Visual Selection: Eye Movements and Attention

Introduction

- Humans make unconscious decisions about what to focus on based on the activity that they are currently engaged in

- Overt - external and observable by others (eye movement)

- Covert - internal and unobservable by others (focus on different features of the same object)

- Examine what is known about overt and covert forms of visual selection and how they affect our perceptions

Eye Movements

- Visual selection is limited by the movement of the eye
    - 130 degrees vertically
    - 180 degrees horizontally

- Two major functions
    - Fixation: to position a target on the fovea where visual acuity is highest
    - Tracking: to keep fixated objects on the fovea despite movements of the object or the observer’s head.

Eye Movements

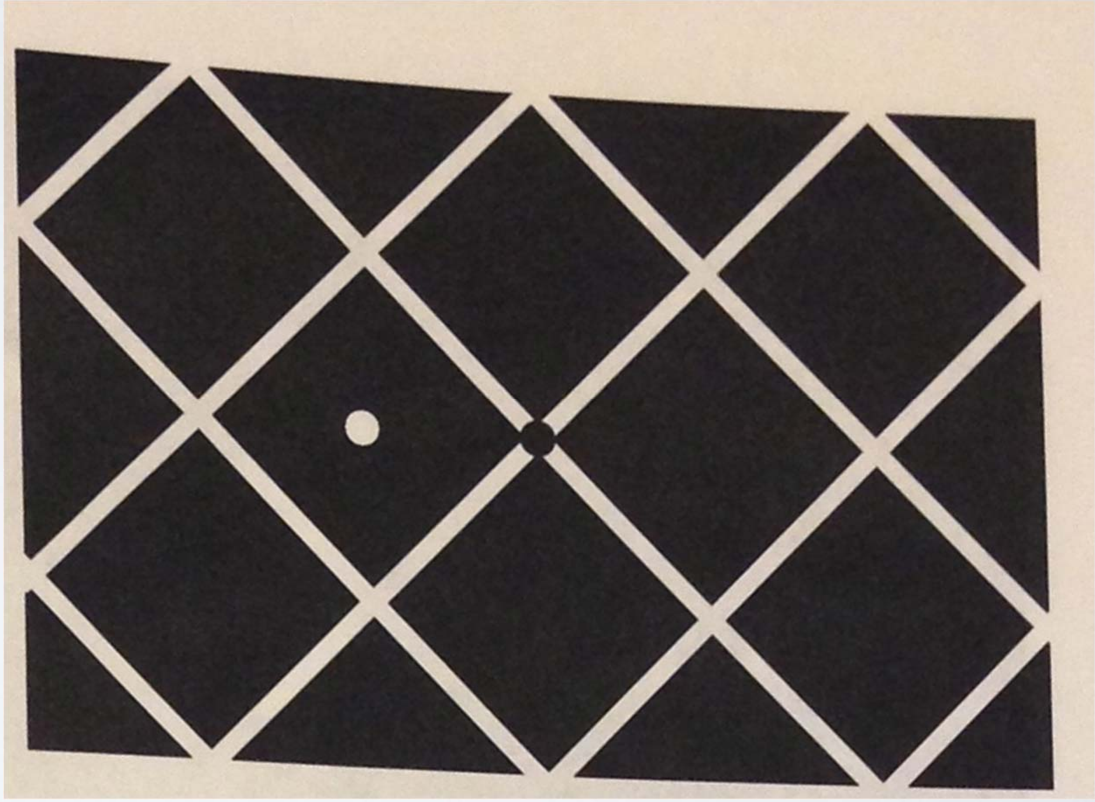
The eyes move first when we divert our attention because it is more precise and requires less effort

Eye move rapidly in order to let all aspects of the environment land on the fovea

