HIGHER CORTICAL FUNCTIONS (continued)

Before we go, these are some notes on the previous sheet:

1- In page 7, we checked about the location of the neurons, the doctor said that:
simple and concentric neurons are in V1 (primary visual cortex).
Complex neurons are in V2.
Hypercomplex neurons are in visual association cortex.

2- In page 11, in the 4th paragraph: it's the **right** side that has to do with emotions not the left. And patients of prosopagnosia are in 3 categories:
The first 99% of them: have bilateral damage.
The second .09% of them: have right side damage.
The last .01% of them: have left side damage.

Today's lecture includes:

1- Damage to where pathway.
2- Sequence, attention and space functions of the higher cortex; mainly the parietal lobe.
3- Language function of the higher cortex.
4- Causes of cortical damage other than strokes and lesions.

- ***Damage to where pathway:***

We already know that there are two pathways in visual processing:
1- Ventral pathway (or what pathway) which is involved in color, shape, and object recognition.
2- Dorsal pathway (or where pathway) which is involved in movement recognition and spatial relationships.

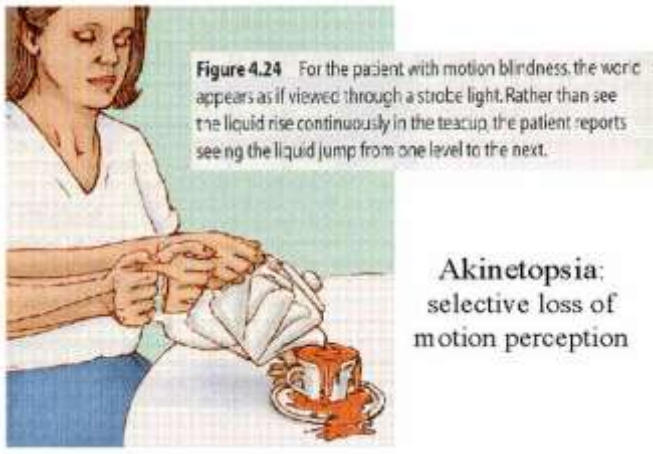
The defects in what pathway were introduced enough in the previous lecture.

Now we will study the defects in where pathway which is: abnormal motion recognition and visuspatial damage, as follows.

1- Akinetopsia:

This is a defect in visual processing of motion (motion perception). The patient can't see movement of things in continuous pattern; they see the moving things as jumping and see only parts and pieces of the motion like in the picture.

Examples:
When the patient pours tea in a cup, they suddenly find that the cup is overfilled and the tea is flowing out.
And before the patient crosses the street, they look and check that no car is there, but suddenly while they cross they see a very nearby car appeared.



-Neuropathology:
Usually it needs **bilateral** lesion in MT (area 4) which is temporo-occipito-parietal junction.
In **unilateral** lesions, the deficit is more subtle.

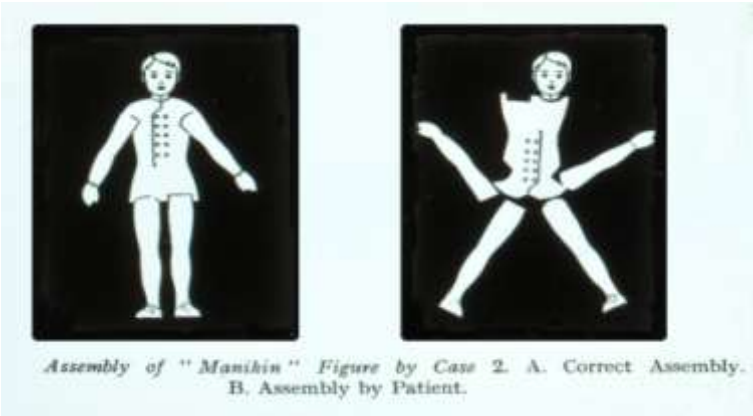
2- Topographagnosia:

This is a defect in spatial orientation and layout of the environment; the patient can't make a mental representation or map of the environment.

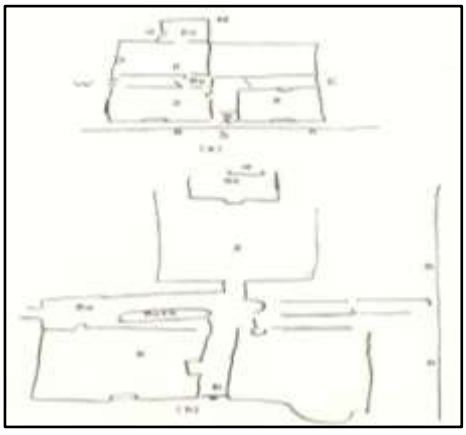
Here the patient knows and remembers the details of the building, but can't remember and process what the route to it is. This means, for example, the patient knows the faculty of medicine, the medical complex and the faculty of Pharmacy, but she can't process the spatial relationships between them and can't process how to go from one to another. ("she" is used because females are at higher risk)
Even if the patient was recognizing the relations between buildings before the stroke, after the stroke she won't remember because processing is impaired; and there is no memory without processing.
Another type of topographagnosia is **developmental topographagnosia**, it's by a defect since childhood not by stroke. And it's the most common type of topographagnosia.

