Psychology 1XX3 Notes – Depth, Distance and Motion – Mar 7th, 2010

Introduction to Depth and Distance:
- We can make depth/distance decisions because we can create a mental image of a three-dimensional world, based on a combination of tap- down and bottom-up processing.
- Remarkably, new visual input from a 2-dimensional retinal surface is processed along with our existing knowledge of the environments objects and surfaces to create this 3-D world.
- This essential skill is aided by the many cues that have been incorporated into evolution of depth perception.

Monocular and Binocular Cues:
- How do we transform flat, two- dimensional visual images projected onto the retina into an accurate a 3-d mental image of the environment?
- Psychologists have identified two main classes of cues that we use to perceive depth in our environment: **binocular cues**, which are depth cues that require two eyes, and **monocular cues**, which are cues to depth that you can get using one eye.

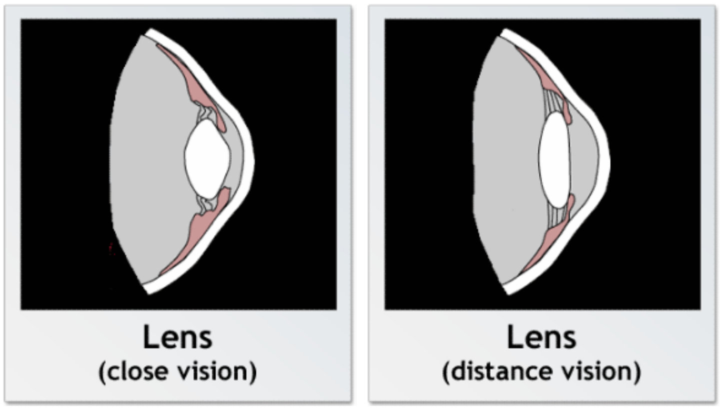
Convergence
- Def'n of Convergence: A cue to depth resulting from the way our eyes turn inwards to fixate on a specific point
- There are two types of binocular cues to depth perception. The first is called **convergence**, which results from the way our eyes turn inwards to fixate on a specific point.
- You can feel this yourself if you look at your finger at arm's length and then slowly bring it towards you while still focusing on your finger. As your finger approaches your face you will feel your eye muscles straining. The feedback that we receive from these eye movements gives us information about depth.
- However, convergence as a depth cue only works for objects that are relatively close, because with objects that are far away, the eyes don't have to turn in at all to fixate on the same point, and the path of sight for your two eyes becomes parallel.

Retinal Disparity:
- Def'n of Retinal Disparity: A cue to depth resulting from the fact that our eyes will each see a slightly different visual scene.
- Retinal disparity is caused by the fact that our eyes, which are located about 6 cm apart, will each see a slightly different visual scene.
- You can see this yourself if you point to an object in the distance and then open and close one eye at a time. You will see your finger jumping around and pointing to a different object when you look with each eye, and these are the two different scenes that each eye is receiving.
- When these two scenes are combined in the brain, the resultant perception is depth. In fact, our visual systems are equipped with a class of neurons that fire maximally only when each retinal image is slightly different.

Three Types of Monocular Cues:
- There are three main types of monocular cues: **accommodation, motion,** and **pictorial cues**.

Accommodation:

- Accommodation involves changes in the shape of the lens as you focus on objects at different distances.
- When objects are near, we make a different accommodating response than when objects are farther away. Just like the binocular cue of convergence, information about an object's distance is coming from the feedback that we get from our eye muscles.
- However the lens can only change so much in shape, and because of this, accommodation is only an effective cue for depth up to about 2 meters.
- For all points beyond this distance, the lens is a constant shape, and so we have to rely on other depth cues. (See image below.)



Motion: Two Types → Motion Parallax and Optic Flow
Motion Parallax:

- The second main type of monocular cue arises from motion, and we can use two different motion cues to perceive depth.
- The first is motion parallax, which refers to the fact that when we pass by a scene, objects in the scene pass by us at different speeds, depending on how far away these objects are relative to us.
- Objects that are close, appear to speed by much faster than objects that are farther away. You can see this for yourself when you drive in a car and look out the window. The fence posts that are right beside the road seem to whiz by, but the buildings in the distance look like they're standing still.
- We can use the speed of the objects going by us in the scene as we move as a cue to how far away these objects are from us.

