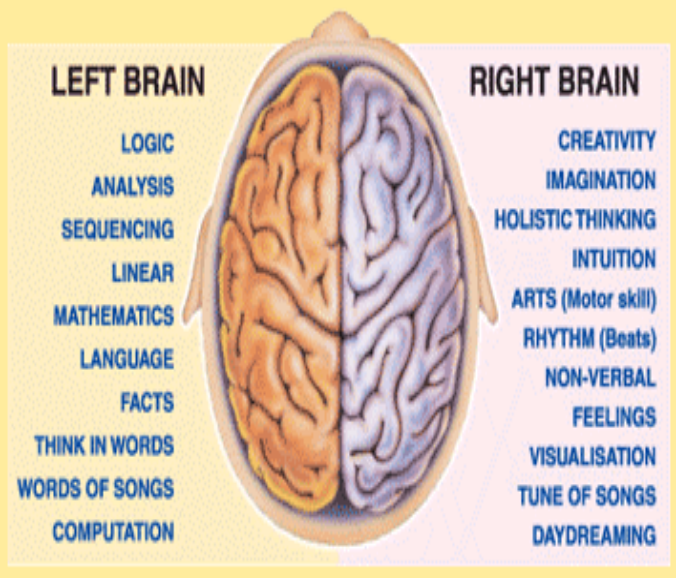
Higher Cortical Functions

This lecture includes:

- Compare between right and left hemispheres
- Cortical processing
- Damage to V1 (Primary visual cortex)
- Damage to “What” pathway (Lingual/Fusiform gyrus)/area V4
- Achromatopsia
- Color Anomia and Color Agnosia
- Damage to occipitotemporal Gyrus (complete /Partially)- Prospagnosia/Agnosia
- MRI for a patient with a lesion

➢ Right and left brain functions:

- The two hemispheres look like each other and they are almost identical, but they have some differences in their functions.
- The right hemisphere is the “nice” part of the brain that is responsible for enjoying music, expressing emotions and how do we taste art :P …This is not 100% accurate yet not 100% wrong because as we said each hemisphere looks similar to the other but with some variations in anatomy and physiology.



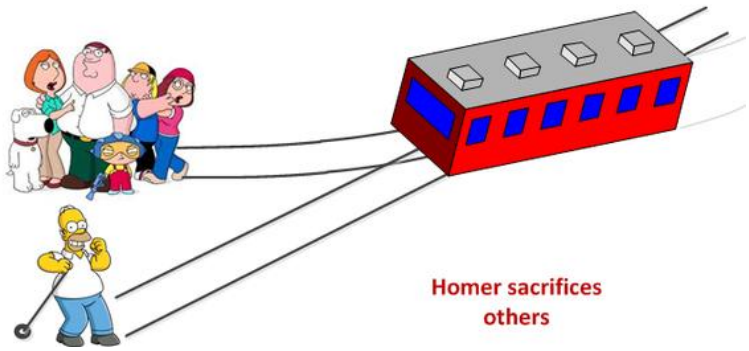
For example:

- The function of the precentral gyrus on the right side of the brain is the movement of the left side; also the function of the left precentral gyrus is the movement of the right side.
- Also, there is a somatosensory cortex on both the right and left side of the brain.

- And this is applied to all parts of the brain; we have language area on both the right and left sides of the brain and both are related to language, but there is variation in the level of analysis of language between the two sides.
- In addition, we have visual cortices on the right and on the left sides and they, especially the primary visual cortex, will be activated identically; that means they look very similar on both sides of the brain. However, **the difference is when we go to association and processing cortices, here one visual cortex may be activated more than the other due to certain things or the other visual cortex may be activated more due to certain other things.** This might be due to the fact that some of the visual cortex has to do with emotions, color and art, and the right side here is concerned with these differently from the left side.
- Remember that there is a certain connection between the right and left hemispheres and in case of damage to one of them, one can compensate for the other by time and practice.