-Neuropathology: lesion in the right parietotemporal which is the **dorsal** stream.
(Right is more than the left since it's involved more in space processing).

If the lesion was large enough and made more damage in the right parietal, in addition to not knowing the maps of areas, the patient will not be able to draw the map of their own house (they will draw each room right but the relationships between rooms is distorted). And if the lesion was larger and more involved in the right parietal, when you ask them to assemble the structures of the body, they will do that as in the picture. This is called **spatial relationship distortion.**



Assembly of "Manikin" Figure by Case 2. A. Correct Assembly. B. Assembly by Patient.



In summary: if the lesion was small in the initial part of the dorsal stream, the patient will have topographagnosia. If the lesion was large enough to reach the more rostral part of the dorsal stream, the patient will have complete distortion of orientation.

3- **Landmark agnosia:**
This is not damage in where pathway (dorsal stream), instead, it's in what pathway (right ventral temporo-occipital lesions like **Right lingual gyrus;** the ventral stream of visual processing).
Remember that the patient of damage in what pathway can't recognize objects so this also applies on buildings and landmarks. The patient can see the whole map in his mind, but how the shape and other details of the building can't be exactly known because the patient can't recognize objects.

- ***The parietal lobe:***

Of the other higher cortical functions that we should study are those that have to do with time, sequence, attention and space. Time processing is mainly in the temporal lobe and there are some indications that it's also in the parietal lobe, however, it's still under research so we neglect talking about it in neurological and psychiatric tests. So we focus today on sequence, attention and relation of space; most of them are in the parietal lobe.

- **Anatomy of the parietal lobe:**

  We already know Broadmann's division of the parietal lobe, that is, areas 3 - 2 - 1 - 5 - 7 – 40 – 39 - 43. There is a further division of area 5 into A and B, and area 7 into A and B, and so on.

  There is another easier way of dividing it is into alphabets: PA (parietal area A), PB, PC, PD, PE, PF, and PG. The first three alphabets (A, B, and C) are in the primary and secondary somatosensory and these are the posterior superior part of the parietal and are involved in the main association cortex and the main higher function processing (multiprocessing) of the parietal lobe.

- **The function of the parietal**:

  It's summarised in simple one phrase: **SPATIAL INFORMATION PROCESSING**, or relationship between things in space. The right and left parietal have similarly this function but the right works with spatial information with regard to artistic, space, emotions, and colourful issues. Whereas the left works with regard to serious and analytical issues, and "work" side of the brain.

  By knowing this main function, we can explain most of the deficits that are due to damage in the parietal.

- **An experiment was made to study the function of the parietal lobe by James Lynch:**

He is the same scientist that studied the visual receptive fields (concentric, simple, complex, and hypercomplex – recall that experiment from the previous lecture). He was curious about what is the response of the neurons outside the visual cortex (striate cortex) and about how the processing takes place. He recorded from one neuron **in the parietal lobe** and started the experiment by moving a piece of raisin in front of the hungry monkey in order to identify the location at which this neuron fires and works.

But surprisingly he found that there is always a firing in the neuron whatever the location of the piece was in the space ("surprisingly" because that scientist expected only one location to fire). However, this doesn't last for more than 15 minutes of holding this experiment.

It's found that once the monkey is satisfied (because after every successful trial in the experiment the scientist gives the raisin piece to the monkey as a reward so by 15 minutes the monkey doesn't need to eat more), the firing and attention is less because raisin is no longer a target of interest.

So the point from this study is that there is an area that is responsible for orientation in space and directing attention for objects of interest and this is found to be **the parietal lobe**. And what calls the parietal lobe, at the very start, to pay attention on something is the **prefrontal lobe** which is activated by hunger in this case.