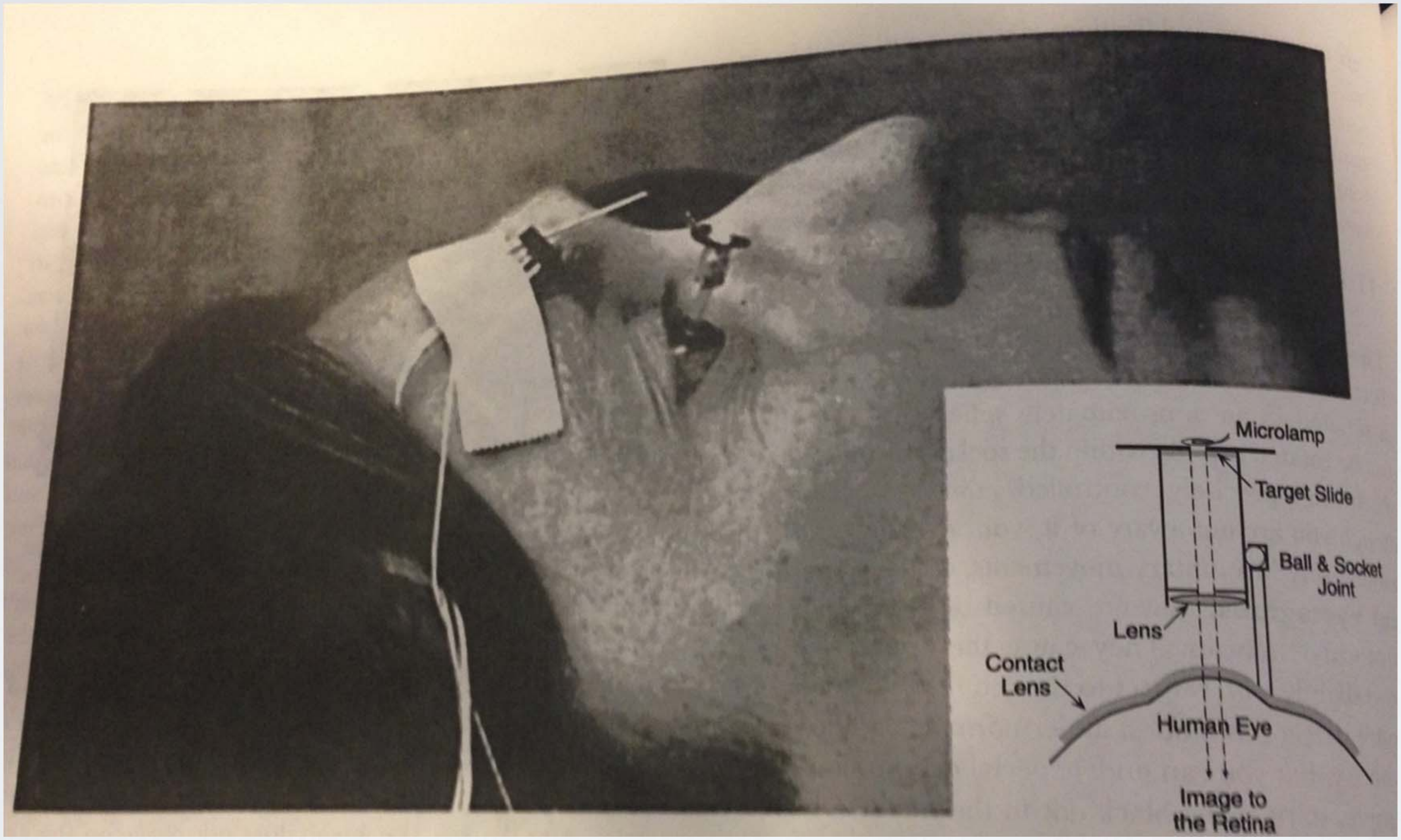
There are four different types of eye movements

Physiological Nystagmus

- constant tiny involuntary movements
- Cannot be controlled
- result of 6 strong, precisely controlled extraocular muscles
- stabilized images



Test to understand importance of physiological nystagmus



Alternative Test

Sophisticated computer graphics system tracks the eye movements

Image presented on the screen moves with the eye so that the image on the retina is stationary

Results and Conclusion

When the image is stable on the retina, it fades away.

Visual System appears to create regions based on visual contours

works largely by detecting moving edges and reconstructing the visual world from that information

Krauskopf (1963) - red circle and round disk

Physiological implications

Even though there are ganglion cells that are more sensitive to static images, by the time the information gets to the visual cortex, very few cells produce sustained responses to unchanging stimulation.

Still not quite sure how the physiological mechanisms that fill in the sensory experience after adaptation to moving contours works.

Saccadic Movements

Very rapid abrupt eye movement

Brings new objects of focus to the retina

Happen while looking around a stationary environment (reading)

Considered “ballistic” because once the movement has begun, it cannot change its trajectory

Saccades

150-200ms to plan and execute

Actual movement takes 30ms

Eye moves at 900 degrees per second

Fixation lasts 300ms in order to process available optical information

Saccadic Suppression

Blur is not perceived while eye is moving from point A to point B

Type of visual masking - the clear images at the end points dominate the visual system

Experiment where before and after where black but the in between was illuminated with a strobe

The subject perceived the blur

Smooth Pursuit Movements

Tracking an object that is moving

Provide visual system with extra information that is not perceived because the image is not moving on the retina

ndividuals with dynamic acuity can track fast object bette

Baseball players

Can be improved with practice

Differ from saccades in several important aspects:

smoothness - smooth and continuous rather than jerky and abrupt

feedback - movements require constant feedback based on feedback from the image and therefore cannot happen without a target to track. saccades cannot change their trajectory.

Speed - maximum velocity of 100 degrees/second (vs. 900)

Acuity - the image of the tracked object is clear (move finger back and forth across text and focus on it, the text is blurred. stop moving the finger but look back and forth, the text is clear again.)

