COURSE: ***OPTO 416 - Physiology Of Vision II***

UNITS: ***2 + 0 = 2***

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RECOMMENDED TEXTS:

1) VISUAL PERCEPTION by Cornsweet

2) VISUAL PERCEPTION – A Clinical Orientation by Steven H. Schwartz

3) OPTOMETRY by Keith Edwards and Richard Llewellyn

Topics

1) Visual Perception

- Understanding Visual Perception
- Perception of Depth
- Perception of Motion
    - Directional Sensitivity
- Perception of Shape
- Perception of Size
- Perception of Distance
- Perception of Time

2) Optical Illusions and Entopic Phenomena

- Description of Optical Illusions
- Causes
- Significance to the Visual System

3) Color Vision

- Mechanisms of Color Vision
- Color Vision Defects and their Significance

Lecture 1

Understanding Visual Perception

Let us begin by distinguishing between visual sensation and visual perception.

VISUAL SENSATION

- Sensation: the process by which sensory receptors receives stimulus energy from our environment

Ali Saleh is looking at a metal box. Visual sensation is the process by which the (outline) Image falls on the retinae.

VISUAL PERCEPTION

Visual perception is the process of organizing & interpreting sensory information.

While looking at this box, the image of the box first falls on both retinae and then this image is transmitted to the brain by what is known as 'point-to-point projection' . When these images arrive at the cortex, they combine with the following:

- Visual perception from the other objects the person sees (simultaneously) in the background.
- The memory for past experience.

All together, these result in visual perception.

In visual sensation, only an outline image of the box falls on both retinae.

In visual perception, he figures that he's looking at the box from a distance of about 20 meters. He makes out the edges of the box and using the light gradient on the box (light and shade) to judge its size. He remembers from past experience that this is a heavy duty box used by people who are moving houses. In fact, he distinctly remembers it as the type of box that was used when they were moving house last year.

Therefore in less than a second, Ali Saleh makes the seamless transition from the visual sensation of the edges (outline) of a metal box, to the visual perception of that box as the sort of heavy duty container used by people who are moving house and which was used by time whilst moving house last year.

It is worthy of note however, that in certain cases – for example the case of a flash of light – visual sensation is virtually identical to visual perception. In such cases, the image has no form, shape or size to speak of, and more importantly contributions in the cortex from other objects in the visual field (which are simultaneously perceived), and from past experience, are minimal.

LEVELS OF VISUAL PROCESSING

Perception of visual information involves building a mental picture of the visual scene. According to Marr (1980), these visual representations occur in the following stages:

- First, from the edges of objects in the scene, a basic sketch is made representing those edges as lines.
- Second, a 2-dimensional sketch is made of the scene, in which surface characteristics such as color, curvature and texture are determined.
- Finally, a 3-dimensional model is developed through which the complete structure of the object is appreciated. In this final model, the object id 'turned over' in the mind so that whilst looking at the object from only one perspective, one can imagine what the object would look like from all other perspectives.

SPECIFYING VISUAL INFORMATION

The image received on the retina is just a pattern of different light intensities and wavelengths, which may change from moment to moment.

Objects can only be seen if their luminance and/or color is different from that of their background. Experiments have demonstrated that luminance differences are much more important than color differences for distinguishing objects from their backgrounds.

For any one object, its luminance depends on the following:

i) The amount of light falling on its surface.
ii) The amount of light the object reflects.

Now, on any one object, the luminance varies from point to point. In the visual scene, spatial variations are caused by illuminance or reflectance changes leading to bright portions and dark portions on any one object.

Luminance changes across the body of an object are very important for visual perception. For example, knowing whether a luminance change is caused by a change in intensity of illumination, or a change in the reflectance (of different portions) of the object of regard, is important for the accurate perception of the lightness or darkness or change in color of a particular surface.

One important function of luminance change is its role in edge detection. Edges are defined by the following characteristics:

a) Contrast: This is the magnitude of luminance change between two points.

b) Spatial Frequency: This refers to the scale at which the luminance changes occur. These changes could occur at high or low spatial frequencies.

Spatial frequency is calculated by measuring the number of cycles of the waveform per degree of visual angle (1 cycle = 1 light band + 1 dark band).

