Psychology of Emotion: Theory and Applications
Professor Dilwar Hussain
Department of Humanities and Social Sciences
Indian Institute of Technology, Guwahati
Module 3, Lecture 7: Emotions and the Brain

I welcome you all to lecture 7 of the course titled Psychology of Emotion Theory and Applications. So it is overall lecture 7 and it is the second lecture of module 3. So module 3 is about understanding the physiological impact of emotion or what physiological changes happen around us whenever we experience emotions. So in the last lecture, we discussed emotion and how it impacts your body and today's lecture will be talking about how emotion is associated with physiological changes in the brain itself. So before we talk about today's lecture let me give you a brief recap of the last lecture where we talked about how emotion is associated with various physiological changes in the body.

So in that context, we have discussed, all the emotions you know kind of involve our body. You know certain physiological changes happen whenever we experience some emotions, particularly intense emotions. So, some physiological changes happen in the body and we all might have experienced that whenever we experience anger or fear there will be some changes in the body which can be very much visible if it is a very strong emotion. So, fear may be associated with shaking of the body, an increase in heart rate and so on.

So lot of these physiological changes are very apparent. So, in that context, we have discussed primarily physiological changes associated with the autonomic nervous system and hormones. So autonomic nervous system we have already discussed is the part of the nervous system which controls all the automatic functions of the body. So, it kind of you know conveys signals from the brain to the different organs or internal glands of the body such as digestion, heartbeat and all kinds of things, breathing patterns and so on. These are all controlled by the autonomic nervous system.

They do not need our conscious intervention, they happen automatically, and in that context, we have discussed sympathetic part of the autonomic nervous system is primarily responsible for most of the emotions. Whenever we experience some emotions, particularly, intense emotions, the sympathetic nervous system activates the body you know or physiological changes happen it gives more energy to the body to deal with the situation. So all these things we have discussed. The second aspect is you know we talked about different hormones that are present in the body where you know the release of a lot of hormones is associated with the experience of the emotions. So in that context, we have discussed adrenaline, cortisol, dopamine, serotonin, estrogen and testosterone. So there

are other hormones but these are some of the major hormones that we have discussed.

So adrenaline and cortisol are mostly related to experience of stress, anxiety and also particularly distress. So, all kinds of distress or stress-related emotions kind of lead to the release of stress emotions, particularly adrenaline and cortisol. So, adrenaline and cortisol are mostly related to the stress system, stress whenever we experience stressful experiences or emotions which are very distressing they generally lead to the release of adrenaline and cortisol. Both of these hormones are related to kind of preparing the body to fight with the situation or kind of deal with the situation by giving extra energy by increasing heart rate and so on. There are certain differences in the pathways of how adrenaline is released and how cortisol is released so there are differences we have discussed in the last class.

Dopamine and serotonin are also called happy hormones primarily they are all in the you know positive mood and so on. So today's lecture also we will discuss in little bit more detail about dopamine and serotonin. Estrogen and testosterone are also related to changes in the mood, particularly estrogen it is primarily found among females and the changes or fluctuations in the levels of estrogen can lead to you know shifts in the mood and so on. Testosterone has also been found to be associated with aggression and anger apart from its impact on mood and so on. So these are some of the things that we have discussed in the last class.

So today we will be talking about primarily physiological changes in the brain or changes in the brain associated with emotional experiences. The key concepts that we will be talking about in today's lecture are brain lateralization and, the triune brain model. We will also be talking about the role of the amygdala an organ in the brain and its role in emotions and we will be talking about some neurotransmitters you know lateralizations which are primarily associated with certain changes in the brain itself like dopamine, serotonin and endorphins. So we will be looking at their roles in emotional experiences. So let's start today's lecture.

The concept of lateralization is kind of one of the most popular concepts in neuroscience that says the brain is divided into two halves. So if you have seen the anatomy of the brain or any picture of the brain you might have seen there are two distinctive parts in the brain left brain and the right brain. So this division of the brain itself is the concept associated with lateralization basically talks about this division. So, there are two divisions of labour kind of concept, two parts of the brain with some distinctive functions associated with them. So brain is divided into two halves with distinct functions so that typically is called the concept of lateralization.

So there are two parts of the brain right half of the brain is primarily responsible for

emotions while the left brain is primarily responsible for language and logical thinking processes. So it's more like one part is dominant for certain tasks another part is dominant for some other types of tasks that is the concept of lateralization. Now researchers kind of tried to study these or how they came to know about these kinds of functions. So different strategies were involved. Some of the researchers they looked at these functions of each half by temporarily paralyzing one side by testing the functions of the other part. So one side was temporarily disabled by using certain chemicals and then typically we see which and what kind of functions are dominant in the other part because only that part is active the other part is kind of non-functional at that time.

When the left half is paralyzed a picture may elicit emotional experiences which means only the right half is doing the functions so the functions of the other half could be very clearly seen through this kind of experiment while when the right half is paralyzed it may lead to logical thoughts and meaning related to image. This is how some of the experiments were done and these functions were discovered. Now people with a dominant left half so, some people may be more dominant some part of some side of the brain could be dominant for some other people another part could be dominant, so depending on that certain functionalities or dominance of certain functions could be visible in human behavior. So people with a dominant left half are often described as analytical people, people who are very analytical lot of logical thinking, and critical thinking so typically their left half of the brain is more active while the people with a dominant right half are often seen as more imaginative, creative and emotional. Creativity and emotional aspects become much more dominant for people when the right half of the brain is more dominant, which means it is more functional for whatever reason. However, now this lateralization concept that you know is not a kind of varied definitive only that if right half only does this and it cannot do any other thing so that it is not that kind of definitive division of labour but it is more of a dominance of certain functions rather than only exclusive functions.

