditions forming an impression of another person and a sequencing task.

So, there were two conditions in one condition we have formed an impression of another person, we will be given some information and other will be just a sequencing task, you know what happened at what point. Now, here participants were asked to view pictures of people and these pictures were paired with statements about their personality such as, at the party, he was the first person to start dancing at the table.

A cue indicated how the participants should think about the faces, so this cue would indicate how they should think about these faces and these kind of statements. In the impression formation task, the cue would indicate that the participants make an inference about the personality of this individual in the picture, whereas in the sequencing task, the cue prompted that the participants just to remember the order in which specific statements were presented in relation to a particular face.

So, at the party he was first to dance at the table. He went and started dancing on this song, he sat down because he was tired. So, there might be three statements and he had to order them about what happened at what time. In the impression formation task, you are not really

concerned with the sequence of the statement or anything. But, just make your own impression of this individual.

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- Both conditions needed participants to think about other people, but only the impression formation task required them to think about the internal states of other people.
- The impression formation task engaged the MPFC much more than the sequencing task did.
- The results of the study suggest that MPFC activation plays a strong role in forming impressions about the internal states of other people, but not in thinking about other types of information regarding another person.
- So, they conclude that social cognition relies on a distinct set of mental processes.

Both these conditions needed participants to think about other people, but only the impression formation task required them to think about the internal states of other people. How, is that person a very jolly person? Is that person a very fun loving person or not? Now, the impression formation task engaged the MPFC much more than the sequencing task did. Remember, the sequencing task is also implicating you to think about the other person but, not just as meeting their internal states.

So, the result of the study suggest that MPFC activation actually plays a very strong role in forming impressions about the internal states of other people, but not in thinking about other types of information regarding another person. So, they concluded that social cognition actually thinks of this kind, relies on a distinct set of mental processes.

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- Other studies have demonstrated that the relation between the MPFC and impression formation is specific to animate beings such as dogs, but is not present when individuals form impressions of inanimate objects.
- All in all, these studies indicate that the MPFC is involved in reasoning about the intangible mental states of other beings, and may also play a role in the ability to change perspective.

The right temporoparietal junction

- Is a region of the brain that has been associated with making inferences about other people's mental states, albeit in the right hemisphere (rTPJ).
- Saxe conducted a series of studies to investigate the specificity of this region. She began with localizing the TPJ by using similar logic developed in fMRI studies of face perception

- Saxe developed a similar method to identify the rTPJ region engaged in theory-of-mind judgments (Saxe et al., 2006). The localizer task is based on the Sally-Anne *false belief Task*.
- In one of the versions of this task, participants are made to view a series of drawing that depict scenarios involving the characters Sally & Anne. The picture begin with Sally placing a marble in a basket and then leaving the room. After Sally is gone, Anne moves the marble into a drawer. Sally then comes back into the room.
- The critical question here is "Where will Sally look for the marble?"
- To be able to answer this question correctly, participants will need to ignore their own knowledge about the location of the marble and answer from the perspective of Sally. As Sally is unaware of Anne's manipulation, she would expect the marble to be in the basket where she initially left it.

Now, other studies have demonstrated that the relation between the MPFC, figure out this. Saxe developed a similar method to identify the rTPJ region engaged in theory-of-mind judgements. So, basically they used the Sally-Anne false belief task. Now, in one of the versions of this task, participants are made to view a series of drawings that depict scenarios involving the characters Sally and Anne.

The picture basically begin with Sally placing a marble in a basket and then leaving the room. After Sally is gone, Anne moves the marble into a drawer. Sally then comes back into the room. Now, the critical question here is, where will Sally look for the marble? In the drawer or in the basket, to be able to answer this question what basically participants need to just ignore their own knowledge of the marble being in the drawer.

But, basically trying and estimate that Sally does not know where it is. So, she should actually look at the drawer.

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- Participants who were not able to recognize that Sally does not share their knowledge predict that she will look in the drawer.
- Saxe's localizer task also presents a series of false-belief stories as well as control scenarios involving falsehoods that have nothing to do with mental states of other people.
- When brain activity across these different conditions was compared, a region of the rTPJ was found to be consistently engaged in the theory of mind conditions.
- Researchers highlight the exact location of activity within the rTPJ for each participant and then later activity in this region is examined for differential activity in relation to a series of other tasks that measure person perception.

Participants who were not able to recognize that Sally does not share their knowledge, basically predict that Sally will look in the drawer. Now, Saxe's localizer task also presents a series of false-belief stories as well as some other kinds control scenarios involving falsehoods that have nothing to do with mental states of other people.