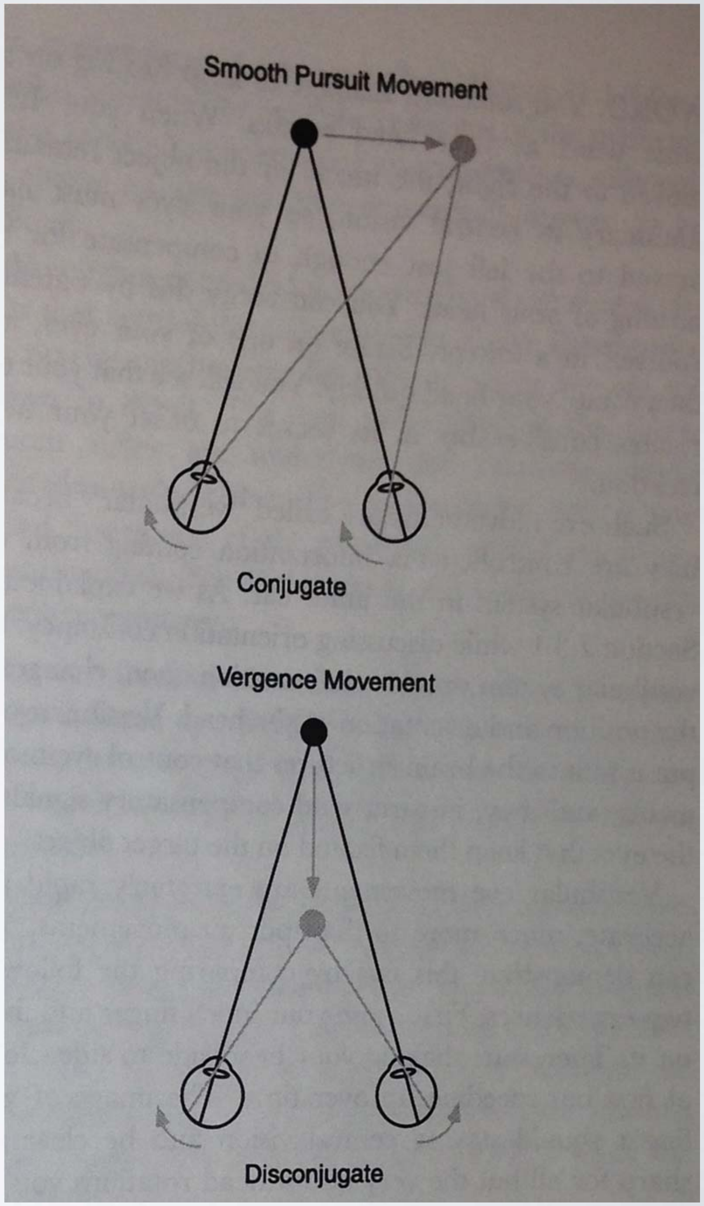
Vergence Movements

Select the distance of the target from the observer's head

Near objects produce strong convergence

Far objects produce weak convergence

Eyes move is opposite directions



Vestibular Movements

Movements that keep the image on the fovea while the head is moving

Controlled by information coming from the vestibular system (inner ear)

movements are extremely accurate and fast

Finger experiment

Optokinetic Movements

Caused by head movements when a large object is fixated on and there are optical translations of the whole visual field

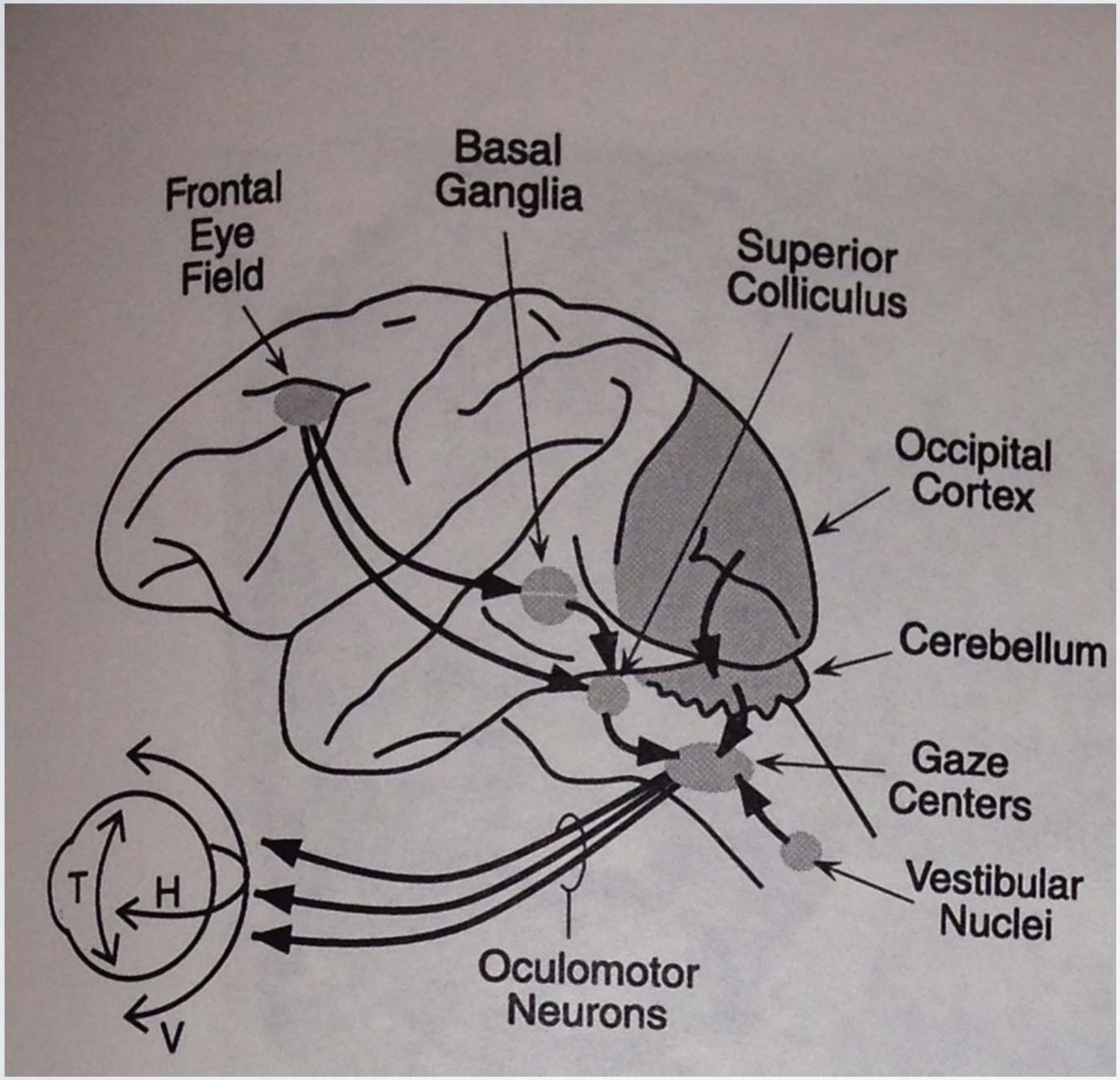
optokinetic reflex: person in a cylinder that is striped and spinning. The eyes find a stripe and follow it for a large angle and then snap back and find another stripe involuntarily

Physiology of the Oculomotor System

Different eye movements often work all together but their control centers are scattered throughout the brain.