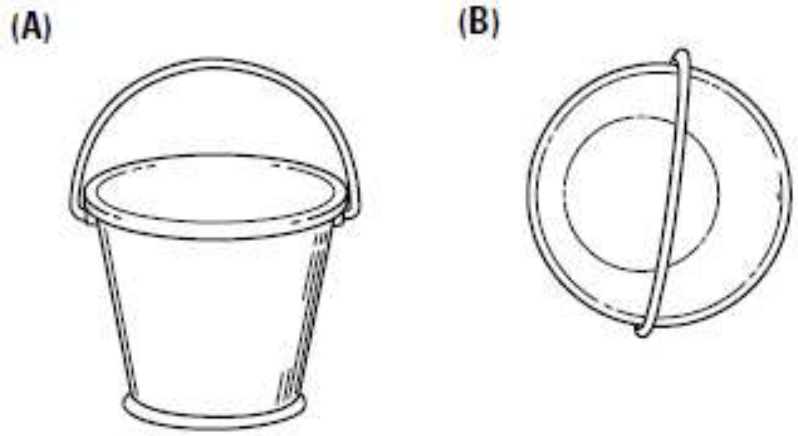
In brief:
The prefrontal is involved in planning and targeting oneself to do things, its loss makes the patient inattentive as in ADHD. In that monkey, the prefrontal knows that the monkey is hungry and that there's a raisin so it plans to focus only on it; so it tells the parietal lobe to pay attention. Then, after recognising the raisin by the vision and recognising its location by the dorsal stream, the parietal lobe works on spatial processing and orienting all the attention on part of the visual field where the raisin is and following it as it is being moved.

- **<u>Right parietal lesion:</u>**

1- Object recognition will be lost, especially if the object is in an unfamiliar view.

We said that object recognition is the function of the ventral occipitotemporal stream or, in other words, object recognition occurs in the temporal lobe and temporooccipital gyri. (Recall objects agnosia and previously mentioned landmark recognition).
The patient with right parietal lesion knows that the left picture is a bucket, because it's shown in a familiar view. But, if you show them the picture on the right, they will not know it because they can't rotate it spatially in their brain to match this picture. Since orienting things spatially is more of **artistic** function than of serious function, the **right** parietal lobe is involved here.

This means: we normally know the bucket in the left picture because it's stored in the visual association cortex by the ventral stream; we recognise it by the parietooccipital gyri. But in order to know the right picture we should re-orient the common known shape, and this takes place when the ventral stream communicates with the right parietal lobe. So if the right parietal is lost, orientation, rotation and recognising of objects shown in new unfamiliar view will be impaired. And pay attention, if the ventral stream is lost, neither the familiar nor the unfamiliar views will be recognised (because we already don't have the common view).

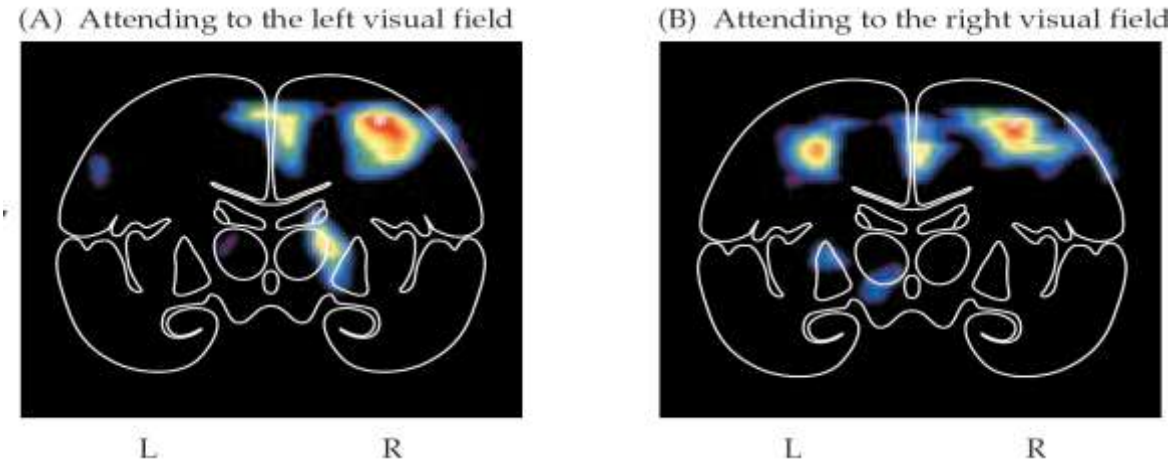


2- Contralateral neglect:

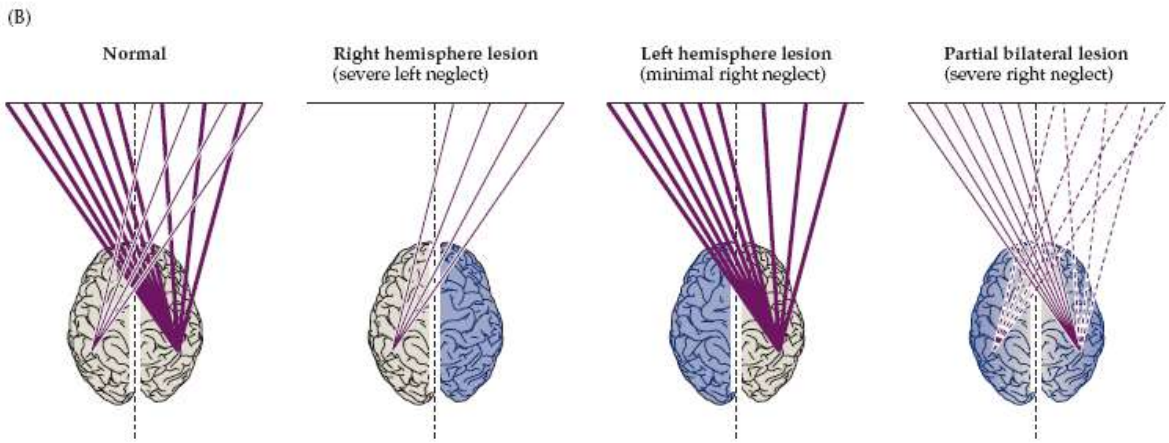
Orientation and spatial information processing are not the only functions of the parietal; also the general representation of space for us is by the parietal (having a general scan of the world around us is by the parietal lobe). Most of this processing of spatial relationships is in the **right** parietal lobe. When we study a functional MRI for people that are looking or orienting themselves in the space, we get these results:

- When they look to the **left** side, the cortex which has to do with spatial relationships and orientation in space, which is the parietal, is in the **right** side and it will work **alone** without the need of corpus callosum and left hemisphere.
- When they look and orient themselves to the **right** side, the **right** parietal starts working on spatial relationship then it communicates with the **left** to make it (the left side) control the motor and vision and to make it pay its attention to the right visual field. So here **both** the left and right hemispheres are working.

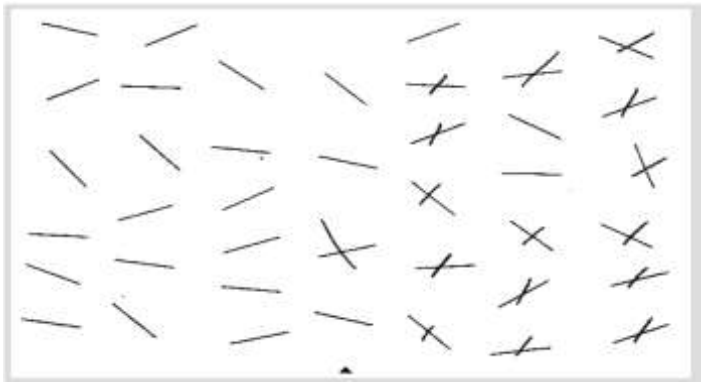
This concludes that the right parietal is more important and more involved in spatial orientation than the left. (The left side can do this but only a little and mainly for the right visual field)



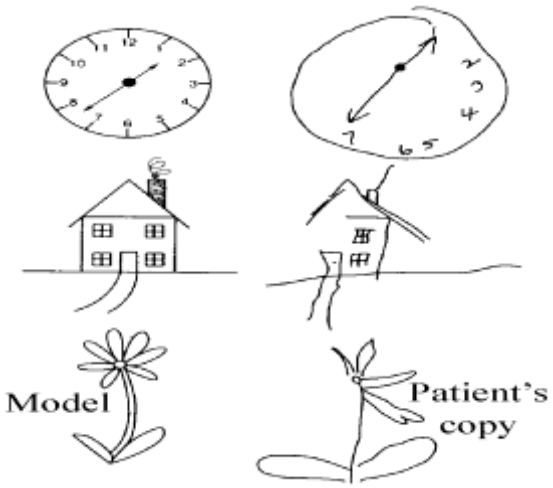
If there is a lesion (loss) in the left hemisphere, there will be a little neglect to the right side because the right hemisphere almost compensates the loss.
But if there is lesion (loss) in the right hemisphere, there will be almost complete neglect of the left side and this is called **the left neglect**.



The patient of **left neglect** doesn't have any problem in vision and gets sensation of the left side normally, but doesn't care about anything there. If you ask the patient to cross the lines that he sees, he'll cross the ones on the right side only (see the picture).