So, different other kinds of falsehoods can be created as well in the task. But, when brain activity across these different conditions was compared, a region of the rTPJ was found to be consistently engaged in the theory of mind conditions where you are basically move to estimate the mental stage of others.

Researchers highlight the exact location of the activity of the rTPJ for each participant and then later activity in this region is examined for differential activity in relation to a series of other tasks that measure person perception. So, the rTPJ is an important area which is basically involved in person perception, estimating what other persons are feeling.

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- Activity in rTPJ has been associated with reasoning about other people's mental states, but it responds only in specific situations.
- In a study, participants were presented with three kinds of information about a person: social background, mental states, and a life event. For instance, about a fictional person named Lisa, participants may get to hear the following information: Lisa lives in New York City with her parents (social background), but wants to move to her own apartment (mental state), and she finds out that the apartment she wants is available.
- The study found that the rTPJ was significantly activated when participants were presented with information about a mental state compared to when they were presented with information about social background or life event.

Activity in rTPJ has been also associated with reasoning about other people's mental states, but it in a very generic way. It is not about all kinds of decisions, but in a very specific situations.

Let us look at this more deeply, now in a study, participants were presented with three kinds of information about a person, their social background, their mental states, and a life event. For example, a fictional person is somebody named Lisa, I could tell you that Lisa lives in New York City with her parents, so this would be the social background. I could tell you that she wants to move here in her own apartment so you know her intentions.

About what she is looking up nowadays and she then, I could say that she finds out the apartment, she finds out where the apartment available which is a life event. So, now she knows where the apartment is available and the shifting is going to happen. Now, the study found that the rTPJ was significantly activated when participants were presented with information about a mental state.

So, the fact that she wants to have her own Apartment that is a mental state. But, it was not such activated when they were presented with a information about the social background and life event. So, you can see when the mental states are explicitly involved, only then the rTPJ activation is observed.

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- At the moment, two hypotheses have been offered about the activity in the rTPJ.
 - One of the hypothesis suggests that rTPJ is a region that is specialized for reasoning about the mental states of other people, and the MPFC more broadly supports reasoning about other people and their mental states.
 - Another hypothesis suggest that the MPFC supports reasoning about social tasks, and the rTPJ is important for redirecting attention in both social and nonsocial tasks.
- In one study, participants brain activity was measured in relation to processing information about a person's physical appearance ("Raj was a very slim boy."), internal physiology ("Sheela was starving because she had skipped breakfast.") or mental states ("Ravi knew that his sister's flight has been delayed by 10 hours.")
- The study found that the MPFC was recruited in relation to information about physical appearance and internal physiology but the rTPJ was recruited for information about mental states.
- These findings favor the first hypothesis.

Now, two hypotheses have been offered to explain the activity in the rTPJ. One of the hypotheses suggests that rTPJ is a region that is specialized for reasoning about the mental states of other people, and the MPFC more broadly supports the reasoning about other people and their mental states. Another hypothesis suggest that the MPFC supports reasoning about social tasks, and the rTPJ is important for redirecting attention in both social and non-social tasks.

So, there are two possibilities, one is that rTPJ is a region that is specialized for reasoning about the mental states of other people, and for the other kinds things MBFC is really good. Another hypothesis says that the MBFC actually supports reasoning the social tasks, what rTPJ does is that it allocates your attentions to social and non-social aspects of the task. So, in one study, participants brain activity was measured in relation to processing information about a person's physical appearance.

For example, Raj was a very slim boy, their internal physiology, sheela was starving because she had skipped breakfast or their mental states. So, Ravi knew that his sister's flight has been delayed by ten hours. So, the study found that the MPFC was recruited in relation to information about physical appearance and internal physiology but the rTPJ was recruited for only information about mental states. So, these findings actually favor the first hypotheses.

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- In another study, it was reported that the same region of the rTPJ is significantly activated in relation to the false-belief localizer task used by Saxe and colleagues, and in relation to redirecting attention away from nonsocial cues that signaled invalid information in the attentional cuing procedure (Posner's task).
- Such a finding suggests that indeed, the same region of the rTPJ may support the control of attention for social and nonsocial stimuli.
- On further investigation, Saxe and colleagues found that the rTPJ has two distinct regions, one dedicated to mentalizing and the other dedicated to reorienting attention (Scholz et al., 2009).