The three pairs of extraocular muscles
Fastest acting muscles in the body and are controlled by separate nuclei in the brain stem called gaze centers which control the extraocular muscles via the oculomotor neurons

The various eye movements are cause indirectly from other parts of the brain and go through the gaze center and oculomotor neurons to create movement



saccades - frontal eye fields

smooth pursuit movements - through cerebellum to gaze centers

vergence movements - occipital cortex

vestibular movements - vestibular nuclei

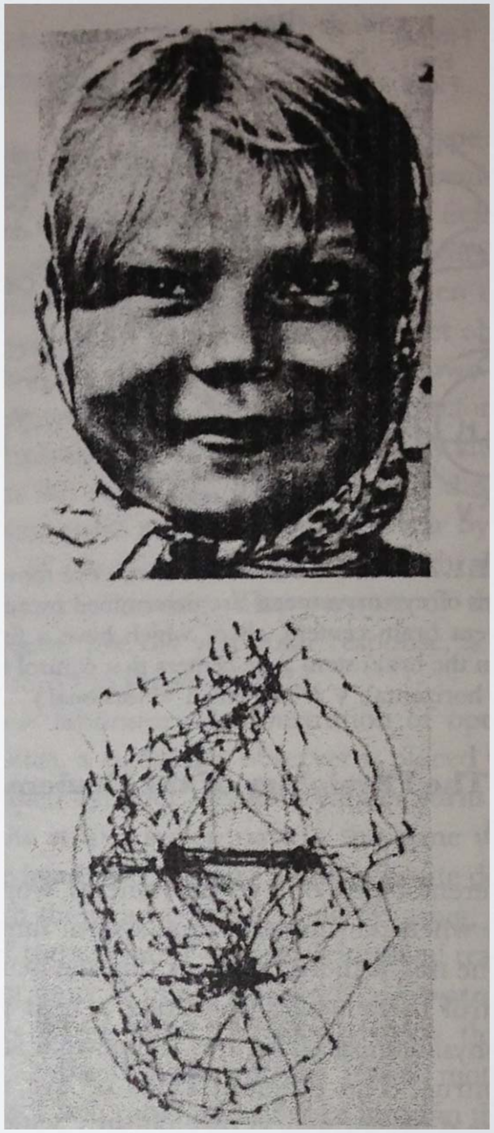
optokinetic movements - cortical motion pathway and subcortical pathway

Saccadic Exploration of the Visual Environment

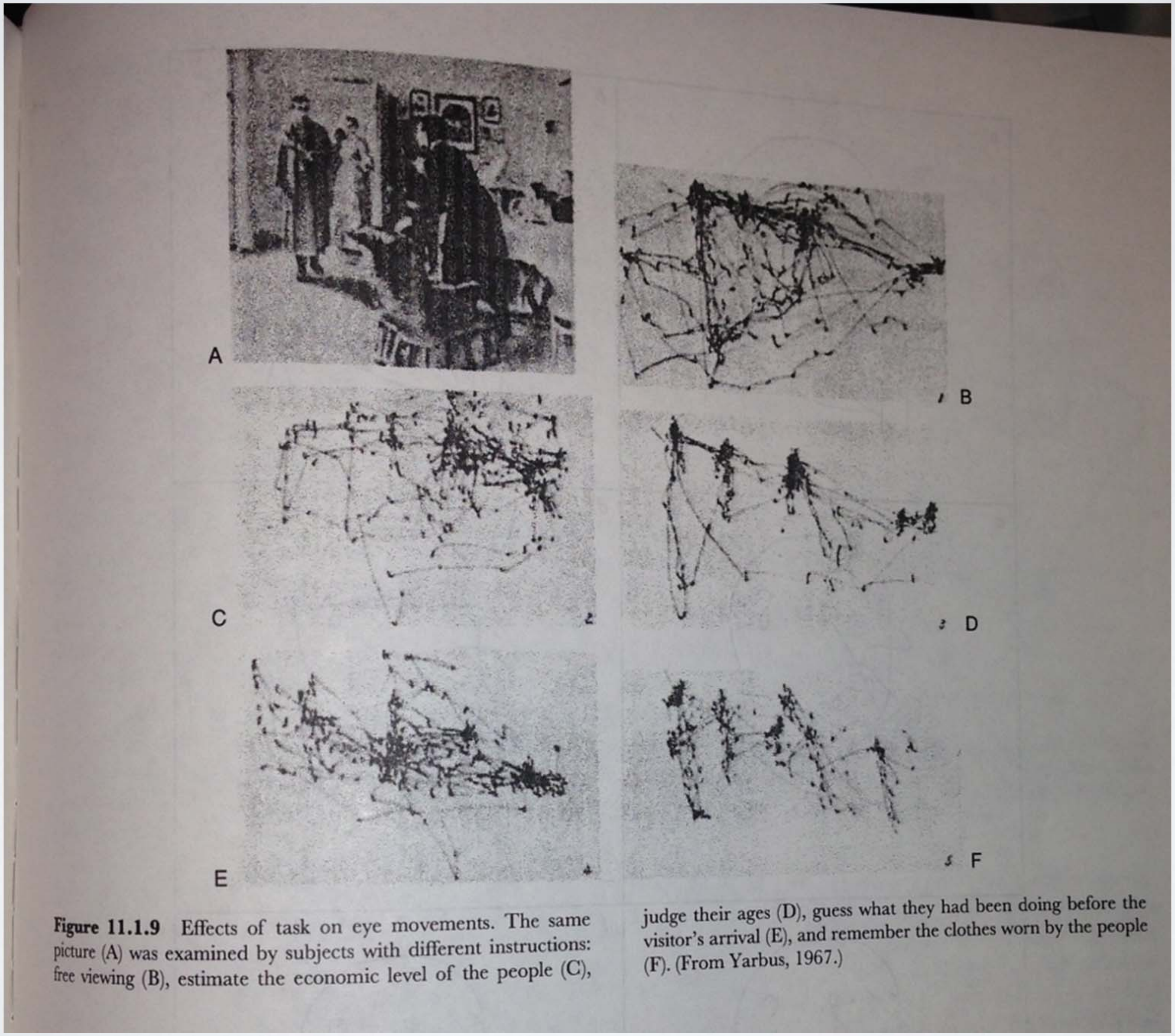
Constant movement to take in enough information