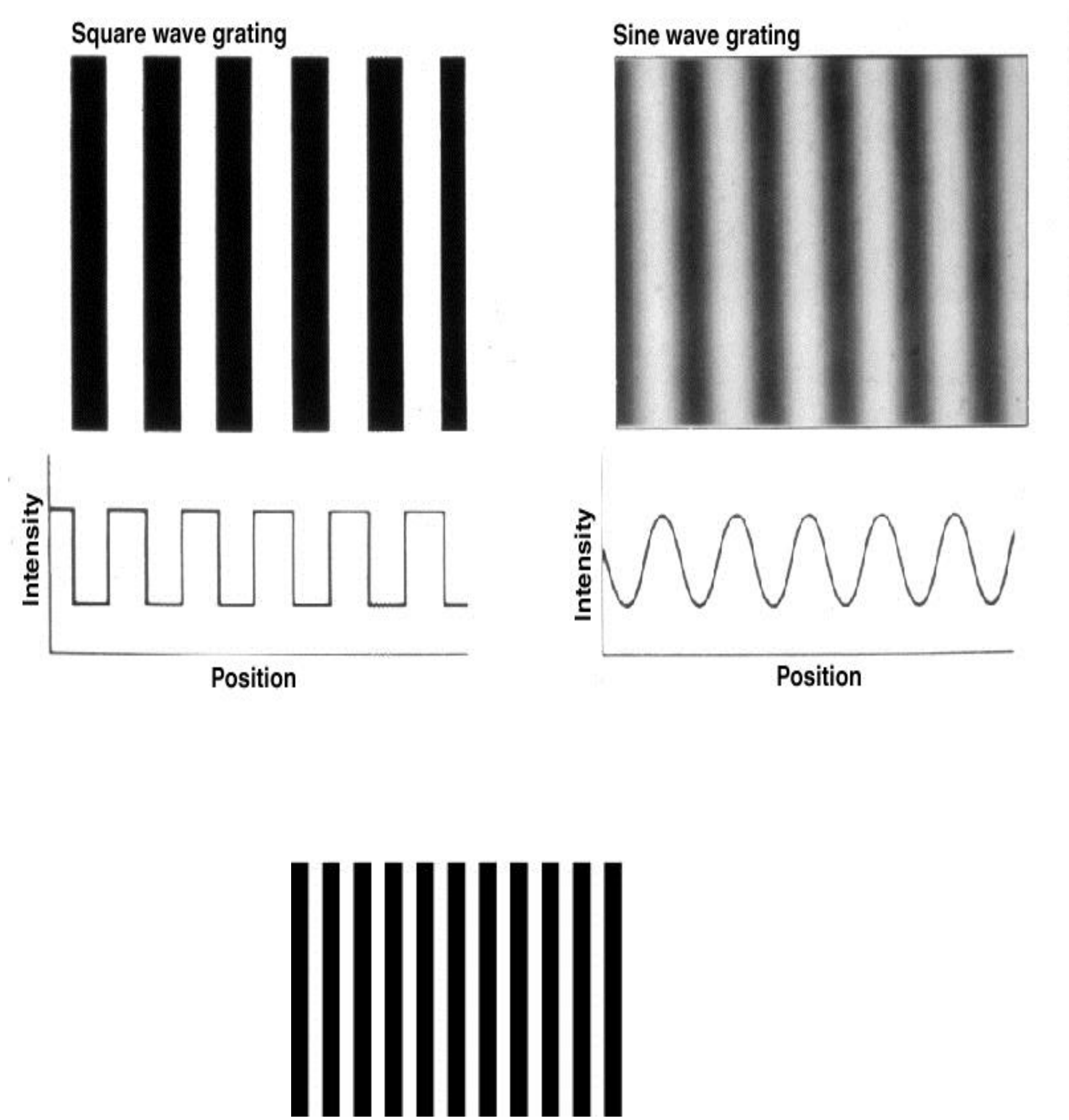


Figure 1A Medium Spatial Frequency Square Wave Grating
1B Medium Frequency Sine Wave Gratings
1C High Frequency Square Wave Gratings

OPTICAL PROCESSING

- When an image is formed by an optical system, aberrations (e.g. coma, spherical, chromatic) occur and these cause a reduction of the contrast of all spatial frequencies.
- Knowing the amount of contrast loss for every spatial frequency gives a complete description of system quality.
- The relationship between contrast loss and spatial frequency is called the modulation transfer function (MTF) of the system.
- The performance of any image-forming system can thus be described by its MTF. However, as regards the human visual system, part of the MTF is described by the quality of the optical components of the eye. The optical transfer function (OTF) describes the quality of the eye's optical system.
- Ocular OTF depends on pupil size but it generally shows reduced contrast with increased spatial frequency. Furthermore, very high spatial frequencies are totally lost resulting in a further blurring of the image.
- Therefore the image of any object formed by the retina is always more blurred than the object. This situation also holds for other image-forming systems.

Lecture 2

The blurring out of higher spatial frequencies has a very important advantage for visual processing. To adequately explain this advantage, let us consider the following points.

- ✓ Let us look as each rod and each cone as a camera. Each camera catches the image of a tiny portion of the entire visual scene (which contains the primary object and its surroundings).

- ✓ The spaces between these rods and cones determine how many points of the visual scene are captured as images and therefore how much detail is seen by the eye as a whole.

- ✓ These spaces between the rods or between the cones is called ***sampling frequency (or spacing frequency if you like).***

- ✓ If the visual scene contains spatial frequencies, which are similar to the sampling frequency of the rods (or of the cones), a form of destructive interference called ***Aliasing*** results.

- ✓ Sampling frequency is highest at the fovea. This means that the spaces between photoreceptors are smallest at the fovea. This is because we have a high concentration of cones at the fovea (about 330,000/mm^2). In addition, the spacing between the cones at the fovea is highly regular.

  High cone density and regular cone spacing at the fovea is necessary for the perception of fine detail.

- ✓ Optical aberrations, it has been mentioned, cause a cut off of very high frequencies from the visual scene before they reach the retina. These frequencies, it has been found, are very similar to the sampling frequency of the foveal cones. Therefore Aliasing would occur were these high frequencies allowed to reach the retina.

✓ In the peripheral retina where the sampling frequency of the rods is low, there is bound to be some Aliasing since most of the frequencies from the object/visual scene are low to moderate.

✓

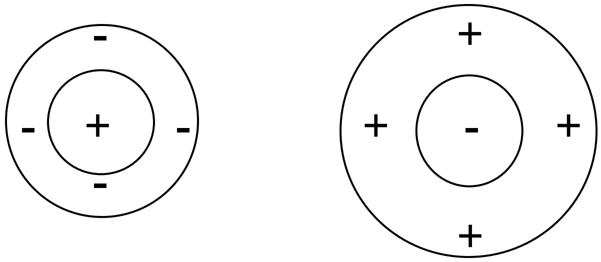
- ✓ People with uncorrected refractive errors suffer image blurring (loss of high spatial frequencies) as well as a reduction of contrast at the remaining frequencies. Further, the higher the optical defocus, the greater the cut-off of higher frequencies and the greater the contrast reduction at lower frequencies.