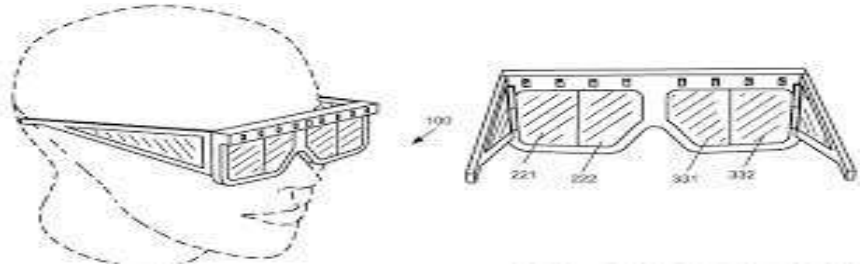


As in the next picture (on the left), the patient draws all the numbers onto the right side of the clock. The picture on the right shows the art of an artist with right parietal lesion, as he recovers he goes back to drawing on the left side.



If the lesion is large enough, the patient not only forgets the left side of the world, but also, he forgets the left side of his body. This is called **nosognosia**. This patient shaves only the right side of his face, and even forgets his left hand! If the lesion enlarges more, it may impair the sensory and the motor in the left side and here, **the patient denies that these left limbs are his and denies that all the left side are parts of his body**. For example the patient says " someone's hand is attached on me!". **Or** in other cases **the patients know that they have left limb but deny that they are impaired**; for example if you ask a nosognosia patient that has left paralysis to lift up his left hand, he will tell you "I did" but indeed it wasn't lift and if you try to convince him that it wasn't lift as in front of a mirror, he won't believe that this defict is his left hand.

In left neglect, the patients' main problem is that they can see the left side but can't pay attention to it, so one of the solutions of the left neglect especially if the lesion was only small is the **Curved Prism Lenses**. Their mechanism is to bring the left side of the world to the right side (shift the visual field from left to right).



Sometimes if the stroke causes a lesion of 50% the parietal lobe, there can be a recovery by therapy. If 90-95% is lost, recovery is unlikely but by training and other brain areas recovery might occur if the brain has some plasticity.

- **<u>Left parietal lesion:</u>**

Just like the right parietal, the left parietal has the function of spatial information processing. But as long as this side is more involved in serious real life; analysis; work; movement especially in the right handed; and language, spatial information processing is concerned here with these tasks.

This extra text is just to help understand the functions of the parietal lobe (clinical case from the Doctor's reference):

H. P. was a 28-year-old accountant who was planning his wedding with his fiancée when she noticed that he was making addition errors as he calculated the budget for their reception. At first, they joked about it, especially given his occupation, but in the following weeks H. P.'s problem with numbers became serious. In fact, he was no longer able to do a simple subtraction such as 30 − 19 in which the solution requires "borrowing" 10 when subtracting 9 from 0.

At first, H. P. simply put it down to working too hard, but soon he began to have trouble reaching for objects. He was constantly knocking over his water glass, because his reach was clumsy and misdirected. He began confusing left and right and having difficulties reading. Some of the words appeared to be backward or upside down, and he could not make sense of them.

Finally, when H. P. visited a neurologist for testing, it was obvious that something was seriously wrong. Indeed something was: he had a fast-growing tumor in his left parietal lobe. Unfortunately, the tumor was extremely virulent and, within a couple of months, he died.

We find that the symptoms of left parietal lesion are:

1- **Acalculia**:
the patient becomes very poor at mental arithmetic and can't solve maths problems; because doing arithmetic is a task that is of spatial nature. If you ask the patient (whatever the size of the lesion was) to solve a simple problem such as 6 – 4, they solve it because this depends on memory (temporal lobe and ventral stream) and the spatial demands and relationships are few. Even if the problem is more difficult like 984 - 23 it still doesn't need that spatial operation so 90-99% of the patients solve it. But, if the problem was complex such as 983 – 24, the patient can't solve it because it requires spatial processing (which is borrowing). It's not the problem of numbers or memory because these are in the ventral stream and temporal lobe; it's just the problem of spatial processing here in the parietal lobe.

2- Problem with **language**:

This is mainly for the same principle. Recognition of stored words occurs in the ventral stream, and any lesion of it leads to alexia. But here concerning the parietal lobe, processing of the words and language takes place.
According to the doctor's reference, "Language has many of the same demands as arithmetic. The words "tap" and "pat" have the same letters, but the spatial organization is different. Similarly, the phrases "my son's wife" and "my wife's son" have identical words but very different meanings. Patients such as H. P. may have a clear understanding of individual elements, but they are unable to understand the whole when the syntax (the arrangement of words and phrases to create well-formed sentences in a language) becomes important."