Must let all areas fall on the fovea

Yarbus conducted experiments in which he found what parts of the image people found most important



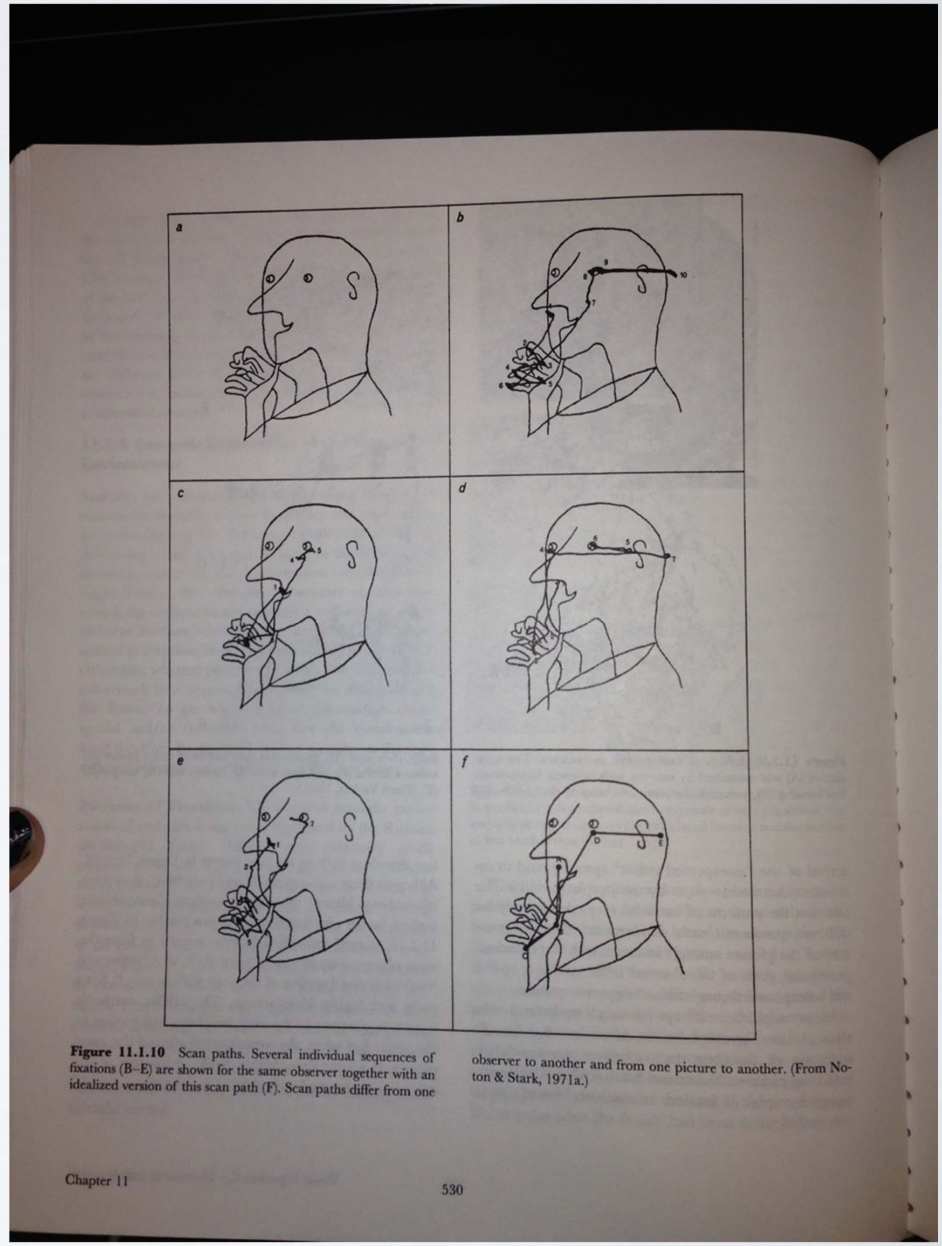
Saccades change based on the task at hand



Scan Paths

Norton and Stark (1971) identified recurring sequences of saccades for a given image