Receptive Fields and Edge Detection

- It has been demonstrated that interpretation of the visual image begins in the retina
- The retina is responsible for the early visual processing stage of edge detection.
- Two requirements for any edge detection mechanism are:

  I. Detection of spatial luminance changes across the image
  II. Distinguishing between big and small differences, which may occur in the same image area.

  Both requirements above are met by ***Retinal Receptive Fields***.



On-centre (X+) ganglion cell

Off-centre (X-) ganglion cell

- Each retinal ganglion cell will only respond to a stimulus if it falls within a circular group of rods or cones known as the ***receptive field*** of the ganglion.
- Looking at the receptive field schematics above, ganglion cells will display varying responses to light sources depending on whether these light spots fall within the center circle or the peripheral circle.
- The maximum response in either type of receptive field will occur if a spot of light completely fills but is limited only to the inner circle.
- If a spot of light falls inside the inner circle but does not fill it, the ganglion cells in that receptive field will respond to that light, though not maximally.
- If we have a light spot that completely fills the inner circle, and also fills part of the outer circle, we get a ***laterally inhibited*** response. A laterally inhibited response is a below maximum response as a result of the spot of light stimulating oppositely charged areas (+ and -).

- A large spot of light, which completely fills the larger circle, will elicit the minimum response from that particular receptive field.

- As a result of the phenomenon of receptive fields, it becomes clear that ganglion cells are more sensitive to contrast than to luminance. In other words, we are more dependent on the difference between the brightness of an object and the brightness of its background (than the brightness of the object alone) to determine how bright or dark the object is.

- Two white objects with the same luminosity will appear to have different brightness values if they are placed against different backgrounds (one light and one dark). This phenomenon is referred to as ***Simultaneous Contrast*** (i.e. the dependence of the brightness of one region on the brightness of adjacent or surrounding regions).

- There are different sizes of receptive fields. Smaller receptive fields are associated with high-definition foveal vision, and larger receptive fields are associated with peripheral rod vision.

- Recent evidence suggests that smaller receptive fields are enclosed within larger ones.

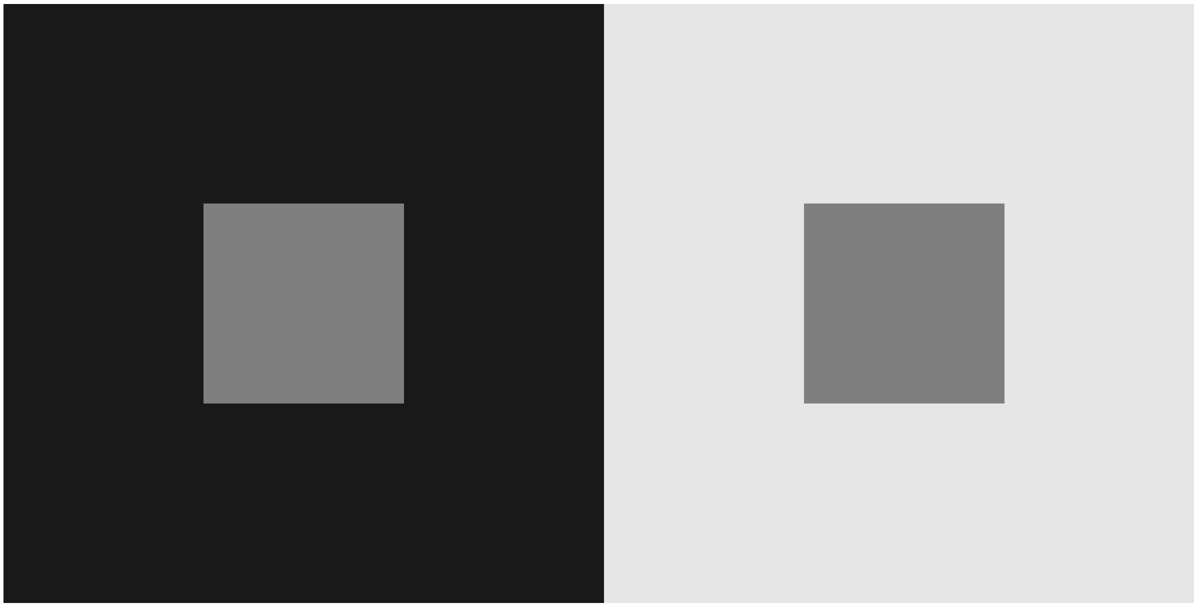
  The advantage? Any one portion of an object can be analyzed simultaneously at different frequencies (high spatial frequencies of small receptive fields and low spatial frequencies of large receptive fields.

- Whenever the eye looks at an object, the retina has many receptive fields looking at every portion of every edge of the object simultaneously. This method of edge analysis is called ***Zero-crossing***. We can then say that the retina detects edges by locating Zero-crossings in the image.

- The terms X+ and X- are used to refer to spatially opponent ganglion cells.

- X ganglion cells have small receptive fields and are responsible for the resolution of fine detail.

- Y ganglion cells have large receptive fields and respond best to rapidly moving stimuli.