In another study, it was reported that the same region of the rTPJ is significantly activated in relation to the false-belief localizer task used by Saxe and colleagues, and in relation to redirecting attention away from non-social cues that signalled invalid information in the attentional cuing procedure that is Posner's task. So, such a finding suggests that indeed, some region of the rTPJ is involved in the control of attention for social and non-social stimuli.

So, here is you can say that some evidence is there for the second hypotheses also. On further investigation, Saxe and colleagues found that the rTPJ actually has two distinct regions, one region is just dedicated to mentalizing mixed estimating that the other people mentally stays. The other region is actually dedicated to reorienting attention. So, what we can say is rTPJ is actually doing both the things.

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The superior temporal sulcus: Integrating non-verbal cues and mental states

- In several situations we need to pay attention to nonverbal cues rather than verbal cues about individuals to be able to understand and/or estimate their mental states.
- Moreover, patients with language comprehension deficits are better at detecting when someone is lying than are individuals without language deficits and control participants (Etcoff et al., 2000).
- Nonverbal cues such as body language, posture, facial expressions and eye gaze play a powerful role in person perception.
- Regions in the fusiform area and the amygdala use the facial expressions to make social judgments.

Now, let us talk about the superior temporal sulcus, in several situations we need to pay attention to nonverbal cues rather than verbal cues about individuals to be able to understand and or estimate their mental states. Moreover, patients with language comprehension deficits are better at detecting when someone is lying than are individuals without language deficits and control participants.

So, in some sense when you are sort of (())(12:24) with the whole activities involved in the language comprehension. Then, maybe you start paying more attention to the nonverbal cues as these people with language exit are probably better at tearing vendors, if somebody likes it or not. Not by talking to them or understanding about what they are saying, but just by observing their nonverbal behaviour.

Then this nonverbal behaviour basically include cue such as body language, posture, facial expressions and eye gaze and so on. Now, regions in the fusiform area and the amygdala found to use the facial expressions to make social judgements.

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- In the first year of life itself, children develop joint attention i.e. the ability to monitor another person's attention.
- One of the ways children do it is by noting the direction of people's gaze, something that is unique to humans.
- Tomasello and colleagues (2007) suggested that eyes evolved a new social function in human evolution, by supporting cooperative social interactions. Further, eye gaze is also found useful for understanding when other person's words are not matching their mental states.
- Investigating on the same lines, David Perret discovered that the cells in the superior temporal sulcus of the monkeys, are helpful in identifying head position and gaze direction. Some cells in the STS are known to respond to head direction while others responded to gaze direction.
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In the first year there is a development for the researchers, for example in the first year of life itself, children develop joint attention. Joint attention, that is another person's attention.

One of the ways children do is by noting the direction of people's gaze, something that is unique to humans. Because, we have this white region and when our black region is looking at some places, it is easily distinguishable. We can sort of move where the person is looking at actually. So, Tomasello and colleagues suggested that eyes evolved a new social function in human evolution, by being able to support cooperative social interactions.

Moreover, eye gaze is also found useful for understanding when other person's words are not matching with their mental states. For example, if somebody is tell you sorry and they are not communicating in the same way. It is not that he sorry is very incisive sorry and all that. Investigating on the same lines, David Perret discovered that the cells in the superior temporal sulcus of the monkeys, are helpful in identifying head position and gaze direction.

Some cells in the STS are known to respond to head direction, while others responded to gaze direction. So, the superior temporal sulcus can handle both of these tasks.

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- This ability to distinguish head positions from eye gaze allows the possibility of using these cues to make inferences about mental states. For instance, individuals who turn their head in the same direction as their gaze may be thinking about different things from individuals who keep their head facing forward but direct their gaze to a different direction.
- More evidence showing that the STS is important for interpreting eye gaze in relation to mental states comes from neuroimaging studies.
 - For instance, Pelphrey and colleagues examined whether activity in the STS depended upon the mental states indicated by the shifts of eye-gaze in another person.
 - Participants in their study were made to watch an animated woman who directed her attention either towards or away from a checkerboard that appeared and flickered in her right or left visual field. Randomly, the figure took either 1 or 3 seconds to shift her gaze.

Now, the ability to distinguish head positions from eye gaze allows the possibility of using these cues to make inferences about mental states. For instance, individuals who turn head in the same direction as their gaze may be thinking about different things.

As supposed to individuals who have basically oriented their head in the direction different to their gaze. Now, more evidence has showed us that STS is actually important for interpreting eye gaze in relation to mental states, basically comes from neuroimaging studies. For instance. Pelphrey and colleagues examined whether activity in the STS is depended upon the mental states indicated by the shifts of eye-gaze in another person.