This means that individuals dominated by the left half are not without emotion. It does not mean that people who are very logical and analytical do not have emotions so their right half is also a kind of functional and the only thing is what aspects are more dominant and those dominated by the right half are not without the ability to reason analogically. So people who are very emotional, and creative does not mean that they do not have logical thinking and other kinds of thinking. So it is more like dominance of function rather than exclusive functions. So additionally many factors besides lateral dominance can influence personal characteristics. So what kind of characteristics, what kind of qualities and mental functions one can do is not just determined by lateralization there can be so many other factors that can determine why what are the characteristics of a person.

So this is one of the aspects which could explain the differential functions among people

or dominance of functions among human beings. So this is one of the picture that is taken from one of the research papers. So it very clearly so the lateralization concept can be very clearly visible. So this is the left part, so you can see very clearly a fissure that divides the left and the right part of the brain. So, it is very clear there are two sections of the brain.

So this is the left and this is the right. So left brain has different functions like analytical thought, logical thought, and language more like analyzing, criticizing, discussing, and explaining you know those kinds of functions are associated with like mostly language and thoughts and thinking. The right half is about holistic thought, intuitions, creativity, art, music, and drawing gestures all these kinds of more creative and emotional aspects are more controlled by the right half of the brain. So this is the concept of bringing about lateralization. So that is also one of the aspects where we can explain emotion from the brain anatomy itself.

So sometimes people may be more emotional one of the reasons is that the right part of the brain is taking the dominance and that may make some people more emotional. So experience of emotion may be associated with this concept of lateralization. Another one of the very initial concepts that was given is also called as triune brain model. So this also explains how human brain has evolved for emotional functions. So MacLean in 1952 proposed this triune model of the brain model which is one of the earliest models that describes the brain and emotions and how the brain is associated with emotions. He divided the human brain into three segments. So according to him evolution as evolution happened different segments appeared one above the other in the human brain. So the first one is called the reptilian part of the brain that is responsible for basic sensory survival and reflex actions. So, all the reflexive functions and sensory survival-related functions are done by this part of the brain called the reptilian part of the brain. So we will show you the picture in the next slide. So, this is the most basic function which is probably shared with all the other animals also, the instinctive functions that are required for survival. So whenever some danger happens automatically you try to run away or something like that. So instinctively you run away, you do not have to think much. So those kinds of basic survival-related reflex functions are controlled by the reptilian part of the brain.

Then the next part that evolved above the reptilian brain is called the mammalian brain which is in charge of emotional experiences. It is also called as limbic brain. So the mammalian part of the brain is responsible for all the emotional experiences that happen. So, some of the animals can experience some emotions basic emotions. So it is it can be seen in mammals including human beings.

So that part of the brain kind of evolved to kind of help us to experience diverse emotional experiences. The last one that evolved as the outer layer of the brain is called the neocortex.

This is the part that most recently evolved all these convolutions that we see whenever you open the skull the outer layer of the brain that is called as the neocortex. So it is neo means neocortex that was developed. So it kind of deals with all the complex thinking process reasoning in human beings.

So one of the reasons human beings can think so elaborately and complexly is because of the evolution of the neocortex which is not that evolved in animals. So the thinking process evolved with the neocortex development of neocortex. So this three-part that is why it is called a triune model. So there are three layers of the brain responsible for different functions that evolved, with the evolution of different species.

According to Maclean the brain evolved during the course of vertibrate evolution into three layered organs. This is a kind of evolutionary process with each layer retaining some distinctiveness of its multiple evolutionary origins despite being intimately interconnected. So all these layers are interconnected but they have distinctive functions as well. The consequence of each layer can be seen in human behaviour, particularly the link between cognition and emotions. So all these different layers are kind of interconnected they kind of interact with each other to determine all kinds of complex human behavior. So this is one of the first figures which was given for the triune brain model.

So this is the innermost part is the reptilian part of the brain responsible for all the instinctive intuitive functions, and survival-related functions. It is kind of shared with all the animals. The limbic system then evolved above it, which is mostly related to this is also called the mammalian part of the brain responsible for all emotions. The neocortex which is the outer layer of grey matter evolved and with the evolution of this, a complex thinking process evolved and it is primarily seen in human beings. So the reptilian brain that we have seen is the first part of the brain that evolved according to this model is the oldest layer which is referred to as the reptilian brain.

It consists of the brain stem as an organ including the medulla. These are the different organs that are there in that particular part of the brain. So the different organs are there the names are; the medulla, pons, cerebellum, midbrain and so on. These are the different organs that are there in the reptilian part of the brain and they kind of help to survive and carry out all the instinctive functions required which are prevalent in the reptiles you know. So it kind of evolved from the reptiles and whatever reptiles we see they also have this part of the brain and it evolved and remains with us. So, this layer of the brain is not very adaptable. This doesn't change much even with learning. It may not change much, that is, it does all the vital functions, so, it is not very adaptable. It is much more rigid in its functionalities.