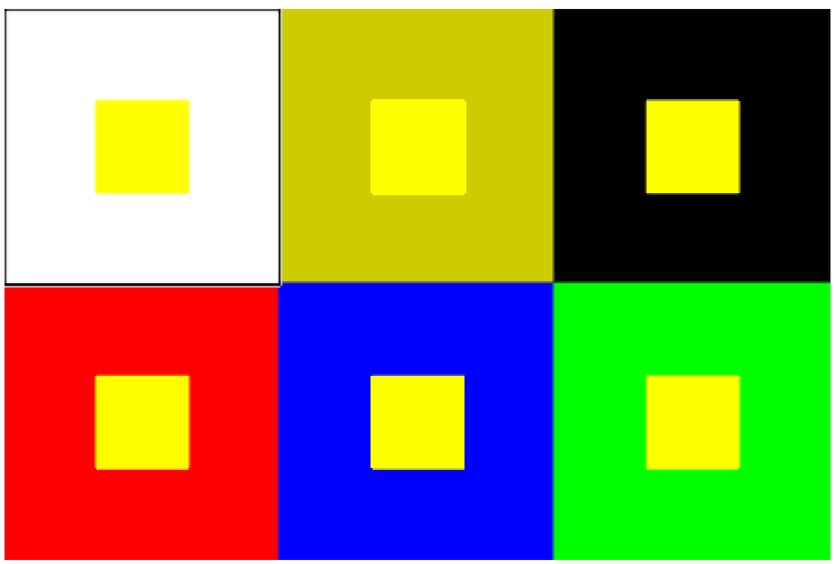


Figure 2A Simultaneous Contrast in Black and Grey
2B Simultaneous Contrast in Color

Which is the darker grey and which is the brightest yellow?

Thus far we should be able to appreciate a simple model in the perception of object shape:

- Edge elements (edge details) are detected in every part of the image simultaneously by receptive fields.
- Brain neurons combine these object elements to form outlines and this also takes place simultaneously for the whole object.

This method of handling information from all parts of the object simultaneously is known as **Parallel Processing**.

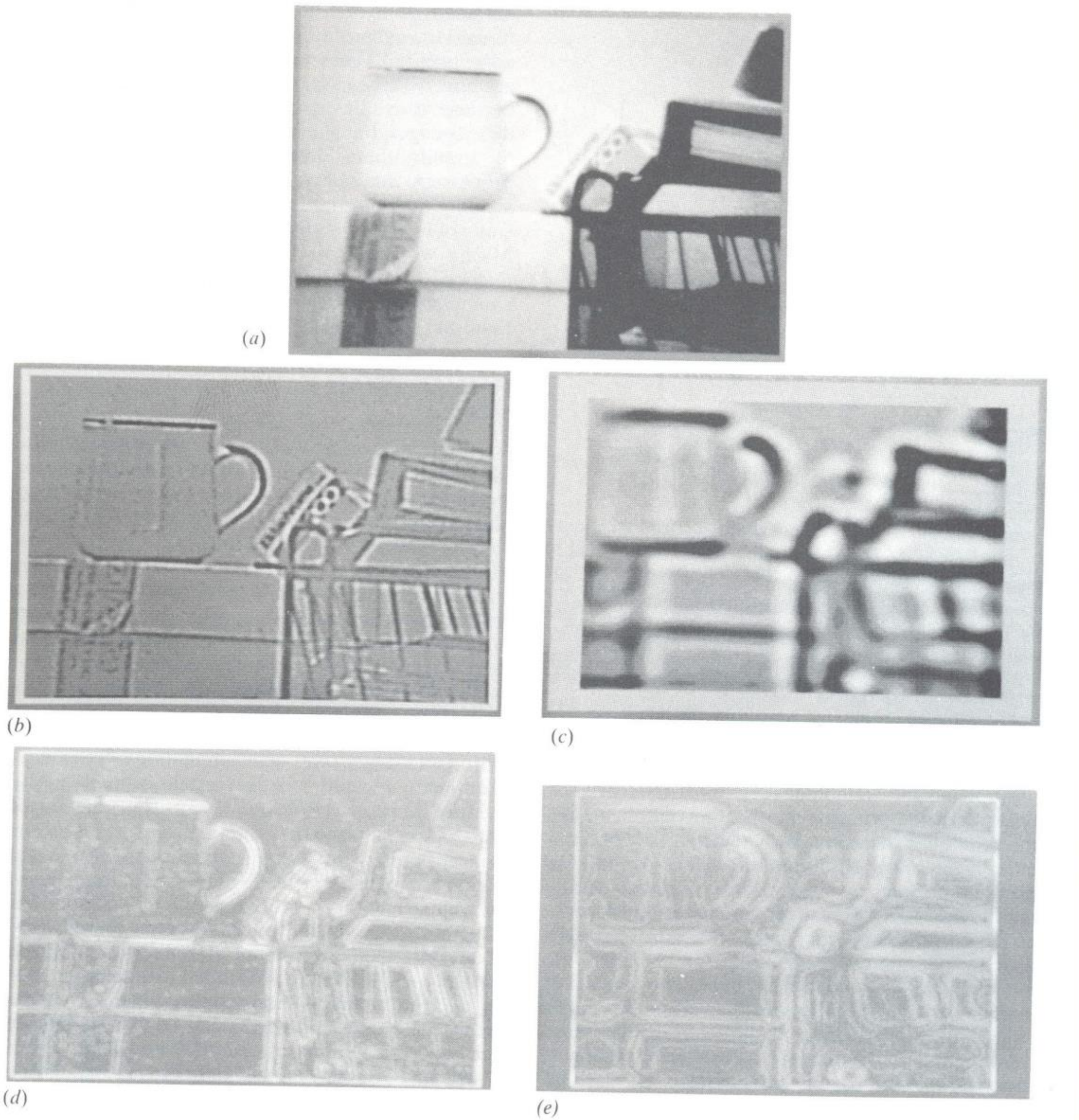


Figure 3 **The original object scene (Fig 3a) has been transformed into how it is perceived on the retina when only the small-sized Ganglion Cell Receptive Fields (GCRFs) on the fovea (Fig 3b) are 'looking' at the object. Fig 3c shows a more blurry image. Here, only the large ganglion cell receptive fields at the fovea are 'looking' at the object scene.**

Figs 3d and 3e correspond to 3b and 3c, respectively, and they show the earliest stage of vision of the object scene when only the edges of the objects in the scene are demarcated.