➢ These are two expiements introduced by the doctor, this is related to the topic of "morals" that was introduced 2 lectures ago and not related to our topic in this lecture:

- **The first experiment (the train experiment)**: There is a train walking on a certain lane and on that lane there are 5 children playing, and there is an adjacent lane on which a person is walking. Imagine that you can't shout to the children to tell them leave but you have a control over the train's lane in this situation. Which decision would you choose, staying on the same lane and protect one person or switching to the other lane to protect the 5 children?
  From this experiment it's true in all societies that 75% go with switching but this doesn't mean that it is the right decision. Indeed, the children are misbehaving when they play on an illegal place, and that man was just walking by! It's not that walking man's fault so why to save those children at the expenses of his life?



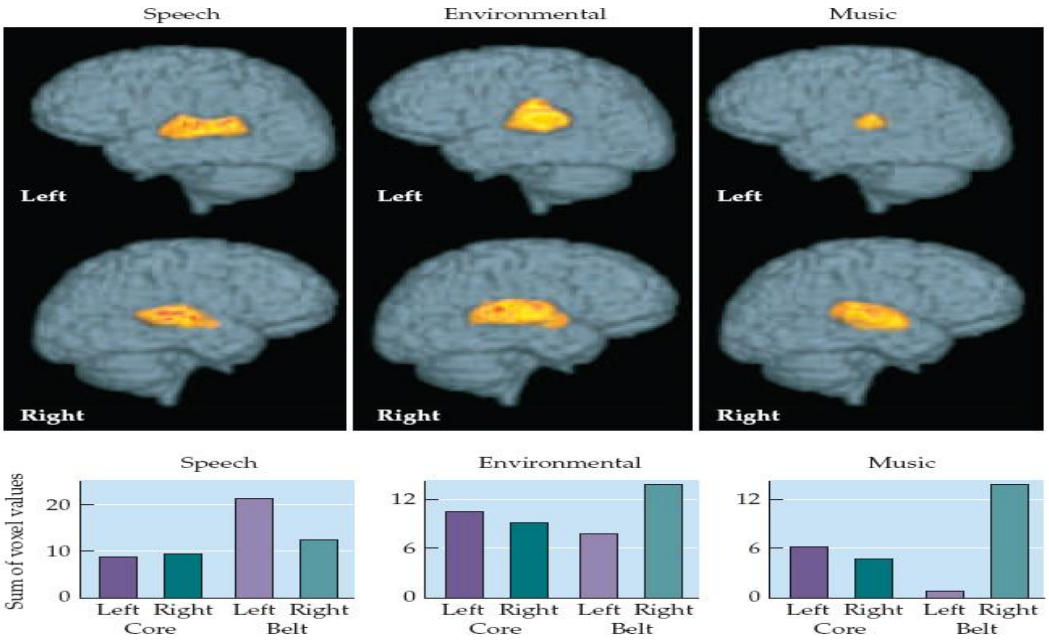
- **Another expirement**: Suppose you were in a war and you go to a refuge (ملجأ) to protect yourself from the enemy and in the same place there is a small baby crying and didn't respond to you when you calm him, of course his loud sound will call the enemy's attention and this forms a risk on all the people in the refuge. The doctor asked about the decision you'll make; either to kill the baby (he'll suffocate by continuous closing of his mouth!) or to keep him alive and display a high risk on the people in the refuge.

(It's an issue of conflict and contradictions that the most choose saving the baby, yet killing the walking man! If you want to know the discussion between the doctor and students please listen to the record).

- we can conclude that: Perception and mind, especially in moral judgment, differ according to multi factors like if someone sees you or no (as in the first experiment), or if you know the people in the situation or no (as in the second experiment). These factors influence our decision either directly or indirectly.