It is not adaptable to learning from experience and tends to repeat instinctive behavior in

a rigid manner. So this part of the brain is not changing much. It is only controlling the vital functions. In humans, this part of the brain governs vital functions such as breathing, heart rate, balance and all these things which are necessary for survival. So in humans, we still have that reptilian part of the brain and it does all these important functions.

Then comes the mammalian brain or limbic part of the brain which is mostly responsible for emotions. It evolved above the reptilian brain. So this part is above the reptilian brain is primarily composed of a group of brain structures known as the limbic system. So mammalian brain has different organs which are connected and they are called collectively the limbic system. This limbic system was first identified in 1800s but it became popular much later because of a neuroanatomist Papez. It was because of his research which he published in 1973. So he first identified this limbic system and it is also called as Papez circuit you know because he was the first person who kind of you know popularized or kind of made it more mainstream by his research that emotional functions of the brain which associated the limbic system became much more evident because of his research. So it is also called as Papez circuit is another term that is used to describe limbic system.

It includes organs like the amygdala, hippocampus ,cingulate gyrus, hypothalamus, ventral stratum etc. So these are all collectively called as limbic system. So we will look into that little bit more. So all these organs are kind of does different functions including the emotional aspects of the brain. So the major functions of the limbic system, all these organs which are in the circuit, they place major functions in terms of experience of emotions in the brain.

So we can see the impact of the limbic system in our conscious experience in the heightened valence positive and negative feelings and also the perceived significance of specific thoughts and images. So whenever we experience a lot of emotion this limbic system becomes much more you know activated because of whenever we experience emotions. So this part of the brain is shared with mammals that is why it is also called the mammalian part of the brain all the other mammals and we can readily observe the prototypical mammalian emotional response in our pets like cats and dogs. They also have you know this limbic system. Then comes the neocortex. The neocortex is the newest development in the brain and typically in the human brain.

So also in the primate brain it is kind of evolved. It is characterized by convoluted covering of the cerebral hemisphere. So whatever the outer layer that we see ,convoluted structure in grey matter that we see, that is called a neocortex. Compared to other mammals the neocortex has significantly expanded in non-human primates and humans. So it is primarily seen in you know primates and humans.

So,more specifically humans led to the development of complex thinking processes. In

humans, this neocortex is responsible for our sophisticated cognitive linguistic motor sensory and social abilities. So, the neocortex is responsible for all these complex abilities that have evolved in human beings. It allows us to be adaptable and creative in response to a constantly changing environment. So this part is more adaptable, with learning it changes all the functions can evolve, and can change, with new learning experiences. This is much more flexible and it helps us to adapt to different circumstances. So adaptability is one of the characteristics of the neocortex. This neocortex also plays a very critical role in regulating emotions because a lot of human emotions if you look at it emotions could generate but then it is our thinking process that also influences our emotions. So there is a very strong connection between emotions and thought processes. Some of these functions will be looking later in some of the lectures.

So neocortex also kind of interacts with emotional experiences and it has important roles to play particularly in the regulation of emotions. So limbic system may be responsible for emotional experience but this neocortex is also kind of interacting with it in terms of regulating in terms of modulating the experiences of emotion and it enables us to have more nuanced emotional experiences. So all the complex emotional experiences that human beings experience, one of the reasons is that this neocortex has the ability of complex thinking process that it can give shape and express itself in all kinds of complex, nuanced emotional experiences. So neocortex assessment of the situation is essential for socializing and controlling the expression of emotions. So it is the neocortex that gives an assessment and interpretation of the situation which kind of you know determines a lot of emotional experiences.

How do you interpret based on that the colors of emotions come into the picture. We have discussed some of these things in the theories of emotions that we have discussed in some of the initial lectures.

Now this Triune model also has many limitations. A lot of newer research has challenged some of these ideas of the Triune brain model proposed by MacLean. It indicates that the sensory emotional higher cognitive processes are not solely confined to individual regions.

So a lot of these newer researchers show that the lot of these functions that are specifically shown only you know that this part of the brain does only this function. So those kind of evidence are not very much you know they are in light of today's research that most of the brain kinds of work in an integrated fashion. So these are not solely confined to individual regions but rather involve activation across all the regions. So lot most of this function requires input from all the different parts of the brain rather than exclusively from some part of the brain. So in that context Triune model is not kind of is challenged of its very you know specific region wise functionalities.

Despite this, this model has given a lot of insights in terms of some dominant functions of different parts of the brain and it helps us to identify different systems particularly the different like limbic system which is responsible for emotions and so on can play a very critical and dominant role in emotions. At least it identifies different structures that still play a very critical role in emotional processes. So, this Triune brain theory can still be a useful framework for understanding the distinct layer of the mammalian brain. Obviously, you know this brain has all these layers there is no doubt about it and they have some of the dominant functions that are you know discussed in the Triune model. Brain functions more in an integrated fashion but this framework still is full in terms of identifying different structures and their functions.

Cortical and subcortical regions of the brain work in a coordinated manner to allow us to experience express and regulate our emotion in an appropriate way. So that's the kind of integrated idea that brain functions in by integrating by taking input from diverse brain regions in an integrated fashion it works. Dysfunction in any of these regions can lead to a range of emotional disorders such as depression, anxiety, and post-traumatic stress disorders.