Contrast Sensitivity and Spatial Frequency Channels

- We now know that the basic requirement for edge detection is contrast.

- To find out how much contrast is necessary to detect the different edge spatial frequencies then becomes useful in determination of the spatial performance of the visual system.

- With a sine- (or square-) wave grating, the amount of contrast needed to detect an edge of a grating (and hence its presence) is called the ***contrast threshold***.

- 1/contrast threshold = ***contrast sensitivity***.

- A graph of contrast sensitivity (plotted for different spatial frequencies) against spatial frequency is known as the ***threshold contrast sensitivity function (CSF)***.

- The CSF is the MTF for the eye. It incorporates the OTF and the neural performance of the visual system, and it gives us very important insights into everyday vision:

    - Fine details require more contrast to be detected (because fine details have high spatial frequencies, which require more contrast to be resolved).

    - Detection of all spatial frequencies is improved if the ambient illumination is high.

    - Visual acuity can be predicted from contrast sensitivity but not vice-versa. This is because VA is measured at the highest range of contrast.

    - CSF is measured using vertical gratings because research has shown that the eye is less sensitive to oblique gratings than to vertical or horizontal gratings.

- There are separate channels (paths) for processing different spatial frequencies from receptive fields. Higher spatial frequencies are processed via different paths from lower spatial frequencies.

- At least 4 of such paths are necessary (and 6 are sufficient) to explain spatial visual performance in the human eye.

- CSF has proved clinically valuable in detection of pathologies that would otherwise have gone undetected if only V.A were used to assess visual function. Such pathologies include subtle reductions of macular integrity, which may not noticeably compromise visual acuity.

Lecture 3

Stereopsis

- Edge detection is improved in binocular vision because binocular contrast sensitivity has been shown to be some 40% better than monocular contrast sensitivity.

- Stereopsis works by detecting geometrical disparities between the images of both eyes (much like edge detection works by detecting luminance differences).

- Let us say Mustapha is looking at the tip of a pencil at a distance 50 cm in front of him. When he closes OD, he sees the pencil against its background (with OS). When he looks at the pencil tip with only OD open, he sees the pencil still, although against a slightly different background. The horizontal difference in the pencil position when viewing with OS vs. OD (or horizontal disparity) is used to calculate the distance between the pencil and the background.

- Stereopsis occurs in two basic stages:

    - ***First, both monocular images are matched so that fusion is possible***. Here, individual points on the OS image are matched (or correspond) with individual points on the OD image. Independent edge detection by each eye is a pre-condition sine qua non for this stage.

    - Second, the fused image is analyzed to judge depth information. How does this analysis occur? As mentioned earlier, there are points on the left image, which correspond with points on the right one. These points occupy different spatial positions. It is the difference between their spatial positions that results in the judgment of depth.

- The lateral separation of the two eyes means that horizontal disparities are more important than vertical disparities in Stereopsis. Vertical disparities are sometimes present, although they are of a much smaller magnitude.

- About 50% of the cells in visual area 1 (V1 or area 17) respond to disparity and therefore participate in Stereopsis. A higher proportion of cells in V2 (area 18) respond to disparity.

- We said earlier that points in the monocular image of OS correspond with points in the image of OD. This is not exactly the case. What happens is that one image point on the OS image corresponds with a particular area of the monocular OD image. This area is referred to as ***Panum's fusional area***.

- The assumption made in describing binocular fusion and Stereopsis is that Panum's fusional area is fixed for any one point. In actuality, the size and shape of Panum's fusional area, vary with the spatial and temporal parameters of the object/s being fused.

PERCEPTION OF MOTION, AND DIRECTIONAL SENSITIVITY (DS)

Before we discuss perception of motion, and directional sensitivity in the visual system, let us first highlight a few salient points about ***Sustained and Transient Channels***.

Sustained and Transient Channels

- When we consider separate channels for low and high spatial and temporal frequencies, we must consider the inter-relationship between spatial and temporal stimuli.
- First of all, what are spatial and temporal stimuli?
    - Spatial stimuli are objects in the visual field whose position and appearance in space are constant (for example, the square-wave grating discussed earlier.
    - Temporal stimuli however, change with time. Two examples are: an object in continuous motion; and a flashing light source. In either case, either the position of the object, or its structure/form are continuously changing with time.
- If those gratings presented earlier were presented on a rotating drum, we would have a spatiotemporal stimulus.
- It has been shown experimentally that the contrast sensitivity of a moving set of gratings has some interesting differences from a stationary set of gratings.
    - The contrast sensitivity at lower frequencies is improved when the gratings are in motion.
    - At the same time, the contrast sensitivity at higher frequencies is reduced.
    - This means that the visual acuity (fine detail) of a moving object is less than if the object was stationary, but, for larger objects, the ability to detect them is better when they are in motion.
- It has been shown experimentally, that, with respect to spatiotemporal stimuli, there are two distinct processing pathways in the visual system.
    - The first pathway (***Sustained pathway***) responds best to stationary or slowly moving stimuli, is responsible for the perception of fine detail, and it corresponds to the X-type ganglion cell receptive fields.