➢ Back to today's lecture and the right and left brain functions:

- Different functions of the brain left and right sides are due to difference in anatomy, size, and complexity of the gyri. Please refer to the following figure while reading the next example on the difference in functions between right and left sides:



- In case of listening to the **doctor speech**, the **left side will be activated dominantly** upon the right side as it is the **left side which is concerned with words and analytical thinking and speech center**. In contrast, when you are listening to the sound of rain and wind and **environment, both hemispheres will be working at the same level.**
  When listening to Music, the **right side will be activated dominantly upon the left side. Notice that both right and left auditory cortex are working** but speech is prominent on the left side, environmental on both right and left sides at the same level, Music mainly right. This is applied to both right and left handed people (90-99% equally). Some of Left handed people have some areas mixed and these people have pathological left handed (deformation in the brain).

➢ Cortical processing:

- Signals will enter to the cortex and it will be analyzed by the brain to be processed and to come up with information from that signal.
- Cortical processing is in two ways**:**

1- Parallel processing:

Each signal here is analyzed separately and has its own pathway, and there might be gathering of the information with each other finally.

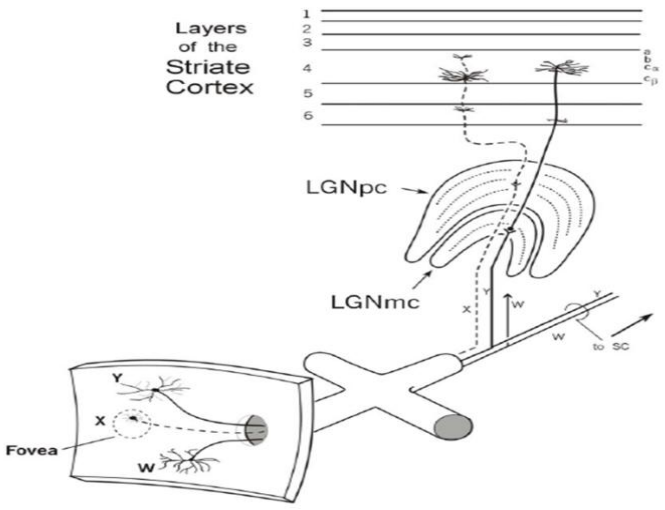
2- Continuous processing:

The same signal is analyzed gradually until we reach to useful information.

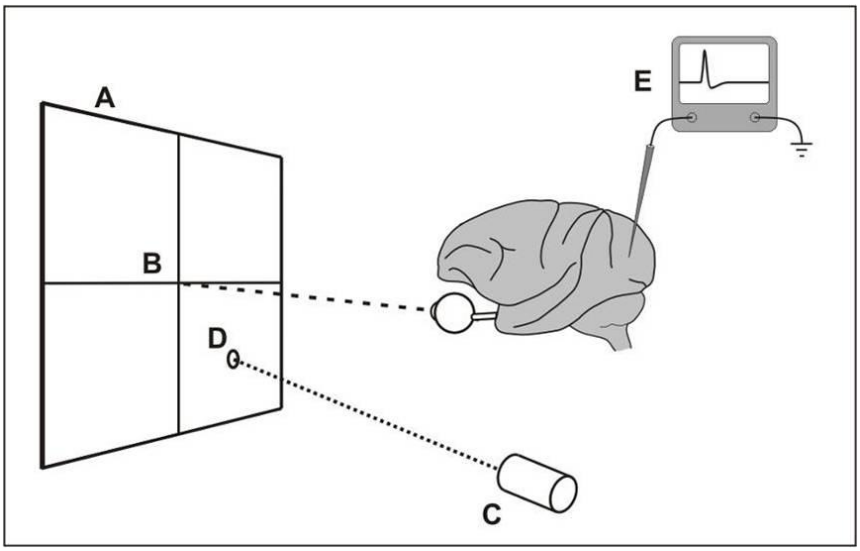
Most of these processing occur together (Continuous and parallel), an example on this is seen in vision; we have what pathway and where pathway separated from each other but in the same pathway there is a continuous processing. The best example of cortical processing is visual processing because vision takes a big part from the cortex, and because it is the most famous understood processing.