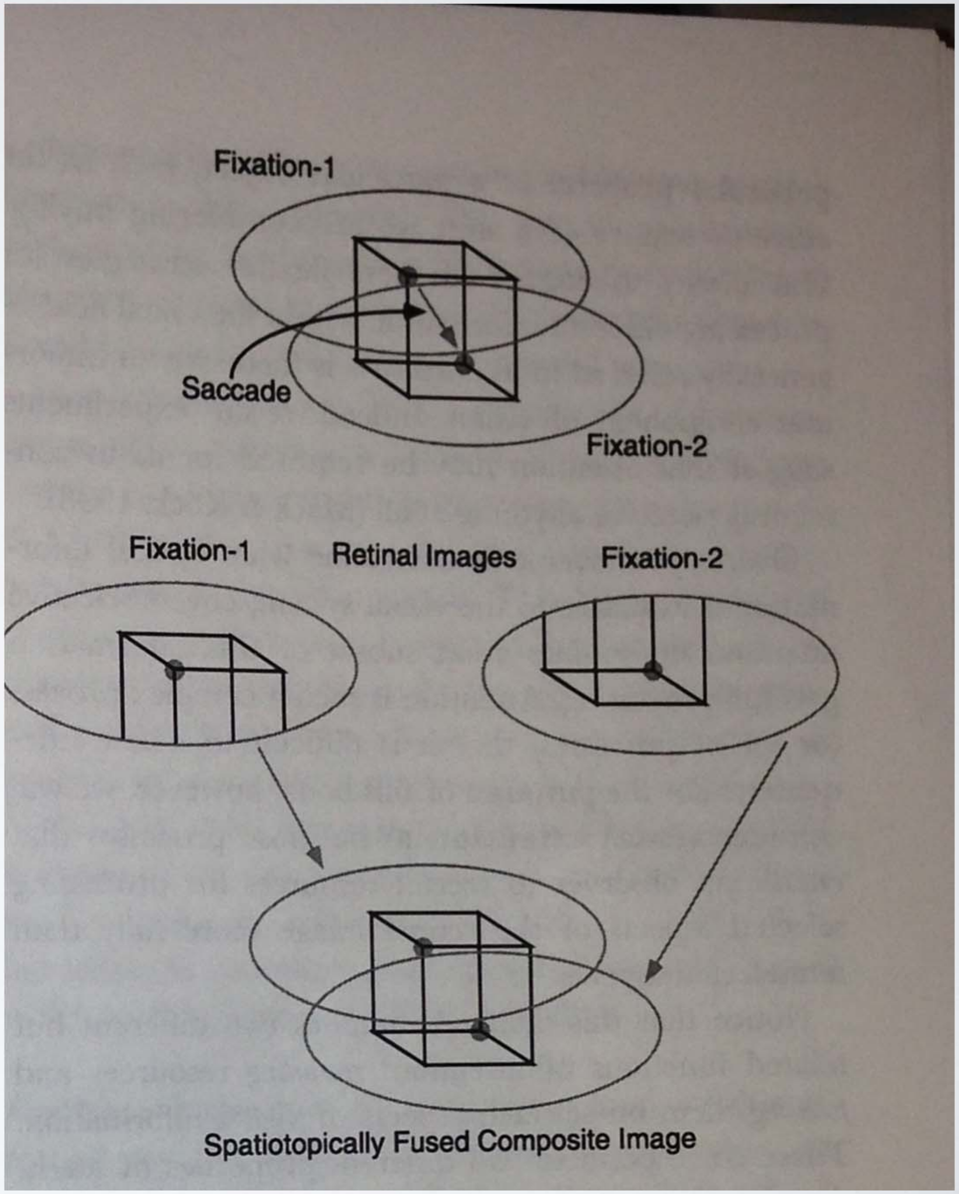
Individuals tend to have the same scan paths when seeing the same image several times



Spatiotopic Fusion Hypothesis

A complex scene is created using many fixations.

These fixations must somehow be put together and it was hypothesized that these fixations were assembled into a spatially organized memory array



Visual Attention

Recent experiments suggest that attention is required for us to perceive anything at all

Visual Attention: those processes that enable an observer to recruit resources for processing selected aspects of the retinal image more fully than non-selected aspects

Capacity - the amount of perceptual resources that is available for a given task or process. Can vary with different factors; alertness, motivation, time of day

Selectivity - attention decides what gets processed and what does not. Selectivity has been more intensively studied and is therefore the focus of the chapter

Various different kinds of selection

Spacial selection - the process of concentrating attentional resources on information from a restricted area of the visual field (camera flash example)

property selection - focusing on different properties of the same object; color, texture, size, shape, etc.

Early v. Late Selection

Paradox of intelligent selection: How can the visual system choose the most important information without first processing all the information to determine what is most important?

Early selection leaves the question of how to determine what is important unanswered

Late selection means that lots of unimportant information gets processed unnecessarily.

