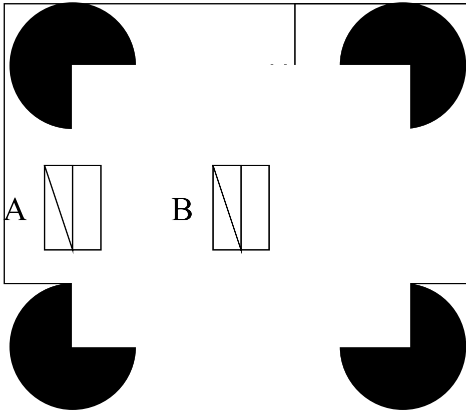


Assignment 2: Visual Illusions

Why are humans subject to visual illusions, and what can these illusions teach us about the visual system? The assigned reading is available from Blackboard:

- Eagleman (2001), Visual illusions and neurobiology

The reading is challenging, so don’t worry if there are some parts that you don’t fully understand. The assignment questions focus on issues that you should be able to understand given the background provided in class.

Each question will be graded by a different person. Please take this into account and make sure that your answers to each question stand alone.

You may discuss the assigned materials with other students, but should provide your own answers to each question. More precisely, your answers should represent your own ideas, and your own way of organizing and explaining these ideas. Please put your ideas in your own words— you may quote key phrases from the article if you like, but as a rule of thumb any direct quote should be at most a few words long.

A FAQ for this assignment will be maintained on Blackboard. Please check the FAQ before contacting us with questions.

SUBMISSION INSTRUCTIONS

Please remember the following things:

1. **Don't change the page structure of the original assignment** (e.g. make sure that you don't use two sides for a question that was originally restricted to one side, and make sure that you don't submit a single page that includes responses to two different questions). If you're using a program other than Microsoft Word, you'll need to be especially careful about preserving the page structure – please make sure that your submission is consistent with the structure of the online pdf version of this document.
1. Print out a copy of your answers and turn it in before the end of class on the due date. Make sure that you fill in and include the cover sheet that appears on the next page. If you decide not to answer one or two questions, submit the blank pages (with empty boxes) for these question. **Please put your name on top of each page** and **print out your answers single-sided**. We will separate your packet and distribute different pages to individual graders.
2. Upload the file to the course website on Blackboard. The file should be uploaded via the Assignments page. The uploaded file will give us a permanent copy of your assignment (in case of query or loss of the paper copy). If you're having trouble submitting your file, try using a different browser before contacting us. Note that submitting an electronic copy alone is not sufficient – **if you do not submit a hard copy, then you will not receive any credit for this assignment.**
3. Question 5 asks you to describe or sketch two scenes. If you choose to submit hand-drawn diagrams for these questions, it's fine to leave the corresponding boxes on the electronic copy blank.

PLEASE FOLLOW THE ABOVE INSTRUCTIONS CAREFULLY.

- If you do not print out your answers single-sided and write your name on each page, you will lose 5% of your grade.
- If you do not upload an electronic copy of your assignment to the Assignments page on Blackboard, you will lose 5% of your grade.
- If your hard copy does not preserve the page structure of HW2.pdf (see Blackboard), you will lose 5% of your grade.

Turn in this homework in class on Thurs September 19 or earlier to Rony's mailbox (BH 336D).

COVER SHEET

Honor code:

"My responses to these questions represent my own ideas and I have not received undue assistance from any source"

Your signature: ________________________

Please choose one of the following options:

▪ I would like to pick up my graded assignment at the end of class. The final grade will be written on the underside of the first page, but I understand that others may see my graded work.

▪ I prefer that my graded assignment not be distributed at the end of class, and understand that I will need to collect it during Rony's office hour .

Your signature: ________________________

FIGURES FOR THIS ASSIGNMENT

Figure I (for question 1). Note that this figure corresponds directly to Fig 1a in the paper – the purpose is to show where positions X and Y lie with respect to Fig 1a.

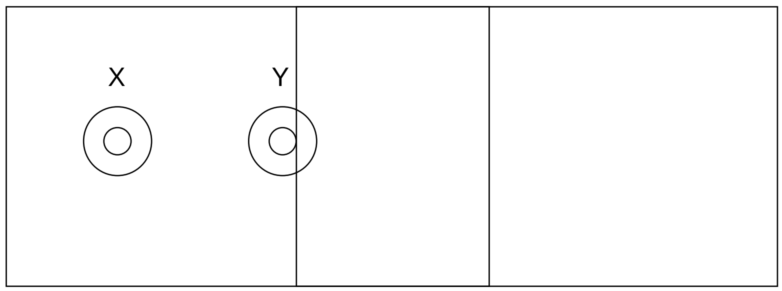
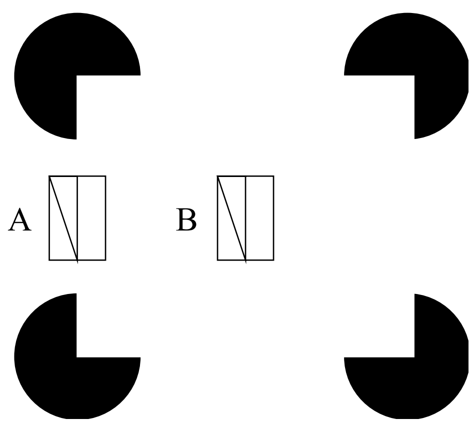


Figure II (for question 2). Note that this figure corresponds directly to Fig 2a in the paper.