➢ Visual processing as an example:

- As we said before **X type** of ganglionic cells which receive more from **cones** are associated with **parvocellular** system which is concerned with **detailed** vision.
- **Y type** of ganglion cell which receive more from **rods** is associated with **magnocellular** system which is concerned with **movement** more than details.

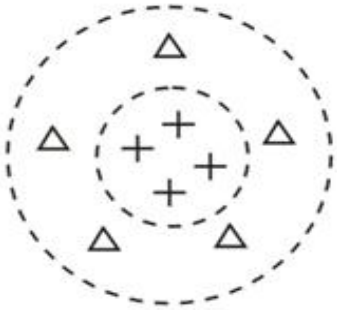


- These X and Y ganglion cells, after going to LGN (lateral geniculate nuclei) which represents Parvocellular (3-6 layers of LGN) and Magnocellular (1-2 layers), will go to primary visual cortex (V1) mainly layer 4. From here processing starts more and more to end up with a picture.
- Before talking about the visual processing we should understand the concept of the receptive field here. From Fundamental Neuroscience book, the receptive field of a neuron is defined as that region of the visual field in which the correct stimulus will have an effect on the activity of the neuron either excitatory or inhibitory. The following figure shows a study on the receptive field:



If we try to make a recording for a neuron in layer 4 in V1 (which is the primary visual cortex), and we put spots of light toward a screen in front of the eye and see whether the studied neuron will respond or no, we will notice that on one spot there is a response on the recorder, but if the spot of light is in the surrounding areas it will

produce no sound from the recorder so there is no electrical signal i.e. there is no response to the stimulus (spot of light) from the studied neuron which means that it is a silent neuron at that moment.
This is called **concentric or centric receptive field neuron** which means that the neuron responds to light in a specific or center spot (where the pluses are in the next figure) and doesn't respond to light when it's in the surrounding area (where the triangles are in the next figure). Remember that these neurons are present in **all V1** (primary visual cortex) and exactly in **layer 4** of V1 because there we receive action potential from ganglionic cell.

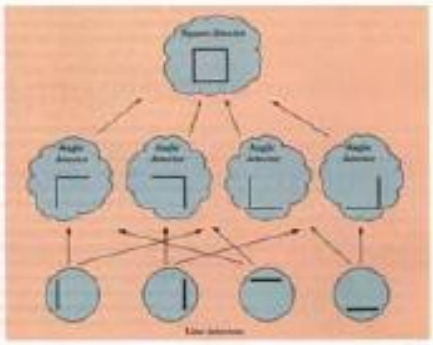


+ = "on" response
△ = "off" response

- Now we come to visual processing, this figure illustrates the whole story:

Visual Image Decomposition

Simple, complex and hypercomplex cells can work together to decompose the outlines of a visual image into short segments, the basis of simple and complex object recognition.



It goes like this:

1- Retina will send **dots** to the primary visual cortex and as layer 4 gets the input processing is started.

2- From layer 4 processing will continue to **layers 2 and 3** (still we are in V1) and there if we start recording from layer 2 and 3 of V1 we will notice that neurons respond to a **line** in a **specific direction** and **specific location**. What really happens is that a group of neurons in layer 4 will go to stimulate or **converge on** specific neurons in layer 2 and 3.
That's why V1 is divided into columns; each column is related to specific orientation. Don't forget that each column contains ipsilateral and contralateral visual inputs. Each column is called: the orientation column of the visual cortex. And the visual cortex is also called the **striated cortex** because it is divided into columns with specific orientation.

> So all the layers of **one column** in the V1 will make identification of **only one line** in **one direction** in the space.

3- Now we will move to **complex** vision (not only one line). When we move to **V2** we will notice that it will respond to **multilines** (3-4 lines) in that area.