Initial Studies

Auditory - could identify that a person was speaking in their other ear but not if it was in English, male, female, etc

Donald Broadbent proposed that the ears used early selection to filter out the pertinent information and choose one input for further processing

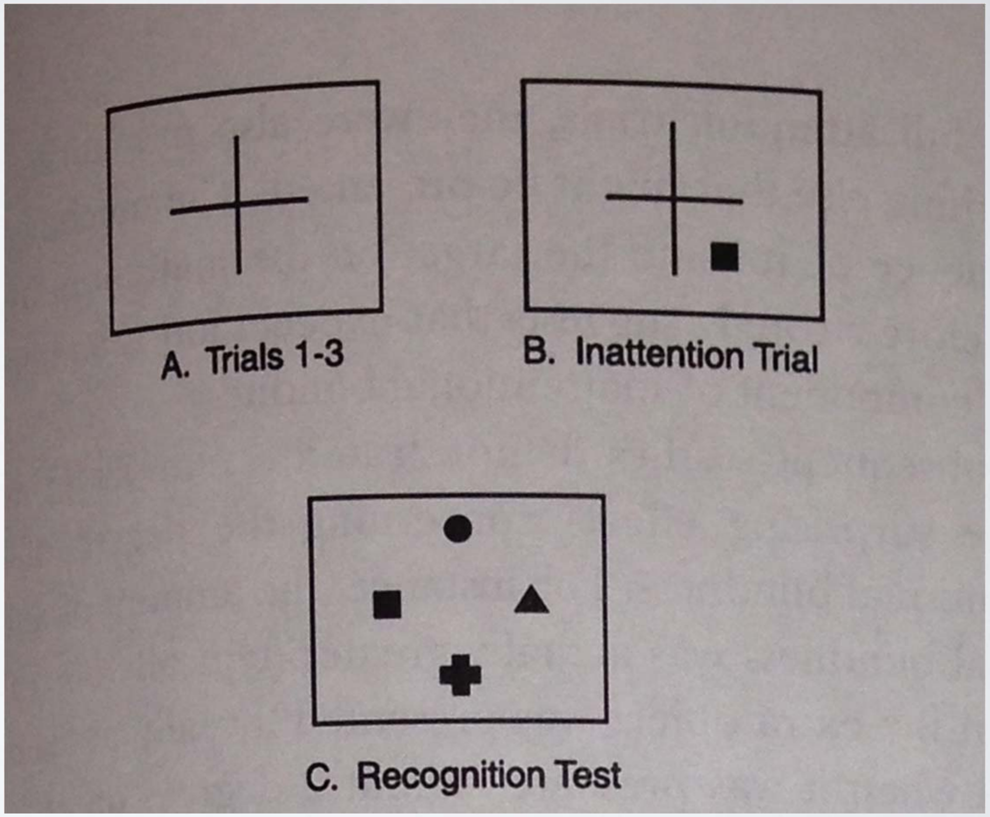
-Disproved

The Inattention Paradigm

Mack and Rock (1998) wanted to know what features could be perceived without attention

Color, position, and location of shape could be perceived without attention but not which shape appeared

This led to the theory that early selection happens in the visual system



Inattentional Blindness

If a person is not expecting to see another object then they will not see it at all

25% of the participants did not see the extra shape at all

The amount of inattentional blindness increased by 50-70% when the object was displayed foveally as opposed to 2 degrees off center

Inattentional blindness decreases with personal connection to the object

Implies late selection

Attentional Blink

Perception of a second target item is greatly reduced when presented within a half second of a first target item

Rapid Serial Visual Presentation - subjects are presented with a rapid sequence of visual stimuli at fixation where visual acuity is the greatest and asked to report targets of a specific type.

No faster than 11 items/sec & second target appears more than 500ms after the initial target, then it too is well perceived

200ms - 500ms the subjects appear to not see it at all

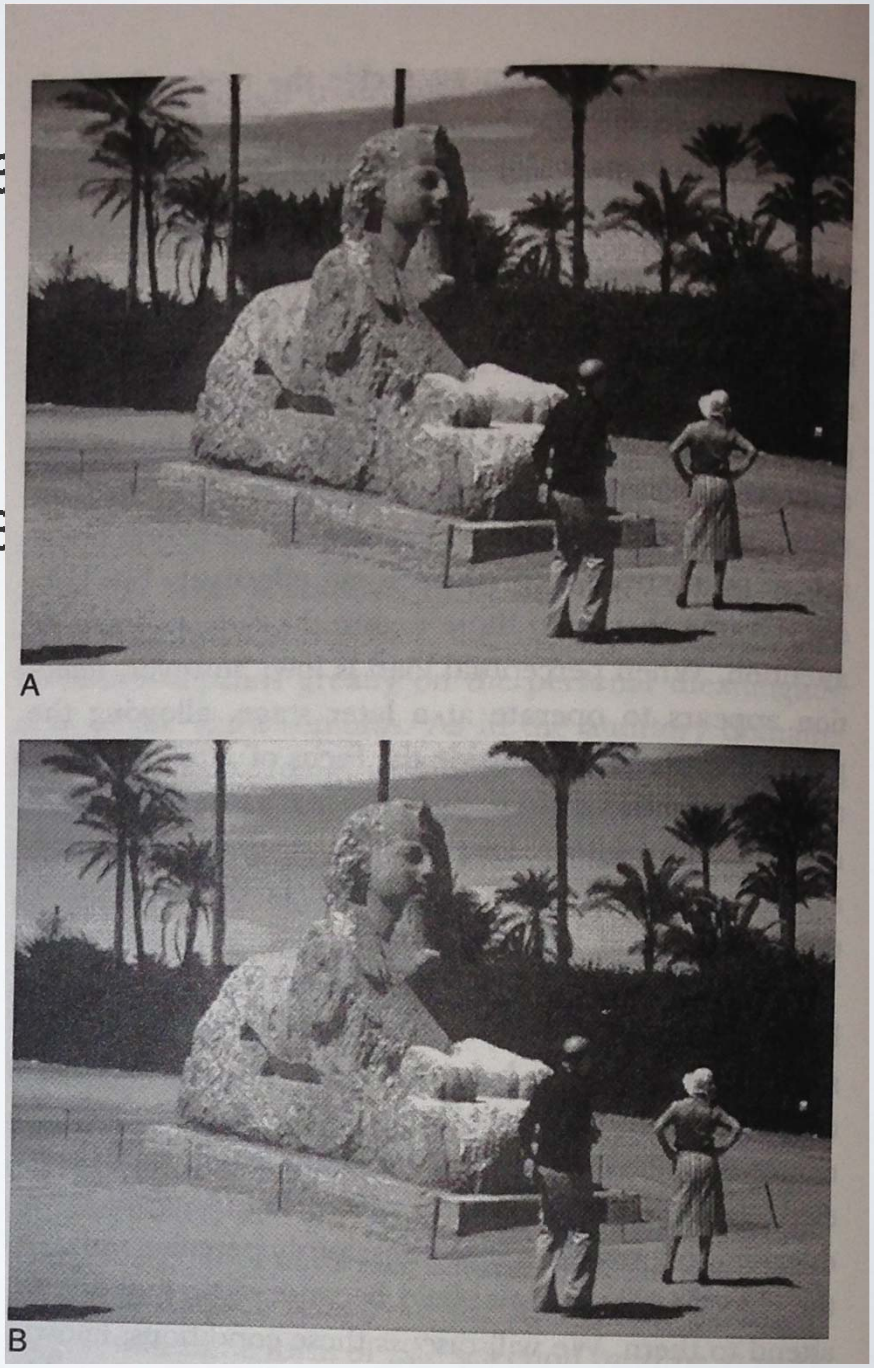
Late stage of selection because subject cannot process the second target while the first is still being processed