Optic Flow:

- The second motion cue to depth is optic flow, which refers to the changing optical projection of a scene that is caused by the motion of the observer, as well as motion of objects within the scene.
- Obviously, as you get closer an object will get bigger, and it will get smaller as you move away from it. Not only does the size of the object that you're focusing on change as you move toward or away from it, so does the entire visual scene.
- As with motion parallax, objects that are close to you will seem to move more in the visual scene and change more in size than objects that are farther away, and these changes in size and motion can give cues to depth.

Pictorial: Seven Types → Interposition, Relative Size, Linear Perspective, Texture and Haze, Shading and Elevation

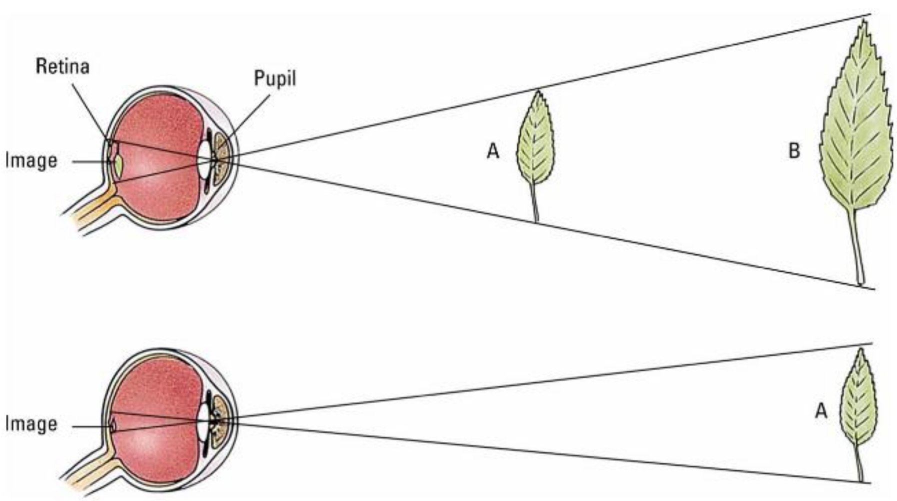
Interposition:

- A third type of monocular cue are pictorial cues, of which there are seven different kinds. These are the cues that artists expertly use to give the impression of depth working on a two-dimensional canvas.
- For example, interposition provides a good clue to depth. When you have an object that partially blocks another, it is perceived as being in front of the other object.
- Interposition is most effective when the objects are familiar and you know what their shapes should be, although it can still provide information about depth if the objects are unfamiliar because of the Gestalt principle of closure.
- For example, if you have two circles that are partially overlapping, you will tend to see the partially blocked shape as a circle and not as a crescent because of the principle of closure. As a result, you will perceive the full circle as being in front of the partially blocked circle instead of seeing a full circle beside a crescent shape.

Relative Size:

- Relative size is another pictorial cue that can provide information about depth.
- If you have two objects that are the same shape but different sizes, then the larger shape will be perceived as closer.
- Another way that relative size can provide depth information with familiar objects is by their size. For example, you know what size a car should be, so if you see an image of a tiny little car you will know that the car is very far away.
- This relates to the concept of optic flow; one way we avoid collisions with other cars is by monitoring the rate of expansion of the approaching car on our retina and keeping this rate constant.
- Obviously, when an object is closer to us, it projects a larger image on our retinas than if the same object is farther away, and we can use this information to gauge depth.
- Example: if you are pulling up to a red light and you get closer to the car in front of you, it will project a larger image on your retina and appear to expand in size.
- It turns out that you rely very heavily on this information to gauge when to stop by keeping this rate of expansion constant. (See image on next page.)

Retinal size of objects



Linear Perspective:

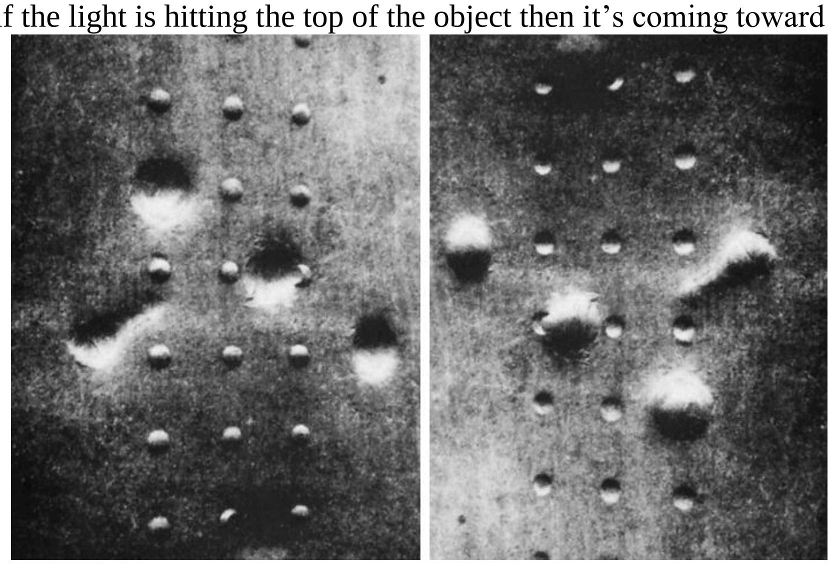
- Another pictorial depth cue is linear perspective, which is really obvious if you've ever looked down a railroad track.
- Even though you know that the tracks are parallel, they appear to converge at a single point on the horizon. This provides a cue to depth because objects that are farther away decrease in size and spacing between objects.
- Artists use these cues to achieve depth with anything that is rectangular, square or cube-shaped, like buildings, shelves, doorways, or roads. The artist should draw lines that converge to capture the farthest point away from the viewer's eye.

Texture and Haze (Aerial Perspective)

- Texture and haze, which are sometimes called aerial perspective, are other pictorial cues that both provide information about depth by the fact that objects that are farther away from us will have fewer details.
- For example, if you're looking at a gravel road, then you will easily be able to see the texture of the rocks immediately under your feet, but as you look in the distance, you will just see the same rocks becoming a uniform grey colour with little texture.
- The same applies with haze. When you are looking at objects that are farther away, it will be harder to see the outline and texture of the object compared to objects that are closer to you.

Shading:

- Shading is another depth cue that artists use to their advantage. Although it cannot give us information about how far away the object is from us, it can tell us what part of the object is close to us and what is farther away.
- Take a close look at this picture of dents and bumps. On the left hand side, the bumps are shaded on the bottom and the dents are shaded on top.
- What happens when you turn this picture upside down. It now appears that what was previously a bump now looks like a dent, and conversely, what was previously a dent now looks like a bump. (See image below.)
- Why is this so? We are so used to light coming from above, like the sun that we automatically use the pattern of light striking an object to tell us whether the object surface is coming toward us or receding away from us.
- If the light is striking the bottom of the object, then it is receding away from us, and if the light is hitting the top of the object then it's coming toward us.



Elevation:

- Elevation is a pictorial depth cue that tells us how far away an object is by how close it is to the horizon.
- Objects that are higher up in a picture, or closer to the horizon, are seen as farther away than objects that are lower in a picture.

Evolution of Depth Perception:

- Since depth perception is an important adaptive mechanism critical to survival, you may expect that it to be present in species that can move about in their environment.
- We can test this ability with the visual cliff experiment. When a large variety of species were tested in this paradigm, including turtles, birds, small and large mammals, and different primate species, there was no doubt that these animals were responding to the available depth cues by avoiding what was perceived to be the edge of a cliff.
- This suggests that a wide variety of animal species are capable of depth perception even with different types and placement of eyes.

Effect of Eye Placement on Depth Perception:

- The type of cues that an animal can use to perceive depth depends a lot on where the animal's eyes are placed on its head.
- Prey animals typically have eyes that are on the side of their heads, like rabbits and fish; these animals have very limited depth perception from binocular cues, and instead must rely on monocular cues.
- Predator animals typically have both eyes facing front, like cats and primates; these animals are able to use both binocular and monocular cues.
- What is the evolutionary advantage of being able to use both monocular and binocular depth cues? In addition to providing information about distance between predators and prey, the binocular cue of retinal disparity is excellent at detecting camouflage.
- Retinal disparity allows you to group together features or objects that are at the same distance. For example, retinal disparity would provide a means of grouping together a zebra's stripes and perceiving those stripes as a separate object that is distinct from the surrounding environment.

The Necessity of Multiple Depth Cues:

- Why would natural selection have led to a visual system that is sensitive to so many different cues for depth? Wouldn't some of these cues be redundant with each other adding more cost to the system than they would benefit?
- The reason we have so many different depth and distance cues is because we needed a visual system that was flexible and capable of processing distance and depth in many different situations.
    - For example, **motion parallax** and **optic flow** only work as cues for depth if you or the scene around you is moving.
    - **Texture** only works as a good depth cue if the surface has a consistent texture and if none of that textured scene is blocked from view.
    - **Accommodation**, convergence, and retinal disparity, only work for objects that are less than approximately 30 feet from you.
    - **Elevation** only works if the scene is relatively flat
    - **Relative size and haze** are most effective if the objects are familiar, and
    - **Linear perspective** requires parallel and straight lines that recede in the distance.