4- Then we will move to a more complex one as these multilines (3-4 lines) will stimulate and converge on one neuron that is involved in processing of **hypercomplexed** type which responds to direction and space but is related also to **volume**. Each shape whether circular or triangular has its own hypercomplex neuron.

5- Then we continue more and more processing through **association** and decomposing of the picture; as different lines will make for example a square with certain volume and if there's a circle inside it then in this step we know that it might be a door. Also if lines make four legs of an object we know in this step that it might be a chair and so on.

- As we move more and more in the what pathway we recognize the object so in the example of 4 legs it might be a chair or animal with four legs; and if it is a circular object is it a ball or fruit and so on.
- Remember: the visual cortices have **37 areas** that have different numbers, names and colors**.**
- A note to mention here is that the doctor said that complex and hypercomplex neurons are not in primary visual cortex whereas Fundamental neuroscience book says "the variety of receptive field types are observed in V1."

➢ Damage to primary visual cortex:

- ***Blind sight:***
  If there is a bilateral damage to V1 there will be blindness, but if you try to put your hands in front of the patient's eyes and sway he will surprisingly blink and he will feel if you smile to him or not …Why this happens?

  Because there is **certain percentage of Y &W ganglionic cells that will go to midbrain** and emotion and superior colliculus and pulvinar and to association cortex so there is still a high detection of movement. If the patient practices on detecting if this object is an apple or a watermelon for example, he can differentiate between them.

  So, they can highly detect movement (swaying hand) and emotions (smiling), and some of them will practice to know the shapes and this is called **blind sight.**

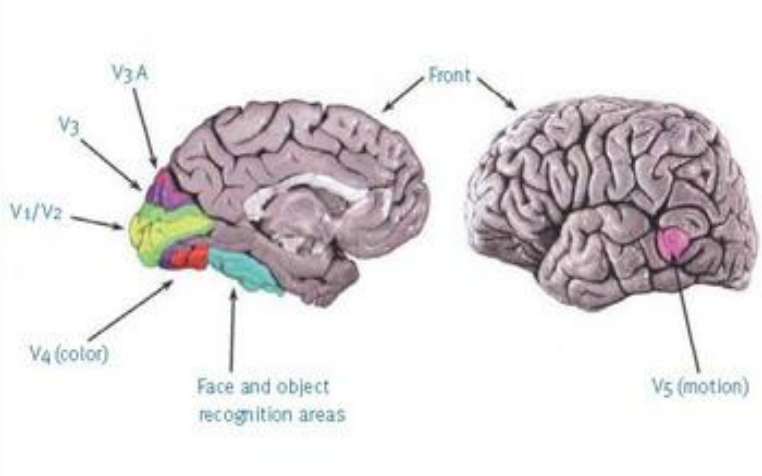
  So always remember: in examining a blind patient, if he can blink when you put your hands in front of him, you can't say that he's cheating or judge that he can see normally; because blinking doesn't indicate that he is not blind.

  In other words: The patient of blind sight doesn't have that much of conscious of vision, but he may remember and feel that there is an object here and can decide that it's a table not a human which is gained by practice.
  The patient has a damage to where and what pathways (damage in V1 and V2) except the pathway through the superior colliculus to palvinar and finally to the association cortex which is the cognitive part.

- ***Visual hallucination:***
  This is just like the phantom limb which is "the sensation that an amputated or missing limb (even an organ, like the appendix) is still attached to the body and is moving appropriately with other body parts –from Wikipedia".
  If a person has his arm cut, cortex is still working and there is a baseline activity so sometimes he will have sensations and feelings about his hand. The same principle is applied to V1 damage, remember that there are 36 areas that are still working so there is baseline activity and some of these areas are association area which take from different parts, so there are some visual activities induced and these areas will become active and form a picture; this will lead to **visual hallucination (produced from basal line activity and activity induced by other areas).**

So, damage to V1 leads to:	
- Blind Sight	- Visual hallucination

This figure will help you understand the location of the next cases of damage:



➢ Damage to what Pathway:

-Information will be received from secondary cortex V2 where processing takes place and **this pathway is responsible for shapes and colors.**

-if this pathway is damaged there will be loss of shape information so no recognition of objects and loss of color recognition.