- The second, ***Transient pathway***, responds best to rapidly moving or rapidly flickering stimuli, is primarily responsible for the perception of motion, and it corresponds with the Y-type ganglion cell receptive fields.

- In actuality, because temporal targets almost always have a spatial component, and spatial targets occasionally have a temporal component, the Sustained pathway and the transient pathway cannot be totally independent of each other.

Motion

- Perception is the direct result of spatiotemporal change. However, not all spatiotemporal change is perceived as motion. Think about this: on our wristwatches or wall clocks, we are not always aware of the motion of the second hand. But we do know it has moved because its relative position against the fixed markings on the clock, has changed.

- We refer to these fixed markings (as well as the different color of the second hand from the rest of the background) as ***positional cues*** (positional hints or ideas).

- If we remove all positional cues from our watches then, it would be possible to detect the motion of the second hand by dint (means) of its velocity.

- But from physics, we are made to understand that velocity can be crudely described as ***Speed + direction***. Therefore, it becomes clear that perception of motion is depends on simultaneous perception on the amount and the direction of spatiotemporal change of the object of regard.

Directional Sensitivity

- Directional sensitivity has been suspected to exist for a long time now. This is as a result of motion after effects. Put simply, if Mohammed looks at an object that is moving continuously (in a fixed spatial location) for long enough to adapt to it, then when he now looks at a stationary object, that object appears to move in the opposite direction.

- As you may have already concluded, experimental evidence weighs-in heavily in favor of DS being a property of the transient channels.

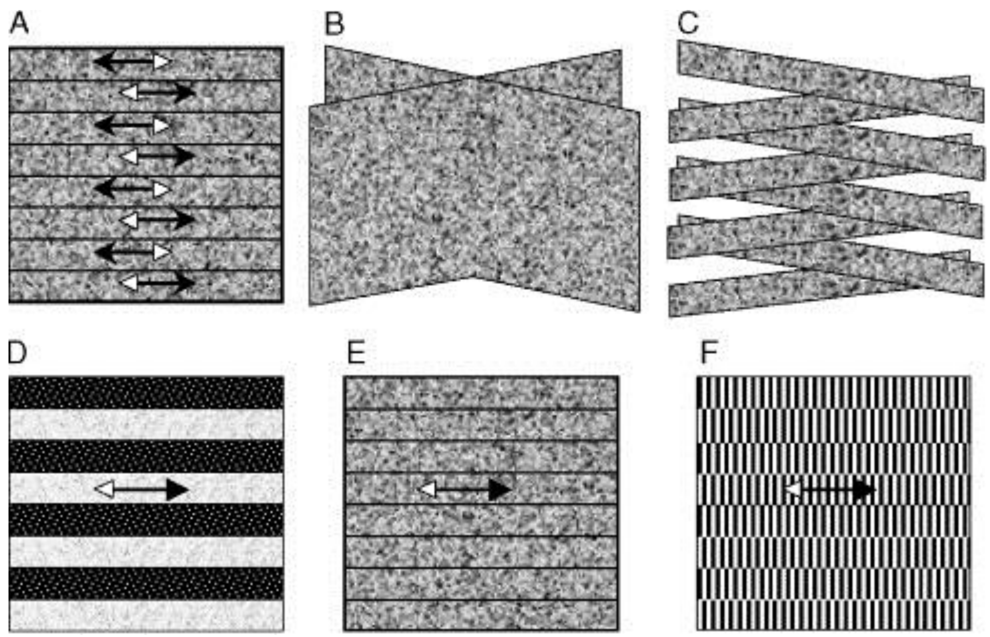


Figure 4 Random Dot Stereograms (RDS).

A is seen by one eye (OS for example), B is seen by the other eye and C is the picture seen by the brain when both eyes are looking, and if stereopsis is present in the subject.

The same is true for D, E and F.

- Looking at the RDS figures above, it becomes obvious that the final picture is a composite picture that can only be seen when both eyes are looking and if stereopsis is present. Motion perception does something similar. If you look at a moving car right now, and then again two seconds later, your brain (if your motion sensation is normal) takes both images of that car and combines them to get a sensation of motion. So in a sense, motion perception is like binocular perception. This is a rather strange but interesting concept.

- The visual processing of motion still isn't fully understood but, as with depth perception, it has been shown that isoluminant stimuli preclude (prevent) motion perception.

Defn. Isoluminant stimuli are stimuli which are uniformly lit across the surface.

- So what if isoluminant stimuli prevent motion (and depth) perception?

- By now we are familiar with the fact that edge detection is heavily reliant on luminance difference across the surface of an object. Isoluminance will prevent edge detection.

- This all means that the critical first stage of motion perception (and of depth perception) is edge detection.

- The basic schema for motion detection can be described as follows:

  - First, the X+ and X- ganglion cell receptive fields combine to locate the edges of an object.

  - The results of the edge detection are combined with the results from the analysis of the Transient Y cells, which detect temporal changes.

  - The sign of the Y (+ or -) shows towards which part of the edge the object is moving, and therefore the general direction of motion.

- Of course the primary function of motion perception is the detection of movement. However, motion perception can be used like Stereopsis to determine the structure of a scene. This phenomenon has been referred to as ***structure-in-motion***.

- Stereopsis works by using disparities in simultaneously perceived images to judge depth. Structure-in-motion works by using successively perceived images to judge the very structure of those images.