- **Interposition** only works if there are objects placed in front or behind other objects
    - **Shading** is a poor cue if the light source comes from directly in front or behind the object.
    - In other words, each of the depth cues we discussed works best under specific conditions.

- Because depth perception is so critical to survival, and it is a skill that is necessary in many different situations, we have evolved the ability to use multiple cues.

The Visual Cliff Experiment:

- Depth perception has been extensively studied in infants using the visual cliff, as you see here. The visual cliff is an apparatus that creates the illusion of depth using an elevated platform. (See image below.)
- On one half of the platform, there is a checkerboard pattern directly under the glass surface. On the other half of the platform, the checkerboard pattern is a few feet under the glass surface, which creates the illusion of a sudden drop-off.

- The infant is then placed in the middle of the platform, and the mother stands at either end and calls to the infant to crawl to her.
- It turns out that about 90% of infants, ranging in age from 6 to 14 months, readily crossed to the shallow half, but fewer than 10% were willing to venture out onto the deep half.
- This suggests that infants who can crawl and who are at least 6 months of age can perceive depth in the visual cliff and have the sense to avoid it.

- These findings sparked a number of studies to determine whether we are born with the ability to perceive depth in the visual cliff or whether this is something that develops more slowly with experience from crawling and falling down.
- Some researchers believe that depth perception is not due to experience with crawling because infants as young as 2 months, far too young to crawl, show an increase in their heart rate when they're placed on the deep side but not when they are placed on the shallow side.
- This increase in heart rate suggests that they have an innate fear of the deep side.
- Interestingly, when animals that can walk right after birth are tested on the visual cliff, such as lambs and kids (meaning baby goats), they show a reluctance to walk to the deep side.
- Taken together, these results suggest that experience with moving around in your environment is not necessary to learn to basic depth perception.
- On the other hand, infants younger than 2 months actually show a decrease in heart rate on the deep side, and no change in heart rate on the shallow side. A decrease in heart rate is indicative of curiosity or interest, and it shows that very young infants react differently to the deep and shallow sides.

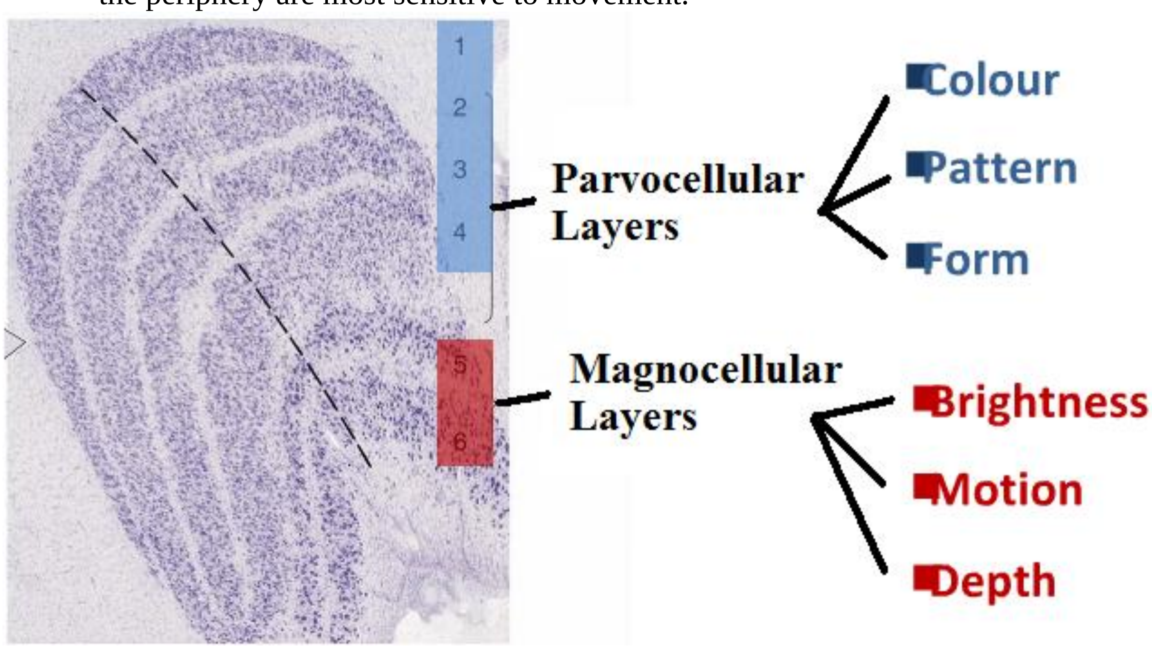
- This difference may be due to experience with crawling. Infants who are more experienced crawlers are less likely than age-matched infants with little crawling experience to cross to the deep side.
- This suggests that there is some increase in either the perception of depth or in fearing drop-offs with more crawling experience, regardless of age.
- Furthermore, infants who were too young to crawl but were given 30 to 40 hours of experience with a walker showed more fear of heights than they did before trying the walker.
- These results seem to indicate that fearing heights is caused by an interaction between genes and the environment.
- We may be predisposed to fear heights, but this fear increases with more locomotion experience.