- **If there is a bilateral damage to medial lingual and fusiform cortex (Area V4),** there will be loss of color processing so there will be complete loss of recognition of colors and the patient starts to see in black and white ..Retina and cones are doing well but the patient can't recognize colors (he can't recognize numbers in color charts). This is called **central Achromatopsia.**

  Achromatopsia can be genetic as there are no cones and this is called **peripheral achromatopsia.** But here we are concerned with people who were able to recognize all colors and due to damage to the brain (V4) they develop Central Achromatopsia.

  In **complete Achromatopsia** there must be damage for Both or **Bilateral damage to V4**; as each part has its own receptive field and own processing and it's not enough to involve the right side as it is the part related more to colors.

- If injury occurs to **more anterior and medial parts**:
  Before reaching here, there has been a little color processing in V4. Now in this area there is high processing related to memory. The damage here results in **color agnosia.** The patient can see colors (can distinguish between green, red, blue colors for example) but when you ask him what is the result from mixing yellow and red together they won't know, so any recognition to colors is not known by him… Also, if you asked him what is the color of the sky he won't know, if you give him colors to draw the sky he will paint it with any color and he will paint the banana green. **So there is no awareness of colors.**

- **If the injury was more anterior (and milder)**:
  Here is the association cortex that has to do with vision. This is an injury of more advanced processing which means there will be awareness of colors and the patient will paint the sky blue and can mix red and yellow colors to make orange colors, but the problem here is that the area that stores the name of colors and communicates with language center is affected. When you show the patient a banana he can't say that this is a yellow color. At the same time, if you ask him to read the word yellow he will read it. So the patient's problem is that although he can read and pronounce "yellow", he can't say it as an answer for the question "what is the color of banana?" Don't forget that he still can paint the banana yellow.
  This case is called: Color Anomia.

- From Wikipedia:
  "Color agnosia is a category-specific semantic impairment pertaining to semantic color associations, such that individuals retain perceptual abilities for distinguishing color, demonstrated through color categorization or hue perception tasks; however knowledge of typical color-object relationships is defective. Color agnostics are assessed on performance coloring in black and white images of common items or identifying abnormally colored objects within a set of images. For example, a color agnostic may not identify a blue banana as being improperly colored.
  This deficit should be distinguished from color anomia, where semantic information about color is retained, but the name of a color cannot be retrieved, though co-occurrence is common. Both disorders linked to damage in the occipito-temporal cortex, especially in the left hemisphere, which is believed to play a significant role in color memory."

➢ Agnosia:

- Up to now we know that in order to know that your eyes are looking… look at a door for example, first you get (by the previously mentioned processing) that it is a rectangle, then processing of its size then processing that it has a circle inside then knowing that it's a door. **Same analysis and processing** are applied on seeing a face and distinguishing it from a watermelon for example, and further distinguishing between Ahmed and Ali faces. **This happens in a step by step and continuous pattern of analysis**; our brain gets for example that this thing moves on four limbs then it's an animal and this thing has wool so it's a sheep. We said before that during processing we can recognize hypercomplexed patterns such as if we recognize circle shape we have to know if it's a ball or apple and this is done by inferior part of temporal lobe which has the **occipitotemporal gyri**.