We differentiate between words and phrases mainly depending on the spatial arrangement of them i.e. words are already stored, but using them as a language requires organising and putting grammar well which requires the parietal lobe. Failure of the parietal lobe to do this leads to language defects as will be discussed later.

3- Also same concept applies to writing; **agraphia**.

4- **Apraxia**:
It's the inability to do **complex** movement although no sensory or motor deficits are found.
We said before that an important cause of apraxia is the impairment in supplementary motor and premotor areas. Now before the motor command is processed in the premotor and supplementary, spatial information of the world and sequencing of the movements to perform the task should be made and this happens in the parietal lobe. (The same idea as that we should know where our body parts are; proprioception or position sense, then we move them). So the lesion in the left parietal leads to a disorder of movement, that is, apraxia. Generally the apraxia that is caused by a lesion in the parietal lobe is more common than that caused by a lesion in premotor or supplementary motor.
Note that commonly apraxia occurs **along with** language defects (Wernick aphasia).
Apraxia patients not only can't use sophisticated tools, they even can't do simple skilled movements such as brushing the teeth.
In summary: the parietal lobe brings from sensation about the space, then the posterior parietal processes these spatial information, then sends to premotor and supplementary motor which in turn send to the primary motor. If there's no spatial processing in the parietal, the patient can't do

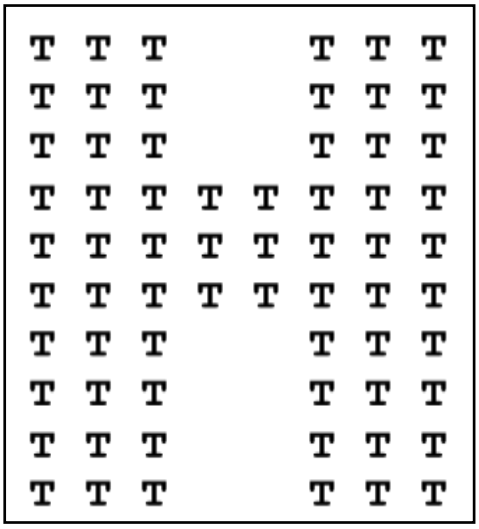
complex movement (apraxia). Also remember that areas 5 and 7 in the parietal send fibres directly into the corticospinal tract.

- **<u>Bilateral parietal lesion; Balint's Syndrome:</u>**

Hemi-neglect may occur especially if the right side was larger or more involved.
But here, mainly there are three deficits:

1- **Simultagnosia**:

If we ask a normal person what is the letter in the picture (left one), they will say that it's a large "H" that's formed of small "T"s. If we ask them what you see in the second picture, they will say there are at least 3 or 4 events happening.



Patients of simultagnosia can see only one thing or two maximum; they can focus on only one part of the world. They will see only one letter of the two (commonly the T) and can see only one event in the second picture.

From the doctor's reference, "When the patient's attention was directed toward an object, he did not notice other stimuli. With urging, he could identify other stimuli placed before him, but he quickly relapsed into his former neglect. The patient's field of attention was limited to one object at a time, a disorder that made reading very difficult because each letter was perceived separately. (This disorder is often referred to as *simultagnosia*.)"

2- **Optic ataxia**:
It is a sort of ataxia (loss of coordination of movement due to a defect such as cerebellar ataxia or sensory ataxia) that happens in **visually guided movement**. Here the relation between motor and vision and sensory is impaired so the patient can do normal movements but can't do motion that depends on vision. The lesion may be large enough to let the patient not able to reach an object on the table under visual guidance (reach some distance around the object and not exactly on it).

Optic ataxia in Balint's syndrome is bilateral, but it may also occur in **unilateral** lesions of posterior parietal either on the left or the right side (called **unilateral optic ataxia**); in the **left** side of right-handed people and in the **right** side for the left-handed people.
And optic ataxia may happen **alone** without predisposing damage of the parietal lobe.

Another form of optic ataxia is the inability to know where the end points of the object are in order to grasp it. As shown in the picture.