So, they actually said that STS is really important here, So, what happened in this study, the participants were made to watch an animated woman who directed here attention either towards or away from a checkerboard that appeared and flickered in her light or left visual field. Randomly, the figure took either one or three seconds to shift her gaze. So, sometimes the person will just immediately look at the checkerboard after one second.

Sometimes, the person will take almost three seconds to shift the gaze to the checkerboard.

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- If the STS is involved solely in tracking shifts in eye gaze, then it would be activated to the same degree in relation to any shift in eye-gaze.
- If on the other hand, the STS is involved in integrating shifts in eye gaze with mental states, then activation of the STS should be related to where the character directs her attention, because eye gaze shifted toward the checkerboard and eye gaze shifted away from the checkerboard would indicate two different mental states.
- Consistent with the latter predictions, activity in a posterior region of the STS varied in relation to shifts in eye-gaze direction. Gaze shifts to empty space evoked longer activation of the STS compared to when the Gaze shifted to the checkerboard.

Now, if the STS is involved solely in tracking shifts in eye gaze, then it would be activated to the same degree in relation to any shift in eye-gaze. If on the other hand, the STS is involved in integrating shifts in eye gaze with mental states, then, activation of the STS should be related to where the character directs her attention, because eye gaze shifted away from the checkerboard would then, basically indicate to two different mental states. Thinking this and looking away from the checkerboard, and directly looking towards the checkerboard. Now, consistent with the latter predictions, activity in a posterior region of the STS varied in relation to shifts in eye-gaze direction.

Gaze shifts to empty space evoked longer activation because it is supposed to be calibrating, when the idea shifted to the checkerboard.

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- The researchers concluded that when the figure unexpectedly did not look at the target, observers were flummoxed and had to reformulate their expectation. As this process took longer, so the STS activity was prolonged.
- Also, they found that the STS activation was also linked to the timing of the gaze, i.e. if the gaze shift occurred at 1 s after the checkerboard appeared, the context effect was seen ; but if it happened 3s after the checkerboard appeared the context effect was not seen.
- The proposed that when the time between the resensation of the checkerboard and the gaze shift was too long, the gaze shift was more ambiguous and the observer did not necessarily link it to the appearance of the checkerboard, and no expectations were violated when the gaze direction varied.

Now, the researchers concluded that when the figure unexpectedly did not look at the target, shifted the gaze to the empty space. Observers definitely would have been flummoxed and had to reformulate the expectations and because this process took no longer, the activity is also sort of prolonged.

Also, these people found that the STS activation was also linked to the timing of the gaze, that is gaze shift occurred at one second after the checkerboard appeared, the context of the gaze effect was seen. So, gaze is shifted here, the checkerboard has appeared here and that is why I am looking there. But, if it happened three seconds after the checkerboard appeared the context effect was not seen.

So then, the participant did not think of this as similar but, thought that we need and that is important. So, the research is proposed that when the time between the resensation of the checkerboard and the gaze shift was too long, the gaze shift was more ambiguous and the observer did not necessarily link it to the appearance of the checkerboard, and the shift of the gaze to that exact location.

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- Finally, in a related study, a similar region in the STS was more strongly activated when a virtual-reality character made eye contact with the participant versus when the character averted his gaze from the participant.
- So, the STS seems to signal the focus of attention of other individuals as well as provide important social signals: like the individual may be trying to orient our attention away from a novel object or maybe wishing to engage in a social interaction.
- These studies also demonstrate that the activity in a visual processing region is sensitive to the context of the observed action.

So, if you look at this entire thing, finally a similar region in the STS was more strongly activated when a virtual-reality character made eye contact with the participant versus when the character averted his gaze from the participant. So, you can see the STS seems to signal which shown to be involved in orienting eyes to the different region in space. Say, for example, correlating the changing mental stage (18:19).

So, the STS seems to signal the focus of attention of other individuals as well as provide important social signals, say for example, like the individual will be trying to orient our attention away from a novel object or maybe wishing to engage in a social interaction. Sometimes, people are sort of you know looking at you and kind of go and ask them, about do you want to say something? That kind of a thing.

These studies also demonstrate that the activity in a visual processing regions is sensitive to the context of the observed action. It kind of takes into why that kind of action is happening? Why the attention is shift from this place to that place and so on. (18:58)we will talk about social permission in the next lecture, thank you.