If the occipitotemporal gyri or these parts of the visual cortex are damaged, this results in **visual agnosia or object agnosia.** This means that the patient can't know what he sees and this can be due to complete or partial damage.
If it is completely damaged he won't recognize any shape.
If it was partially damaged or has subtle damage he won't distinguish certain category like animals (**animal agnosia)** or he **can't distinguish letters and words** and this is called **Alexia**… and if he **can't distinguish faces** this is called **Prospagnosia.**

- There is an area of the brain as we said in the **middle of occipitotemporal gyrus** which will process and recognize faces. If we want to recognize faces the first thing we recognize that it is circular then we recognize if this circle is a type of fruit or a face, if there is a mouth and eyes then it is a face. Then we recognize if this face is for male or female, if it's a male then we recognize whether he has a beard or no then more and more picking characteristics till we recognize the right person. This is presented in the left and right sides and every side has certain characteristics that are processed in one side more than the other but finally both parts work and both parts complement each other.
If both the left and the right sides are damaged, the patient will never distinguish a face. If the patient's friend comes to him after the damage, the will not know his friend anymore!
But, if all the occipitotemporal gyri area is damaged (completely), the patient will not even distinguish that this is a face.
(In the first case the patient only doesn't distinguish this face is for whom, but in the second case recognizing any shape is unlikely.)

- There is a famous person who has written about the second case, he's the neurologist Oliver Sacks. He described the case of some of his patients in his book "The Man Who Mistook His Wife for a Hat".
The patient thought that his wife was a hat; the problem here is that he can't even recognize that this is a face!!

*If the problem was only with faces i.e. the first case (Prospagnosia), we now already know that the patient recognizes that this is a face but can't distinguish if this person is Ahmad or Ali. In order for this to happen the two sides must be damaged. This case happens to old people commonly so they tend to deny that and try to identify people by other cues like gait, mannerisms or facial features, spectacles.

In Prospagnosia, 99% of the patients have bilateral damage of the middle occipitotemporal gyrus, if the damage was only in one side there will be no prosopagnosia as the information in the healthy side and other cues make that there is no problem with recognizing faces.

In certain rare cases, if the left side is the damaged side and it was wide area this might lead to prosopagnosia... Remember that the left side is the side related to emotions and tone and if it is damaged this will lead to damage in both recognizing faces and other cues that can help in recognizing faces (because of damaged emotions and tones)… So here left side alone can lead to prosopagnosia especially if the damage affects connection to other parts.

So, 99% of prospagnosia cases occur by bilateral damage, and other few cases occur by damage on one side only.

- **Capgras syndrome:**

After recognizing the face and the other cues, the picture will go to subcortical area and limbic system. **In rare cases**, the patient comes with his wife to the clinic and says to the doctor that she isn't his wife but looks like her :/
Indeed this person is not crazy.

His case is called: Capgras syndrome.

There are certain schizophrenic syndromes that can lead to this thing. But not always this patient must be conveyed to the psychiatry because if there is a cut due to trauma or accident that cut the connection between the brain and limbic system (emotions). As we just said, in normal individuals when they recognize any face it will be associated with the limbic system (emotions), but here this connection is cut so no emotions will accompany the face that the patient see.

An example By the doctor: when you see someone who you hate it will be associated with Anger, but if see the same person and you didn't became angry or mad then you say: that's for sure he is not the same person and maybe he look like him :P.

So the patient in the example above has had trauma or accident that cut this connection, so he no longer has emotions and warmness towards his wife when he sees her face. So he starts saying that yes she looks exactly like my wife, but she is not my real wife.
Wikipedia defines capgras delusion as "a disorder in which a person holds a delusion that a friend, spouse, parent, or other close family member (or pet) has been replaced by an identical-looking impostor."

There are other factors that can lead to the same thing other than the trauma, but now we are concerned with trauma.

- **MRI:**

There was a slide about MRI for a lesion: "it is a missing slide"

The patient has good V1, V2.

There is damage to what pathway and inferior as well as medial… the patient has **Hemiachromatopsia**

The Damage on the left side so he has >> **Pure Alexia without agraphia**

The damage also involve the anterior part so he has: **category specific agnosia.**

- **Last thing in the slides is the damage to where pathway, this will be discussed in the next lecture.**

Good Luck ☺

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Special thanks to Marah Dannoun