Now the most important part or organ in the brain which kind of research has shown the most significant part in the context of emotional experience is the amygdala. So it's a part of limbic system it's an organ that is in that circuit of limbic system and primarily lot of research has gone into this particular organ and its role in emotions, particularly fear as an emotion.

So we will see some of the research findings here. So the amygdala especially,in the early investigation of emotional neuroscience, the amygdala emerges as a prominent area of interest within the brain's temporal lobe. So within the temporal lobe the part of the brain the amygdala that is where we will see the positioning of amygdala and so on. So amygdala has received a lot of attention because of certain research findings or some of the accidental findings. The amygdala gets its name from the Greek word for Almond because of its shape. It is roughly almond-shaped with a bilateral structure present in each hemisphere. So amygdala it's a bilateral means each hemisphere has one amygdala so both hemisphere has separate amygdala so that is why it's bilateral. So two amygdala are present one in each of the hemispheres. So it receives input from various senses including visions, hearing, pain, enabling it to link various stimuli with outcomes that follow. So it also receives a lot of input from sense organs and it kind of influences the outcome that follows. So additionally it also sends information to the pons and other regions controlling the reflex function. So it kind of mediates a lot of functions. So reflex functions also it kind of mediates information as well as to the hippocampus, and prefrontal cortex. So it is kind of connected with different kinds of organs which does different functions in that context it plays a very vital role.

So all these connections allow the amygdala to play a very crucial part in the mediation and control of major effective behavior such as friendship, love, affection, mood expression and most importantly fear, rage and aggression in all this it plays a role. So in that context, it is a very important structure in the human brain. So you can see some of the important major organs in the limbic system. So the amygdala is somewhere here, so if you see it's kind of circuit where different other organs are connected. So somewhere here it is the hippocampus which does many functions and one of the major functions that it does is the formation of memory it does a lot of functions.

So we will see how the amygdala and hippocampus kind of also are kind of connected in and helps in the formation of memory associated with emotions. So hippocampus then this one is the thalamus, and here it is the hypothalamus. So these are some of the important organs which are responsible for emotional experiences and they are all in the circuit of the limbic system. So, lots of functions of the amygdala actually emerged or it became evident because of certain study of brain damage observation from crisis with the amygdala. So in the cases where the amygdala got damaged because of certain accidents and when an organ or part of the brain gets damaged its functionality becomes much more evident because now that organ is not there. So whatever is visible which was not there earlier can be attributed to that particular structure. So, like many other structures, the amygdala initially caught the attention of researchers due to the behaviors exhibited by individuals who had suffered damage to it. So because of certain reasons amygdala got damaged so lot of different behaviors emerged and that led to the discovery of the functions of amygdala. So some of these case studies we will see now. So in the 1930s two researchers studying monkeys discovered Klüver and Bucy syndrome.

So this is the name of these two scientists, one was Klüver and another was Bucy. They discovered this so that is why it is called Klüver - Bucy syndrome KBS. They first noticed that a set of emotional changes occurred when both anterior temporal lobes including the amygdala were removed. So, they first discovered the impact of the amygdala in the monkeys when both the amygdala were removed from the brain. They observed certain behavioural functions or changes in the behaviour of monkeys that led to some of the ideas of the functions of the amygdala.

After the removal of the amygdala from the brain, these animals failed to recognize the emotional significance of the objects. We all know that certain objects are dangerous so we become careful when we touch those kinds of objects. So this sense also is kind of that sense of fear is that the amygdala was responsible for that when the amygdala was removed this significance of the object that associated with certain emotions that were not visible in the behaviour. So these animals failed to recognize the emotional significance of the

objects for example they approached snakes, picked up lit matches and put faeces in their mouths. So, they put disgusting objects in their mouths. They could not distinguish the emotional significance of some objects. They generally would be afraid of snakes but when amygdala was removed they were no longer afraid of snakes and they could also pick up lit matches. So which was dangerous for them earlier generally a monkey would not do that but when amygdala was removed they could do those kind of functions. A lot of this emotional aspect associated with objects were no longer there because when amygdala was removed. So it was very clear somehow that emotional aspects of amygdala functioning became much more evident. Monkeys with damaged amygdalae also fearlessly approached aggressive monkeys and unfamiliar humans often resulting in injury.

So they were not at all making any discrimination based on what is dangerous and what is not dangerous. So that comes from the experience of or the emotion of fear and that kind of emotion if it is there you judge everything based on what is more dangerous what is less dangerous. Now this kind of judgment was not there in those monkeys where this amygdala was removed for some reason. So it clearly showed the role of the amygdala in terms of emotional experiences particularly fear. Similar patterns were also observed in some other animals like normal rats and mice would stop what they were doing when they detected the scent of a cat generally.

A mouse or rat generally stops and becomes much more alert when they detect a cat somewhere in their environment. However, when tranquilizers reduce amygdala activity, rats become indifferent to the smell of cats. So that they were no longer afraid of cats because cat is a predator it can it will catch immediately and kind of so one of the most dangerous object for a rat. So normal rats would become alert and try to stop doing everything else and run away and those kinds of behaviours was there but when the amygdala was removed those behaviours were no longer visible in the rats when the tranquilizer reduced the activity of the amygdala. Some rats and mice will even fearlessly approach a cat after their amygdala has been destroyed. The concept of fear was kind of removed because of the removal of the amygdala. Humans with damaged amygdala is very rare because it's not ethically possible to do a lot of these experiments, especially in today's world. So, the damage cases were very few and it is not like you can directly damage it and see the impact of it which is ethically not possible. Very limited case studies are available. It's very rare, but some stroke patients often have damaged amygdala and surrounding areas. Some cases of patients who have a history of stroke which led to the damage of the amygdala and associated areas are available.