1) Mach Bands (a) The stimulus in Figure 1(a) of the paper produces an illusion when viewed. Describe what people perceive when viewing this stimulus and explain how this percept is different from the true nature of the stimulus."

People tend to perceive a light vertical band on the boundary between the uniform light region and the gradient, and a dark vertical band on the boundary between the uniform dark region and the gradient. These bands are more pronounced (i.e., the left band is lighter and the right band is darker) than the uniform regions they border. However the true stimulus darkens monotonically from left to right.

(b) Consider two cells with on-center receptive fields located at positions X and Y in Figure I of this document. Which cell is more active? Explain why.

Cell Y is more active. Although the stimulus is identical in each cell's center, the stimulus is darker in cell Y's than in cell X's surround. Since stimulus in the surround has an inverted effect on a center-on cell's activity, cell Y perceives a net brighter stimulus than does cell X and is more active.

(c) Explain in your own words how center-surround receptive fields give rise to the illusory percept that you described in (a).

As explained in part (b), due to the inverted effect of stimulus in a center-on cell's surround, cells slightly to the left (resp., right) of the gradient are activated more (resp., less) than cells with receptive fields entirely in the uniform light (resp., dark) region, and so the region immediately to the left (resp., right) of the gradient appears lighter (resp., darker) than the uniform region.

HW2 **Name: Shashank Singh (sss1)**

2) Illusory contours. (a) Figure II in this document shows a Kanisza square and receptive fields for two V1 neurons A and B that act as oriented edge detectors. Which neuron is likely to be more active when the Kanisza square is presented -- A or B?.

(circle one) A is likely to be more active B is likely to be more active

(b) Explain in your own words why the neuron you picked in part (a) is likely to be more active. Your explanation should include some discussion of neurons that send information to your chosen neuron, and the properties or features that these input neurons are likely to be sensitive to.

A is likely to be more active because it receives excitatory input from two possible sources: horizontal (lateral) input from similarly orientation-tuned neurons with receptive fields above or below that of A (i.e., on edges), as well as vertical feedback from downstream neurons coding for a vertical edge identical to the perceived left edge of the Kanisza square.

(c) Explain in your own words why we see illusory contours in figures like the Kanisza square.

As explained in parts (a) and (b), neurons acting as appropriately oriented edge detectors along the edges of the "square" are activated somewhat above their baseline because of lateral and feedback connections. Thus, we "see" an edge at these locations.

(3) Waterfall illusion. After looking at a waterfall for a while, if you shift your gaze and look at a nearby stationary object it will appear to move upward. Try experiencing an electronic version of the illusion here: http://www.youtube.com/watch?v=oNhcpOIQCNs (NB: this version is different from the standard waterfall illusion, because the waterfall appears only at the end. It demonstrates, however, the basic principle behind the standard waterfall illusion).

(a) After a direction-sensitive neuron has fired continuously in response to a moving grating, the baseline firing rate of the neuron is temporarily lower than normal when the stimulus is removed. Explain how this finding could account for the waterfall illusion.

Since neurons tuned for downward movement are excited by a waterfall stimulus, when the stimulus is removed, they will temporarily fire at a rate below their baseline. Due to this reduction firing from downward-tuned cells, downstream neurons integrating upward- and downward-tuned cells will tend to fire as if receiving a net upward-moving stimulus, resulting in the waterfall illusion.

(b) Suppose that you close your eyes for a minute after looking at a waterfall, then experience the waterfall illusion when you open your eyes and look at a stationary object. Explain why this finding challenges your explanation in (a).

If the reason for the waterfall illusion is that downward-tuned cells exhibit reduced firing after prolonged exposure to the waterfall stimulus (presumably due to fatigue), then, after closing one's eyes for a minute, these cells should no longer exhibit reduced firing (presumably, they have recuperated), and so the illusion should not be observed.

(c) We do not see a motion after-effect after driving a car. Explain why this fact challenges your explanation in (a).

Since neurons tuned for backward movement should be excited by stimuli outside a forward-moving car, these cells should fire at a reduced rate after driving, resulting in an illusion of one's surroundings moving forward, as per the explanation in part (a). Thus, the fact that this illusion is not observed challenges the explanation in part (a).

4) Bistable stimuli. Fig 4c is based on an experiment where the left eye of a monkey is presented with a downward-moving grating and the right eye of a monkey is presented with an upward-moving grating. The monkey carries out an action which indicates whether it perceives downward motion or upward motion.