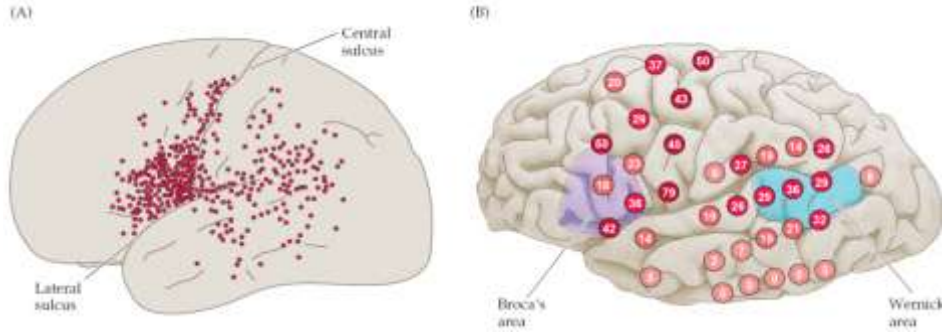
This is an extra description of a patient with optic ataxia, from the doctor's reference:
"She consistently misreached for targets located in the nearby space, such as pencils, cigarettes, matches, ashtrays and cutlery. Usually she underreached by 2 to 5 inches, and then explored, by tact [touch], the surface path leading to the target. This exploration, performed in one or two groping attempts, was often successful and led straight to the object. Occasionally, however, the hand would again misreach, this time on the side of the target and beyond it. Another quick tactually guided correction would then place the hand in contact with the object.. In striking contrast to the above difficulties was the performance of movements which did not require visual guidance, such as buttoning and unbuttoning of garments, bringing a cigarette to the mouth, or pointing to some part of her body. These movements were smooth, quick and on target."

3- **Ocular apraxia:**
Again, apraxia is inability to do complex movement although no motor dysfunction is there so "ocular" apraxia is the inability to do complex movement **by the eye**.
The patients of ocular apraxia **can** move his eyes in any direction but if you ask them to focus on something, they **can't fixate** on it. Normally when we enter an unfamiliar room we scan it to know the area around us then we focus on one thing; those patients **can't do this proper scanning**, too.

- ***Language:***

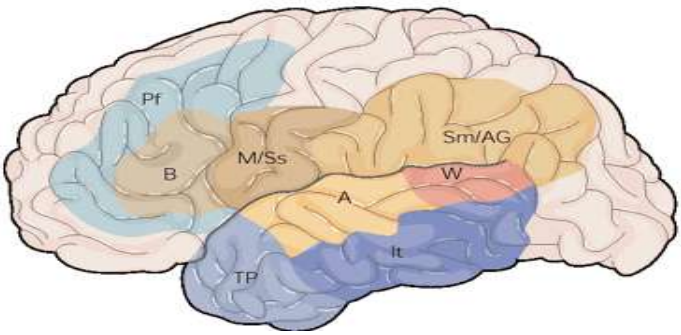
It's of the most important higher cortical functions. Language is not in one part of the cortex but it's **multi-dimensional** in which more than one area are involved. When we **see** a word the visual cortex will work; when we **hear** a word the auditory (temporal) will work; when we **talk** mainly Broca and motor areas will work; when we want to think about the **relation** between 2 words, the premotor and Wernick and ventral part (which has to do with recognition and memory, for example when we hear the word "fork" we go back to memory and association to recognise it) will work.

Before we talk about the traditional knowledge about language, it's good to know the new research that answers many questions the old knowledge can't answer. The new research shows that **all the areas** in the picture are involved in language and the impairment of any area that's involved in language (like the ones just mentioned above) may lead to aphasia i.e. not only Broca and Wernick. This is because language is a complex thing.
This knowledge explains many phenomena that weren't explained before, like the reason why when we ask a Wernick patient to repeat a sentence, he can understand our request but can't repeat! Or when we ask him to tell us the name of an object, he can understand our question but can't answer or can answer wrong!



So after our knowledge about the brain has improved, we found that language processing doesn't lie only in two areas that are Wernick (for comprehension) and Broca (for production or expressing) and we found that Wernick doesn't have a unidirectional path to Broca (arcuate fasciculus) , instead, we now know that the connection between these 2 areas is **bidirectional** white matter. And we now know that we have 3 general areas (systems) for language:

1- The implementation system:
represented in yellow, it includes Wernick and Broca areas.



2- The mediation system:
represented in "blue" (the doctor said next: "including this area in frontal and this area in temporal" so maybe it's what is represented in the two blues). It includes memory and storage of words and visual objects.

3- The conceptual system:
it includes insular and subcortical areas.

Now, back to our traditional knowledge about language areas, which are:
Wernick and Broca areas.
Wernick is involved in comprehension. Comprehension of words is found in secondary auditory and some of the association, but comprehension of big sentences (bigger language) or sentences with hidden meanings occurs in language area (which is Wernick area in spatial parietal lobe) for analysis.
Production of language takes place in **Broca** area.

Language defects:

- In Broca's area:
  The first case discovered was when a patient who had stroke came to the physician Broca, that patient wasn't able to speak in any language yet there was no motor defect in muscles of face and speech. He was able to say nothing but the word "tan", and he could live with this for 20 years!
  When the patient died, Broca studied his brain and found that the area that's known today as Broca's area was damaged by the stroke. So he found that this area is what's responsible for producing and expressing of language not the motor cortex (because motor was intact). Then it was named after him and the aphasia which is produced by it is also named: **Broca aphasia or expressive aphasia**.