So some of the findings are visible from that kind of patients. Urbach- Wiethe disease is one of the names of the disease. It's a condition that happens where calcium gets accumulated in the amygdala and subsequently damages it. Often without much damage,

generally other surrounding areas remain fine but the amygdala gets damaged particularly in this disease. So some of the patients with this kind of disease also became a case study for amygdala functions. Our understanding of the human amygdala is largely based on small number of these kind of patients.

So individuals with amygdala damage exhibit symptoms very similar to those monkeys where amygdala was removed in Klüver - Bucy syndrome where they are no longer afraid of things that they were used to be afraid of . They put inedible or disgusting substances in their mouths. In case of humans they approach strangers randomly when seeking help rather than selecting someone who appears friendly or trustworthy. Even in human beings who had damaged amygdala, fear-related behaviours were no longer visible. So the earlier lot of objects based on their friendliness or trustworthiness people generally judge lot of things and then they approach people and behave accordingly. With the damage to amygdala, those kinds of appraisal and interpretations were no longer there. So people would do things which are dangerous probably because the judgment of danger was not there in their whole cognition. So people with amygdala damage, rate all faces as almost equally friendly or trustworthy when asked to assess them. So that was also another thing in experiments where they were asked to judge faces with different emotions were shown to them. Patients with amygdala damage rated almost all faces equally friendly or trustworthy ,which a normal person would never do.

So certain faces look more dangerous having certain anger emotions so they will not be rated equally in terms of friendliness or trustworthiness but that kind of judgment was not there in the patients with amygdala damage. A lot of this observation clearly indicated the role of the amygdala in emotions and mostly it was associated with fear became much more evident. Fear was the most strong emotion that was important emotion that was associated with all these findings. So we will see more specifically in the context of fear as an emotion and how it is connected to the amygdala. So individuals with the damage to their amygdala display notable characteristics of being fearless towards anything.

So this was kind of evident in all these experiments that were done. Earlier, a person or an animal used to be afraid of certain objects. Now after damage to the amygdala or removal of the amygdala in animals, they were no longer fearful towards those objects. Earlier they were very fearful now they are no longer fearful which is very evident. So this observation prompted researchers to investigate whether amygdala plays very crucial role in fear associated behaviors. At least those findings indicate that amygdala is strongly connected to the experience of fear.

When rats were subjected to amygdala damage they not only failed to acquire new stimuli related to danger but also lost previously learned fear weaknesses. The research showed

that they were not only not fearful in the present context but they even forgot all the past learned fear responses. So that was also lost. Although one study suggested that right amygdala damage resulted in a greater deficit than left amygdala damage some study shows the differences could be more notable in case when right hemisphere amygdala was removed as compared to the left but it was much more profound when both the amygdala were damaged. So all these findings at least indicate that amygdala activation is responsible for experience of the fear.

So some theories are stronger versions and some theories are little less in terms of how they believe about the functions of the amygdala in response to fear. The strongest hypothesis or strongest theory tells us that fear is synonymous with the amygdala. It could be one of the strongest predictions and any individual or creature lacking an amygdala is incapable of feeling fear. So it's the strongest version that fear means amygdala. So without amygdala no fear. A less extreme interpretation is amygdala activity may be crucial for perceiving threatening situation. So it's not like all the fears are associated with the amygdala but it is important for perceiving threatening situations.

So it is very important to judge a situation as threatening or not amygdala is responsible exhibiting fear-associated behaviors but it may not be necessarily required for experiencing fear. So certain aspects of fear may be associated with the amygdala as compared to no fear without the amygdala. So research generally shows more evidence towards the less extreme interpretation. So this emphasizes the constraints of conducting research in the laboratory and so this kind of research are very difficult to conduct especially since you cannot do most of these experiments of human beings because of ethical issues. You cannot damage some organs and look what at its impact. Even in animals there are ethical issues you cannot just do and experiment on animals if it harms it there are ethical issues and the researcher has to take care of a lot of ethical issues.

A lot of constraints are there for doing this kind of research, especially the ethical issues and with animals, they cannot communicate what is happening with them. So you cannot kind of understand and human beings very less cases are there but some whatever cases are there knows more deeper understanding came from those human studies only. So in the context of human fear we will see more in the context of human how the amygdala was associated with fear. What role does the amygdala play in the experience of fear? So that is the those two hypotheses that was proposed . We will see evidences associated with this whether the extreme case was evidence are available or less extreme cases or hypothesis was kind of evidence are associated with those less extreme hypothesis or not. So if the amygdala is damaged which aspects of the fear are affected? So these are some of the things these are the questions that were addressed by lot of researcher.

So while it is uncommon to come across patients with selective amygdala damage few cases as we have been seen where studies were done. Some individual with amygdala damage there is a reduction in the magnitude of distress related startling facilitation as observed in the study with rats. As in the case of rats, that was evidence of similar symptoms or reactions in human beings. Additionally, MRI magnetic resonance imaging studies also showed that the amygdala displays more activity and more heightened activity during fear conditioning and when individuals encounter cues of danger. So whenever they experience fear or some cues related to danger generally at that time amygdala becomes more activated.