Depict example structure-in-motion using random dot kinetograms (RDKs)

https://www.youtube.com/watch?feature=player_detailpage&v=RdwU28bghbQ

Lecture 4

Psychological and Physiological Aspects of Motion Perception

We have hinted on the general concepts of motion perception. Now it's time to delve into some of the more complex aspects of motion perception.

Many researchers have contributed immensely to our current understanding of motion perception. One of those researchers – Werner Reichardt – explained motion perception using a motion detection scheme.

Looking at the Schematic representations in figures 4a and 4b, signals from two photoreceptors are sent to a multiplier (M), which we will consider as being the brain. Between one receptor and the multiplier we have a square with a Δ sign in it. The receptor signals, which pass through this square, reach the multiplier later than the signal from the other receptor. The result? Perception of motion in the direction from slower to faster receptor.

Figures 4a and 4b represent the same scheme in reverse.

Motion is very important for the following functions:

- ✓ Differentiation of an object from its background.
- ✓ Sorting of objects into different depth planes based on their velocities.

Both functions are very related and enable us to detect an object that is moving against a (spatially) constant background, or one that is moving at a different velocity and/or direction from the object.

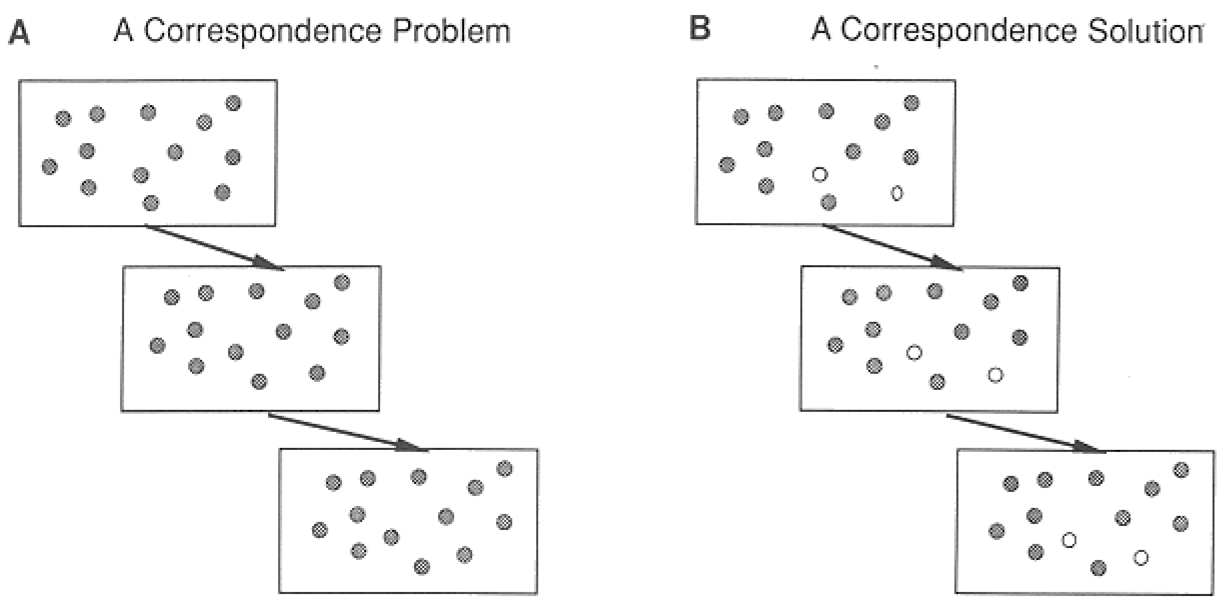
Let us now consider some attributes of motion perception.

Stimuli

By varying the stimuli presented to the visual system, we can more easily study some of its tenets.

Correspondence Problem

Random dot cinematograms, such as those depicted in figures 4a and 4b, present a particular challenge to the visual system.



A B

Figure 4A Correspondence Problem

Figure 4B Correspondence solution

Looking at the schematics, if we look from the first rectangle in 4A, to the second one, and then finally to the third one, we see that the pattern of dots has changed but we cannot tell exactly which set of dots have changed their position.

With figure 4b, we are more clearly able to see which set of dots have moved.

Now if the rectangles in figure 4a were shown to an observer in a rapid sequence, without any effort, he can tell which dots have moved and what direction they moved. This ability to tell the structure of an object as a result of motion (structure-in-motion) has been termed ***'Matching'*** although this term is not strictly accurate.

Aperture Problem

This problem arises from looking at an infinite-sized object from a finite aperture. Let us assume that a very long edge is moving past one receptive field, because of the size of the object, the receptive field should be confused and not be able to tell the direction of motion of the object. But contrary to this expectation, such confusion does not occur. Put in a nutshell, the visual system can organize these receptive fields to rapidly analyze the direction of motion of individual points on the object. If the first impression from that analysis is that the object is moving in the same general direction, the sensitivity of the receptive fields is changed from one of minute detail to one of gross detail. With this gross detail sensor on, the perception is one of a large object moving in a particular direction.

D_{max}

Such a simple expression, but one with boundless applications!

Remember the random dot cinematograms we discussed earlier? Okay, let us assume that we present these rectangles in rapid succession; we agree that the dots appear to move.

Now, it has been discovered that, should the dots in the second square have radically different positions from those in the first square, when rectangle 2 is presented to us a very short time after rectangle 1, the pattern of dots, instead of appearing to move like before, seem to disappear and then re-appear in a different location (such that the images appear to change like in a slide projector instead of like in a TV movie).

D_{max} is the largest change in the position of these dots such that when the two rectangles are presented in rapid succession, the observer perceives a motion of the dots into their new position (rather than a 'disappearing/re-appearing' act).