  The patients here can't produce language nor can they express themselves. The patients become frustrated because they know what they want, but can't say it out or may say it; but very slowly. Not all the patients have as severe aphasia as that patient who came to Broca because when his brain was sectioned, it was found that broca's area was fully damaged also the white matter was included and even the insular cortex underneath (which has a lot of function of multi-sensory processing).
  So not all of them cannot say anything except "tan", some of them have subtle aphasia and talk normally but with continuous pauses because of some words that they can't say (stammer تأتأ).

  Remember that language is **multidimensional** that includes: speaking, writing, pointing, gestures, tone, emotions, and even sign language. Keep in mind that if a deaf person who communicates by sign language got a stroke in this area, he will lose his sign language because it's an area of language as a complex not only speaking.

  This is a video for Broca's aphasia (viewed in the lecture):
  http://www.youtube.com/watch?v=1aplTvEQ6ew
  (or search for the video title: Expressive aphasia - Sarah Scott - Teenage Stroke Survivor)
  This is a popular case whose name is Sara Scott. Since she was 19 years old, one day while she was reading in English class she got stroke and then aphasia. There are many videos that show the stages of her recovery on YouTube.
  This video is a short time after the stroke, when she answered to "what's your name?" she said "Scott" then fixed it and said "Sarah Scott". Notice that she couldn't tell her age spoken nor written. We can see that the stroke was only small not like that of the first patient, so she recovered.

- In Wernick's area:
  This is **Wernick aphasia or receptive aphasia.**
  The patients here can't repeat the speech or mix the letters when repeating. And when the patients try to say a sentence, they can't organise the words in right order so they say meaningless sentences because the words are improperly organised. But they can follow simple orders because understanding of simple orders is not in language area (not in Wernick's area), instead, they are analysed in other areas. This means when you ask him to repeat, the patient will understand your request and try to repeat but can't make it, as noted earlier.

  This is a video for Wernick's aphasia (acting and not real/ also viewed in the lecture):
  http://www.youtube.com/watch?v=UtadyCc_ybo
  (This link is from the slides, but the video is unavailable!!?)
  The patient can't put the letters of the word in their normal order. Notice that she can complete the song; the explanation of this comes next.

99.9% of right handed people have Wernick and Broca on the **left** side and more than 96-97% of left handed have it on the **left** side as well. Others (around 2-4% of people) have these areas shifted to the **right** side or **bidirectional** (divided between the two sides).
Talking about the most common cases; since the two hemispheres are almost similar to each other, what do the equivalent areas do in the right side?
Right Wernick and right Broca areas (the doctor called them this way to help understanding, he said this is misnomer and it's more accurate to say the right side equivalent to Broca and the right side equivalent to Wernick -or right area 22-) have to do also with language as long as the brain is symmetrical. But recall that the right side is involved in music and emotions, that's why its participation to language would be adding **tone and emotions** to the speech.
For example: when asking "Ahmad is here?"
The order and comprehension of the words occur in the **left** side, but the way, tone, emotions and the facial expressions we ask in occur in the **right** side.

If the right side is lost, the patient will have **prosody of speech** i.e. **speeking** without emotions or tone like the newsman speaking if the lesion is in the **right frontal**; or they will not **understand** the tone in others' speech if the lesion is in the **right parietal**.

In rehab and therapy programs for patients with stroke on the left side, they use **tone therapy.** In this therapy they try to put everything in tone and music in order for the patient with aphasia to understand it by the right side (shift comprehension from the left side). This explains why the patient in the last video continues the song; her right side is active not the left.

- ***Pay attention to:***

All the cases we talked about up to now are due to lesions and strokes, and lesions frequency is very few in number. A common cause of those cases is **Drugs**; especially those that have high impact on processing and sensory like the modulators: **serotonin** (the most important, it goes to association), then **norepinephrin** and **neuropeptide** such as cannabis (marijuana).
So we may see those cases as a side effect of normal drugs like SSRI in akinetopsia, or of recreational drugs like marijuana, or toxic drugs.

Some cases are **transient** due to disintegration of the circuit like in **CO** (Carbon Monoxide).

Some cases are due to chronic use of **alcohol**; because alcohol disrupts the GABA mechanism.

And some cases of **neurodegenerative** diseases like multiple sclerosis or Alzheimer.

So don't forget, those cases are not caused by stroke only.

Sorry for any confusion,
All the best!