So that was visible in MRI imaging studies. So there also shows this is when some organs or some parts of the brain becomes more activated when certain functions are done which means those functions are associated with that part of the brain. It is not so easy to make such a conclusion. A lot of other things we need to observe but this is one of the implications of that kind of imaging studies. So numerous studies also found that individuals with amygdala damage have difficulty recognizing fearful facial expressions. So particularly this fearful face was difficult to recognize what kind of emotions they were going through. So if you see a fearful face generally we will understand it. We can say there is fear evident in the face of that person.

So amygdala damage leads to difficulty in recognizing of such fearful faces. So that also shows that fear-related things kind of affected. So in one of the instances woman with this particular condition Urbach- Wiethe disease was able to draw representations of happy, sad, surprised, disgust, and angry faces. She could draw those happy face, surprise face, disgusted face, and angry face but she could not draw a frightened face. This again shows that she was not able to process fear-related things. FMRI studies magnetic resonance functional magnetic resonance imaging studies also showed that amygdala exhibits greater activity when being fearful faces than neutral faces. When fearful faces were shown amygdala became much more active as compared to a neutral face was shown even when they were presented subliminally. It means it was not very clearly consciously visible but subliminally they were presented. Consciously one person may not be aware of what is presented but very subliminally it was presented.

Some studies indicate that the patient with amygdala damage reported experiencing fear and other emotions relatively normally in day-to-day life. Some studies also show that even with the damage of amygdala some people could experience emotions in their day-to-day lives. In a study that compared stroke patients with the amygdala damage to those patients with damage to other areas. So this participant rated a series of picture for pleasantness and unpleasantness and reported how aroused they felt.

So this was the experiment that was done. So in both these cases of patients, one case or

one group where the amygdala was damaged in another group some other areas were damaged and they rated a series of pictures shown to them on the quality of pleasantness and unpleasantness. The research shows that individuals with amygdala damage rated the picture similarly for pleasantness or unpleasantness with other group of patients but they reported almost no arousal in response to unpleasant images. So whenever they could see unpleasant images, there was no physiological arousal which was normal in other kind of people. So at least it indicates that a lot of evidences are there for amygdala , that it is responsible for emotional experience, particularly fear-related emotions but it is not that all facets of emotions are associated with amygdala. So kind of less extreme kind of hypothesis for evidences are generally visible but no doubt most of the evidence shows that it has very strong role to play in the experience of fear.

Now experience of the fear there is another aspect associated with it is the memory. So lot of fear is associated with memory and emotional memory or emotions are associated with lot of memories. So the amygdala can play role in the formation of memory also let us see the evidences. Does amygdala play a role in creating emotional memories? If it plays role in emotions then they should also play role they might it might also play role in formation of emotional memory as well.

So amygdala does not appear to be essential for every type of memory so it is not responsible for all kinds of memory. There are different kinds of memory and we can have a memory for learning facts and figures and there can be a memory for remembering episodes that happened in our life which is called episodic memory. Different kinds of memories are there but we will not go into too much of memory aspects now. For instance a study on patients with amygdala damage found that they could comprehend that a conditioned fear stimuli meant a loud noise as approaching but they did not show a physical response to it.

They could kind of comprehend what is this all about, that this is a response, this is a conditioning response which stimulates fear but they did not show any fear. Mentally they understood this is associated with fear but they could not experience it. So amygdala damage did not hinder their ability to learn facts factually they could learn and understand everything, but in terms of experiencing, their capacity was kind of hindered. So Elizabeth Phelps has also highlighted the amygdala's connection to the hippocampus. As we have seen in the diagram the hippocampus and amygdala are very connected to each other. Their positions are near to each other and the hippocampus does a lot of important functions in the formation of episodic memories.

So to remember an episode of your life is different from remembering facts. So these are different types of memory, remembering an episode of your life and remembering some facts about something are two different types of memory. So episodic memory is more

likely to involve emotions because we remember a lot of episodes in our life especially if they become their emotions are associated with those episodes. So let's say you may remember your last birthday because lot of happiness lot of guests were there, relatives were there you enjoyed you had a lot of happy memories about it. So this is an episodic memory with a lot of emotions also included in it.

So hippocampus kind of mediates the formation of episodic memory. Now amygdala is connected to the hippocampus so it can also kind of contribute to the formation of episodic memory especially the emotional part of it. So amygdala activations related to experiencing strong emotions facilitate this consolidation of long-term episodic memory. So those episodes where emotions are involved it is activation of the amygdala that probably also facilitates this consolidation of long-term memories ,of memories that are by the hippocampus. The interaction of hippocampus with the amygdala may create long-term episodic memories especially emotional memories. So amygdala activation might level specific memories as a strong emotional significance and trigger processes that enhance these memories for future reference.