Over the past couple of decades, D_{max} has become an indispensable tool in the study of motion perception.

Early studies suggested that d_{max} had a value between 15 and 20 minutes of arc, but later studies have shown, rather convincingly, that d_{max} is increased by the following factors, to up to 90 minutes of arc:

- ***Eccentricity from foveal fixation***
- ***Blurring of the image by removing the high spatial frequencies***

In the first case, when fixation is parafoveal, d_{max} increases and continues to do so as we move further into the periphery. This means that larger displacements (and therefore velocities) are better accommodated in peripheral (rod) vision than in central (cone) vision. This is entirely in line with what we would expect.

The second case may seems rather puzzling at first, but when we take into consideration the fact that cone vision entails extremely fine detail (high spatial frequency) recognition, then we may begin to understand this phenomenon.

When the image of an object is blurred by removing the high spatial frequencies from it, cones become less sensitive – and rods more sensitive – to that object. Rods can therefore more effectively assess the movement of what to them, has become a clearer object.

This 'blurring-of-the-image' improved d_{max} now gives a whole new meaning to the term interference. Because all we did by blurring the image was filter out the high frequencies from it, and suddenly, the rods became more active. It therefore becomes clear that the presence of high frequencies in the image inhibits the actions of the rods and thus reduces d_{max}. One may then ask why since we have already determined that there are different pathways for the processing of high and low spatial frequencies. It therefore means that these high and low frequency channels are not completely independent of each other.

Physiological Correlations for d_{max}

More research on the d_{max} phenomenon and how it related to actual cells in the cortex have yielded the following insights:

- In a specific area of the brain known as MT (believed to be specialized for motion processing), the increase of d_{max} with eccentricity is much higher than for V1 cells.
- The largest displacement which gives rise to a directional response is much smaller than a receptive field. Therefore receptive fields are now regarded as being made of many local subunits, each of which is directionally selective.
- Furthermore, neighboring regions in the visual field act to produce an overall sensation of motion.

Heuristics for Motion Perception

Let us reconsider what by now have become our very good friends – the moving dots within successively presented rectangles in the correspondence problem.

How can the visual system resolve the direction of just a small subset of dots in such a complex system? Does it analyze every single possible position in which every single dot might move? The answer to the latter question is obviously no! Because this system will be too tedious, time consuming, and labor intensive to be practical.

We now know instead that over centuries of innovation, the visual system has developed a heuristics system (system of basic rules) by which objects in the real world tend to move. By assuming these heuristics therefore, the visual system does not have to analyze the direction of motion of individual points in a complex mosaic, to determine the direction of movement of the whole mosaic pattern. It checks for a fulfillment of these basic rules and produces an all-or-nothing response (i.e. the whole mosaic is either moving in a particular direction, or it is not).

These heuristics rules (or assumptions) if you like are very common sense, but remarkably accurate and they are:

1. ***Inertia*** This assumption (Newton's first law of motion) is that moving objects don't like to move from position of immobility, but, once they start to do so, become reluctant to stop and will generally tend to continue their motion in the same direction, showing minimal changes in velocity over time.

2. ***Rigidity*** An object in motion tends to move with all its parts together in one piece, and in the same direction. Bits and parts of the ball don't just fly out in dependent directions with the ball in mid-flight.

3. ***Covering and Uncovering*** Well, based on the other two assumptions which must make a great deal of sense to us, this assumption asserts that in such a predictable mechanism for the general movement of objects, as the objects move, they tend to cover and uncover predictable regions of the background.

Cortical Correlates of Psychophysical Phenomena of Motion Perception

Have mentioned briefly the predominant psychophysical phenomena that mediate motion perception, let us try to extrapolate the cells in the brain responsible for some of these phenomena.

From experiments carried out in the cat and monkey, three types of cells play major roles in motion perception. These are:

- ✓ Direction-sensitive cells
- ✓ Velocity-tuned cells
- ✓ Motion-segregation cells

In the first group of cells, there is a particular response to objects moving in a particular direction. However, this directional sensitivity is not just a simple affair as different components of the same object appear to move in two predominant (opposing) directions, and these cells have to decide which the prevalent direction is.

Just to confuse you further, we now know that, for many cells directional sensitivity also depends on the velocity of movement of the object. Various cells respond to various velocities of movement.

Finally, the direction selectivity of some cells depends on the sign of the target's luminance contrast. A bright target on a dark background may produce a different direction index from a dark target on a light background.

The third type of cell – the motion segregation cell – appears not to have any input in motion perception, until the background starts to move as well.

Probably, the most well known type of motion segregation cell is the ***anti-phase cell***, which responds strongly when the direction of movement of the background is opposite to that of the object.

Two basic types of anti-phase cells have been identified:

- ✓ The first type of cells is known to be sensitive only to opposing movements along a particular meridian.

- ✓ The second cell type is sensitive to an opposing background movement, irrespective of the orientation of this movement.

Motion Perception by a Moving Observer

So far, all discussions of motion perception have ignored situations in which the observer is moving. The observer has to be able to control his own movement (and thus maintain his balance) as well as detect the motion of other objects as well.

Take for example the case of headway (which is the distance between two cars on the road). Let us say that the observer is in the vehicle at the back, it has been found that the judgment of headway is much more accurate when the observer is static than when he is moving.

Experiments have also shown that there is suppression of motion perception in the following cases:

- ✓ Patients with III, IV, and VI nerve palsy.
- ✓ Patients with an acquired nystagmus (this is a involuntary vertical oscillation of the eye usually indicative of CNS dysfunction), or congenital nystagmus.