(a) Suppose that the time taken for the experiment is chopped into short (e.g 1 second) intervals. Does the stimulus presented to the monkey ever vary from one interval to the next?

(circle one) Yes No

(b) Does the monkey's percept of the stimulus ever vary from one interval to the next?

(circle one) Yes No

(c) Suppose that the activity of a population of cells in the monkey's temporal lobe correlates with the monkey's action---e.g. it is different depending on whether the monkey chooses "up" or "down." Explain why these cells are probably encoding something other than low-level visual features.

Since the monkey's percept, and thus action, do not necessarily correlate strongly with the true stimulus, if the behavior of a population of cells is found to correlate better with the monkey's action than with the stimulus, then the population is likely not coding for the stimulus at a low level, and hence likely not responsible for coding low-level visual features.

(d) Explain how fatigue effects similar to the example in Question 3a could explain why the monkey alternates between choosing "up" and choosing "down."

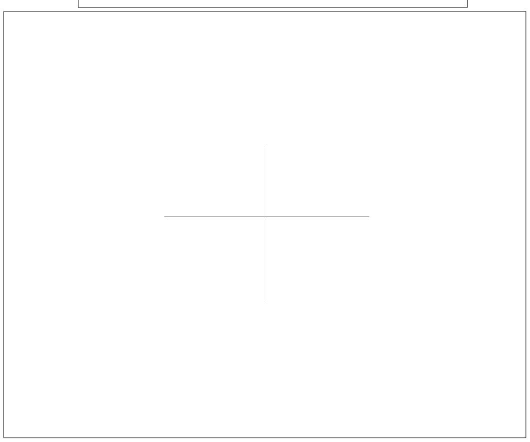
If the monkey perceives the stimulus as moving upward, upward-tuned populations of the monkey's neurons become fatigued, and so percept will move away from the upward stable state, eventually switching to the other (downward) stable state, due to reduced firing of upward-tuned neurons. Similarly, as downward-tuned populations become fatigued, the percept may switch back to the upward stable state. Repetition of this phenomenon will result in the monkey alternating between perceiving, and hence choosing, "up" and "down."

Suppose that a high-quality video camera is pointing at a scene and that a robot is using the data collected by the camera to try to figure out the content of the scene. An interpretation of the scene will be called ``correct'' if it accurately specifies the edges, surfaces, and objects that the scene contains and their relative locations and positions.

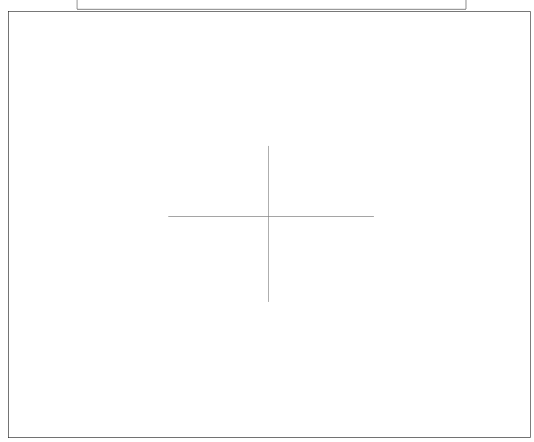
Describe or sketch two scenes S1 and S2 and explain why it is impossible in principle for any robot or computer vision program to interpret both of them correctly. Make sure that your answer specifies what the correct interpretation of each scene actually is.

Your response should not depend on the shortcomings of current robots or computer programs. In other words, regardless of how sophisticated technology becomes in the future, it should still be the case that no robot or program can interpret both S1 and S2 correctly.

Sketch or description of S1



Sketch or description of S2



Correct interpretations for S1 and S2:

In S1, the vertical and horizontal lines intersect. In S2, the horizontal line is longer than in S1 and is further back than the vertical line, and so the two do not intersect.

Explanation why the robot can’t interpret both scenes correctly:

Since the robot receives identical input from the camera in both S1 and S2 and must assign an interpretation based only on this input, the robot must assign the same interpretation to both S1 and S2. Since the scenes are not truly identical, the robot must interpret at least one incorrectly.

(b) Richard Gregory, a psychologist who has written many papers on illusions, argues that “we should expect illusions similar to our own to arise in any effective perceptual system, including future robots.” Support his conclusion by describing a general principle which means that it is impossible for a robot to correctly interpret all possible stimuli. Your response should go beyond the single specific example that you gave in (a). In other words, you should describe a general principle which implies that the number of possible responses to part (a) is vast.

In one sentence, my general principle is:

Since the robot can observe a scene from only one point at a time, the input the robot receives is a projection of a three dimensional space onto a space of at most two dimensions, and hence many scenes will result in identical sensory inputs.

Explain why this general principle means that a robot can't possibly interpret every stimulus correctly.

There exist distinct stimuli which with identical projections onto the robots sensory system, and so, using only its sensory system, it is impossible for the robot to distinguish between all possible scenes, and hence some scenes will be interpreted incorrectly.