So evidence at least shows that amygdala also plays a role in the facilitation of, formation of emotional memories with the help of the hippocampus. There is growing evidence to support this hypothesis as indicated by a study of American soldiers who are wounded in combat. So one of the study found that among those who experience brain damage those combat soldiers who experience brain damage outside the amygdala. So whenever somebody is in a war situation there can be damage in any part of the brain or any area wherever that attack has happened. 40 per cent develop post-traumatic stress disorder. So wherever post-traumatic stress disorder is a disorder where now people after a traumatic event very intense emotional experience the person develop may develop a PTSD or post-traumatic stress disorder where there are symptoms like you know re-experiencing the person again and re-experiences those memories again and again and there is also avoidance to this because these are very distressing they don't want to face them. So they avoid them and there is a lot of hyperarousal associated with those memories whenever you remember them ,you become very disturbed and so on. So these are the symptoms of PTSD. A lot of the soldiers where the damage was not in the amygdala or any other part of the brain 40 percent of them develop PTSD. So PTSD is a common thing that generally soldier develops after traumatic events like war which has characteristics of vivid intrusive memories of that traumatic event of war situation. In contrast they found none of the soldiers with brain damage that involved amygdala developed this disorder. So the soldiers whose brain was damaged and the amygdala was damaged in those region where amygdala was there, then none of them developed PTSD. To develop PTSD you need to experience those fears again and again, that is the main symptom. If the amygdala is not there then this fearful emotional processing will not be there. So they did not develop PTSD because

the processing of emotions or formation of memories of emotions and fear is not possible without this amygdala. It plays very important role in those kinds of formation of memories. So when these memories will not be formed because the amygdala has been damaged so then there is no question of developing PTSD. So this also indirectly shows evidence of role of amygdala in formation of emotional memories. So just a final thought on amygdala is that you know a lot of pieces of evidence are there no doubt, amygdala plays a very important role in the formation of memories and emotions and particularly the fear emotions. Now concluding a lot of these studies is not so easy because a lot of complexities are there as we have seen the brain is an integrated organ. Lot of functions are done , every part brain does it in an integrated way lot of these functions. So separating function of one organ exclusively is very difficult you know. You cannot do this because most of the functions are done by every aspect of the brain so separating one part is very difficult. Thus, identifying the psychological processes that are influenced by specific brain structures is a very complex and time-consuming process. This is what a lot of these evidences show. While researcher may observe increased activation of a structure during the particular task, like the amygdala we have seen for fear related things, or a decrease in performance when it is absent as we have seen. Now each of these tasks may include multiple aspects, multiple areas of the brain also, and multiple psychological processes, researchers only make educated guesses about such processes associated with a particular structure and one needs to rule out a lot of these possibilities which takes time and mostly the dominant functionalities only comes out. Exclusive functionality is not so easy to separate. So there are a lot of practical constraints and concluding lot of this kind of studies is not so easy and it is very time-consuming but at least it indicates the dominant functionalities of certain structures because of some multiple evidence.

So lastly we will be talking about neurotransmitters. These are are basically chemical messengers which are released in the blood as well as between the neurons that carry messages between neurons, one neuron to another ,so when a chemical messenger is put so it conveys message from one neuron to another neuron this is how the messages are conveyed in the nerve cells and target cells all over the body which could include glands, muscles, neurons and so on. So these are neurotransmitters that play a very important role the functions are done the functions of the body is contributed by neurotransmitters.

These molecules are continually at work in our brains coordinating everything from breathing to heartbeat to learning and concentration level. Everything is controlled by a lot of these neurotransmitters. They can also influence our psychological functions like fear, mood, pleasure and joy. So emotions are also influenced by neurotransmitters so we will see only those neurotransmitters where the emotions are associated with them. Some common neurotransmitters in the brain are serotonin, dopamine, epinephrine, norepinephrine, endorphins and so on. So we will see dopamine we have discussed a little bit in the last lecture but little bit more we will be discussing here.

So it is a neurotransmitter that plays a major role in both pleasures and problems. So it is a kind of in the last lecture we said these are like happy hormones or neurotransmitters which plays role in your experience of pleasures and happiness and mood particularly enhancing mood and other things. So it is produced in this part called the ventral segmental area. So this is in the midbrain and helps different parts of the reward system communicate with each other. So it is a kind of associated reward system. So it kinds of gives you pleasant experiences whenever there is a reward and that kind of positive thing Dopamine plays a very important role making it essential for feeling of anticipation and reward.

A positive mood is associated with dopamine. Dopamine motivates also goal-oriented behaviour, reward system and other things. Many recreational drugs change this dopamine reward system. They increase this dopamine level, such as cocaine. It prolongs the effect of dopamine in the synapse. So when dopamine is released between two neurons they prolong that dopamine release. So the more dopamine will be released the more positive mood and pleasure they will experience and so on associated with those drugs. So this is kind of chemically inducing dopamine in the system. It prolongs the effect of dopamine which is why they become more addictive and more pleasurable. So people find it difficult to not take them.

Even caffeine can increase dopamine release so you feel good when you take caffeine. Alcohol can also increase dopamine activity in the reward circuit though the exact mechanism is still not clear. A lot of these things are where we get a lot of pleasure out of it. Dopamine lot of this system dopamine release could be one of the factor. Different drugs become addictive because of the effect of dopamine reward system.

So studies have found that individuals addicted to drugs like cocaine, amphetamine and even alcohol. These people generally as they take more of these drugs they also have fewer dopamine receptors in the reward circle. So if they have fewer dopamine receptor circles this also reduces the ability to experience pleasure from other things. They need more intense doses of such substances to experience pleasure out of them. So as people take drugs and other things they need more and more doses of it.

They now have reduced ability to experience pleasure from the same quantity because they now have fewer dopamine receptors. So they need more and more and more and more intense those kinds of thing and they lose the ability to get pleasure out of other things in life. So that is why addiction becomes possible. One of the reasons or mechanisms is this dopamine activity. So addiction to certain behaviours like even gambling, shopping, playing video games, sex and many others may share some of the same neural mechanisms.