Introduction to Motion Perception:

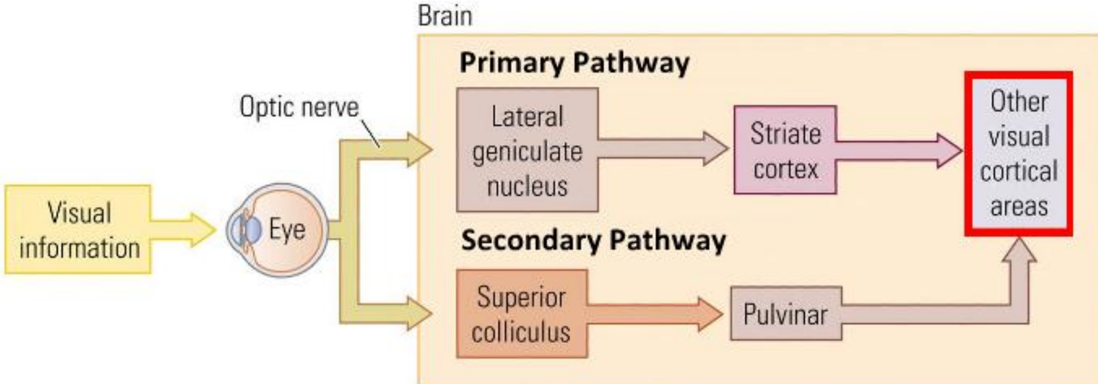
- We need to be able to perceive movement in some of these objects, such as a car that is driving towards us, and to not perceive movement in some other cases, such as when we're reading and our eyes are jumping across the page.
- To be effective, our visual system has to be able to compensate for our own movements to perceive movement of objects in the environment.
- Movement can also be an excellent cue to perceiving forms, in one study by Johansson in 1973, actors were dressed up in dark clothing with about ten lights attached to their joints, such as ankles, knees, hips, wrists, elbows, and shoulders.
- When participants were shown still images of the actors performing various actions, it was very difficult to tell that the lights even belonged to a human.
- But with a few seconds of motion, participants could quickly tell what action the actor was doing, and also the actor's gender!

The Neural Pathways of Motion Perception:

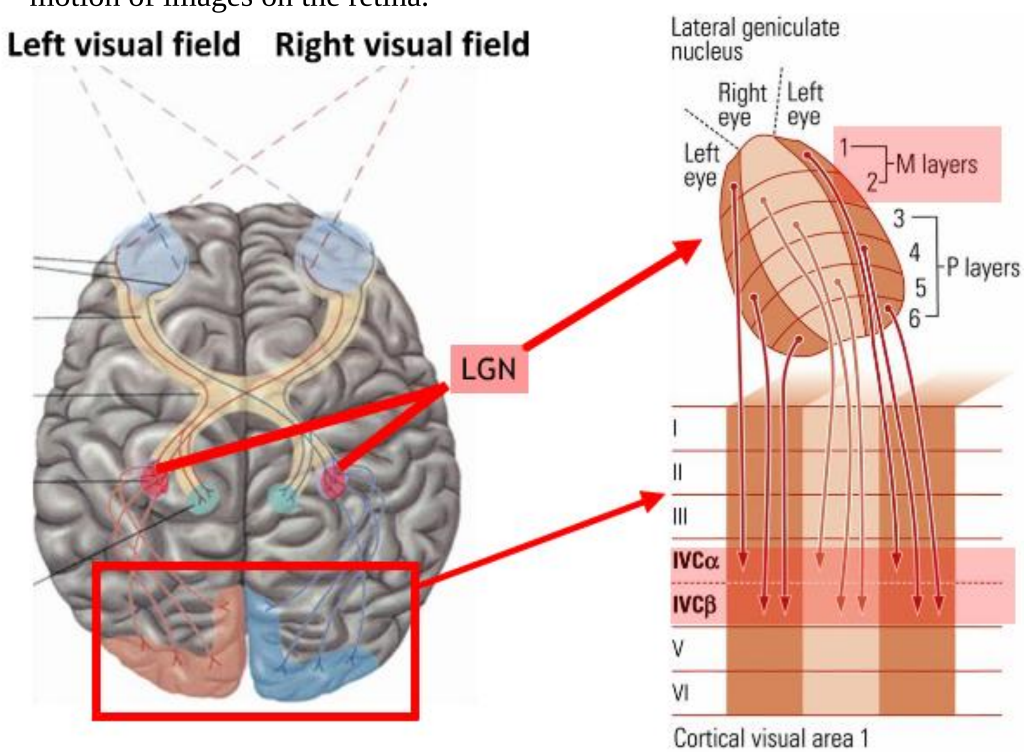
- The signals that leave the eye and project to the LGN are carried by two main classes of ganglion cells: the parvo- and magno- streams.
- The parvo cells are highly involved in detecting colour, pattern, and form.
- The magno cells are crucial for detecting changes in brightness as well as motion and depth. These cells are found throughout the retina, although the ones found in the periphery are most sensitive to movement.



- From the retina, some of the magno cells send axons along the secondary pathway, or to the superior colliculus, then onto the pulvinar of the thalamus, before finally reaching the parietal lobe.
- This secondary pathway is important for detecting the location of objects in space, as well as controlling the direction of eye gaze so that it shifts towards the object.



- Most of the magno cells, however, send their axons along the main pathway to the LGN.
- Information from magno cells is processed in two of the layers of the LGN, while the remaining four layers are reserved for input from the parvo cells.
- From the LGN, information from the magno cells goes on to layer IV of the primary visual cortex, where there are some cells that respond to the direction of motion of images on the retina.



- For instance, when we discussed feature detectors with form perception, we learned that some complex cells are particular about the direction of movement and will only fire if a bar stimulus is moving from right to left but not if it is moving from left to right.

The Waterfall Illusion:

- To demonstrate the direction selectivity of MT neurons, consider a motion after-effect called the waterfall illusion.
- If you stare long enough at a waterfall, with time you will adapt to the downward motion. If you then look at a stationary scene, you will experience a very odd sensation in which everything will appear to move upwards.
- This after-effect occurs because the MT neurons selective for a particular direction fatigue.
- Consider two sets of MT neurons, one sensitive to upward motion, and one sensitive to downward motion. Your brain computes overall motion direction by comparing the output of these two populations of neurons.
- If your upward motion selective neurons are firing more than your downward motion selective neurons, you will perceive upward motion.
- After staring at the downward motion of a waterfall for a long time, your downward sensitive MT neurons will become fatigued and inhibited - This means that even though your upward motion sensing neurons are still just firing at a baseline level, they are responding more relative to your tired downward motion sensitive neurons; the net result is that you will perceive upward motion that does not exist!
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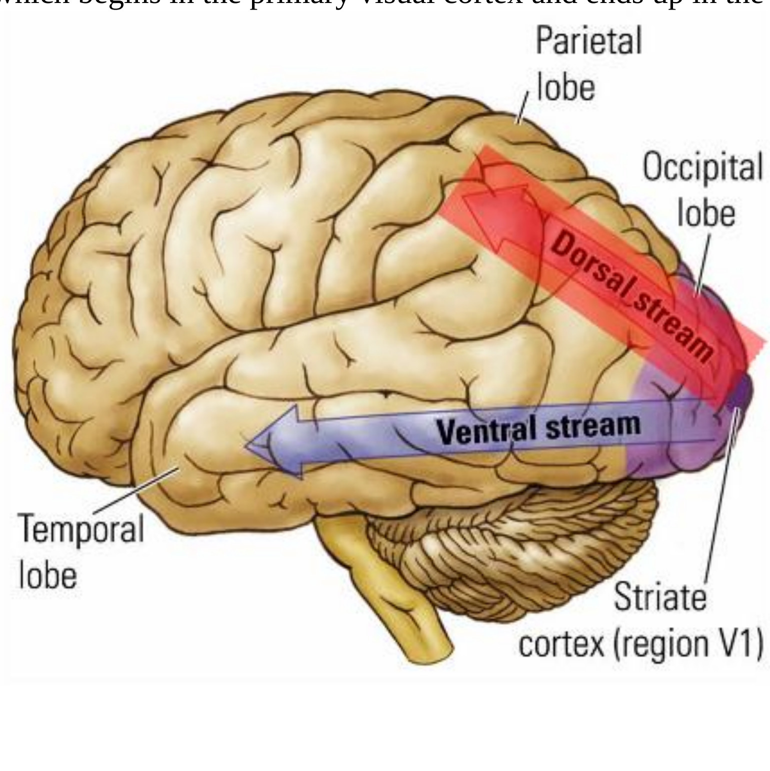
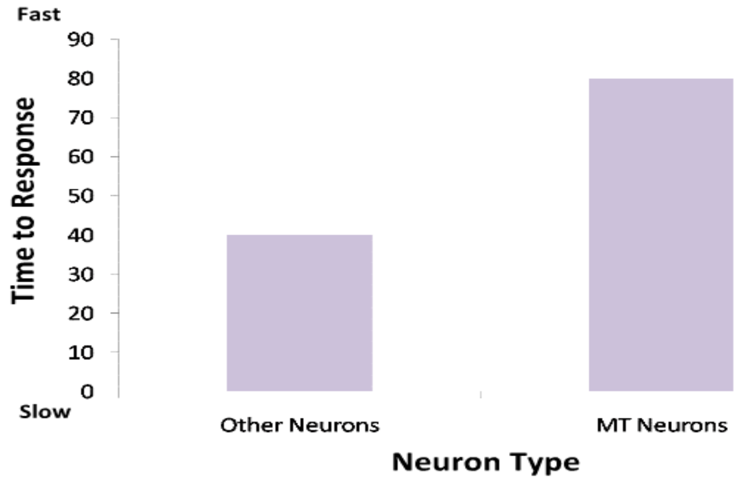
- In any case, the input from the parvo and magno cells that arrives in the primary visual cortex is treated as three separate types of information that correspond to colour form, and movement.
- The movement information goes on to the extrastriate cortex, where it is processed in visual area 5, or VS, before it reaches the parietal lobe.
- The extrastriate cortex is where information gets segregated into two streams according to what type of information is being processed.
- We already learned that colour and form are processed in the ventral or the "what" stream, which goes from the primary visual cortex to the extrastriate cortex and then on to the temporal lobe.
- Movement information, however, is processed in the dorsal or the "where" stream, which begins in the primary visual cortex and ends up in the parietal lobe.



- Studies with monkeys have shown that area V5 of the extrastriate cortex, which is also known as area MT has neurons that are sensitive to movement information.
- If a monkey suffers damage to area MT, then it won't be able to perceive stimuli that are moving.
- Because the information that is being processed in area MT has to be up-to-date in order to correctly process movement, the axons that transmit information from the magno cells are thick and heavily myelinated.
- This increases the speed with which visual information can be transmitted to area MT.
- Compared to other regions of the extrastriate cortex, area MT is designed to respond much sooner to any input.



Motion Agnosia:

- Case studies of patients with specific neurological deficits can give us a glimpse of what life would be like with limited motion perception and reveal the neurophysiological mechanisms that underlie these skills.
- One patient, L. M., suffered brain damage in area V5 of the extrastriate cortex and lost her ability to detect movement.
- To her things that were moving appeared frozen, and they would seem to jump from one place to another.
- She could not pour herself a cup of tea because she wouldn't see the level of the tea rising slowly in her cup, but instead, she would see a solid spout of tea coming from the tea pot one second, and the next second she would see tea spilling over her cup and onto the counter.
- She did, however have normal vision for everything else, and could read, recognize objects and name colours.
- Even though her only problem was with perceiving movement, she was still able to perceive form from movement.
- If she was shown a blackened out person with lights on their joints, she would be able to recognize these lights as a person, even though she could not perceive the lights moving at all!
- Contrast this with another patient, R. A., who had brain damage in a different region of the extrastriate cortex.