These activities are also like addiction to drugs. A lot of these activities can become addictive. These activities can activate dopamine reward circuits. So they activate these dopamine actions and they almost like the addictive activity. People become much more addicted to them because of the pleasure associated with dopamine activation. So research has shown that treatment for Parkinson's disease also sometimes increases dopamine levels. Then one of the side effects could be people becoming addicted to gambling problems and so on. As the activity increases they also become addicted to some other things like gambling and so on. This could be because of changes in the dopamine activity in the reward circuit. Serotonin is again another neurotransmitter that is also involved in a variety of psychological processes including memory, appetite control, and sleep but exact role in emotional experience is not yet clear but there are a lot of indications. Research has shown that serotonin also plays significant role in mood as it is also evident in dopamine.

Specially this is also used in the treatment of depression where anti-depression medications called selective serotonin reuptake inhibitors. A lot of anti depression medication uses serotonin or increases tries to increase the level of serotonin and keep the serotonin in the synapse for a longer period thereby increasing stimulation of serotonin receptors. So to change the mood from depression to let us say make them normal and so on. The relationship between serotonin and depression is very complicated and a lot of things are still not clear. A lot of this medication that tries to enhance or increase the level of serotonin in the synapse does not start improving mood initially but after a week generally, the mood becomes better.

So the test of this hypothesis that depression is caused by inadequate serotonin levels has produced inconsistent findings. So it is not a very consistent finding did not support this particular hypothesis. So low levels of serotonin have been linked to aggressive behaviour as well as demonstrated in the laboratory research in rats, mice and monkeys. So serotonin can be also linked to aggression apart from this mood. Human studies have also found that people with low serotonin levels are more likely to commit violent crimes including arson and repeat offences after being released from prison.

So low serotonin could also kind of stimulate aggression and violence and so on. Children and adolescents with low serotonin levels are also more likely to reengage in violent behaviours. So lot of research indicates that serotonin is also linked to violence and aggression. Additionally, people who survive violent suicide attempts with low serotonin level are more likely to attempt suicide again. So if suicidal people have low serotonin level they are more likely to repeat those kinds of suicide attempts again and again.

So this may be linked to low serotonin levels. A review of available human literature found that relationship between decreased serotonin and increased violent behaviour was

consistent although moderate in size. So lot of studies show this relationship but the relationship may be of moderate size, not a very strong correlation. So at least it indicates that it can play very important role in this particular behaviour.

The last one is called beta-endorphins which is also another neurotransmitter that plays a very important role in the positive mood and kind of pleasures. These are mostly opiod peptides kind of neurotransmitters that is also very important for regulating emotions. One of the well-known examples is beta endorphins which function as body's natural pain killer. So beta-endorphin is more like a natural pain killer, like morphine given for pain killing. So it is like naturally produced morphine in the body. A lot of pain both physical and emotional pain can be reduced by the release of endorphins. So in that sense it is very important to connect with emotions.

So this endorphin is a blend of the word endogenous morphine since it operates similarly to morphine that is self-produced. So it is like self-produced morphine which helps you to release or remove pain. Although not all physical traumas result in endorphin release, endorphin activity in the brain stem can reduce pain responsible of physical traumas and so on. So in pain release, it may help. Several studies have connected alterations in beta-endorphins activity with both physical and emotional pain. So both physical and emotional pains could be associated with low endorphin levels and both humans and laboratory animals also experience reduced endorphin release during times of social grief and loss.

So whenever we experience emotional pain or grief or sadness generally there is a decrease in the release of endorphins. So the increase of endorphin release, your mood gets better. Lots of research also shows that when we do physical exercise, endorphins are released and it helps you to enhance your mood. So after exercise generally people feel good mood. One of the reasons is release of these endorphins. So in one study baby guinea pig wept when separated from mothers indicating distress and low endorphin release. So whenever these pigs kind of separated from their mothers and they experienced distress endorphins release was very low. However, they ceased crying when given a mild dose of endorphin to replace the decreased endorphins. When external morphine was given to replace the decreased endorphins, they stopped crying. So it immediately had an impact on the mood.

Conversely when given naloxone, a medication that blocks endorphins activity they cried even harder. So when endorphin was further blocked they started crying harder. So it also shows emotional pain and sadness is also associated with low levels of endorphins. Another study asked young women to describe life events including sad and neutral ones. PET scan which is positron emission tomography is a scanning technique. It revealed the decreased endorphins release in various brain regions when the women recounted sad events but not other types of events. Again sad events when they kind of discussed sad

events ,this PET scan showed decrease endorphins release in the brain. So this also shows its association with mood and emotions. So its endorphins mediate both physical and emotional pain. So both physical pain as well as emotional pain is associated with probably low endorphins level and with the release of higher endorphins level mood becomes much better.

So these are some of the findings related to neurotransmitters which are associated with emotions. So it is very clear from this module that emotions are associated with a lot of physiological changes in the body as well as brain and all these changes are associated with different emotions and we cannot talk about emotions without really looking at the physiological changes that are associated with emotions. So understanding physiological changes is very important to understand the impact of emotions. So this module I think we have tried to touch up on some of the important aspects of it and this understanding will help us to understand emotions in a better way. With this, I stop here. Thank you. Thank you.