Change Blindness

People are poor at detecting changes in a visual stimulus if they occur in an area that they are not focused on

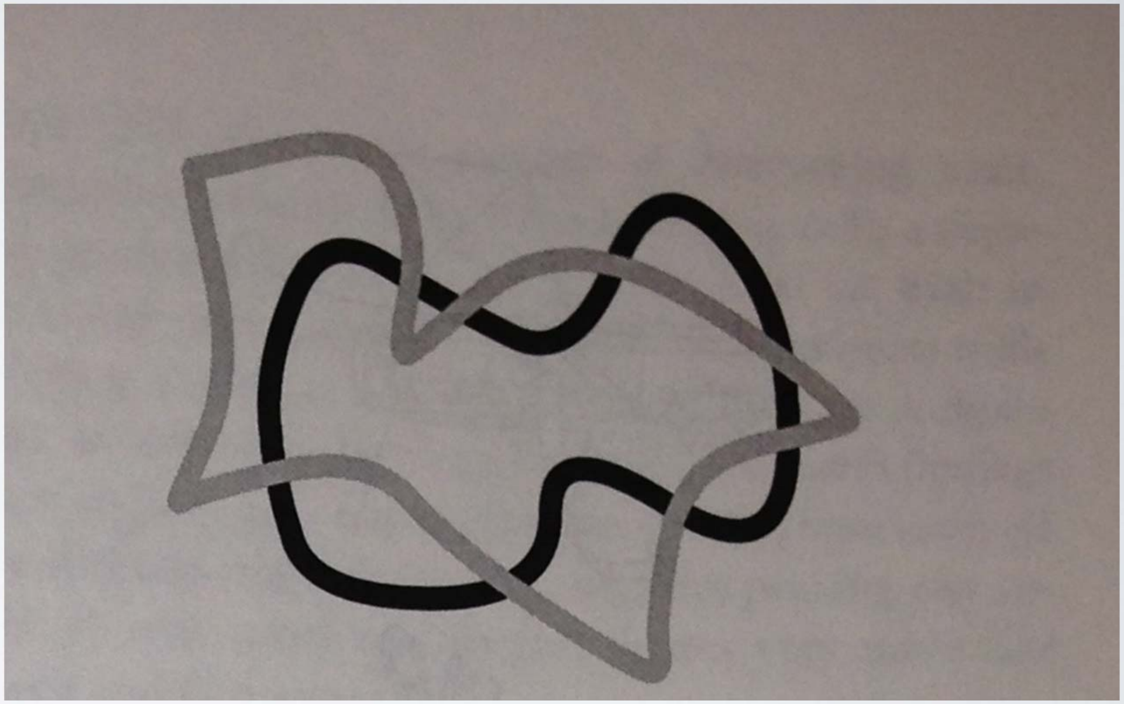
Ex. Man with map and door
50% of people noticed the change

This theory says that we do not perceive what does not have our attention. Wolfe (1999) theorized that we perceive everything but without being the focus of attention, there is no memory of them. He calls this inattentional amnesia.



Intentionally Ignored Information

Information is actively suppressed because it is not pertinent to the task at hand



Two object are presented on top of each other but in two different colors.

Negative Priming Effect
When the same object is shown first in the unattended color and then in the attended color, it took subject longer to identify the object

Costs and Benefits of Attention

Items that have out attention get more processing, items that do not have our attention get less processing

For this to be evolutionarily useful, the benefits of this system must outweigh the costs

Attentional Cueing Paradigm

Michael Posner came up with the Attentional cuing paradigm which is particularly good at examining costs and benefits

The test flashes a light at subjects to the left and right of a central focal point.

A cue indicated where the flash was likely to occur:

--> meant that the flash was 80% likely to occur on the right

<-- meant that the flash was 80% likely to occur on the left

+ meant that it was equally likely for both sides

3 Trials

Neutral trials - since the subject was focused equally on both sides, this test was used as a baseline for the reaction time

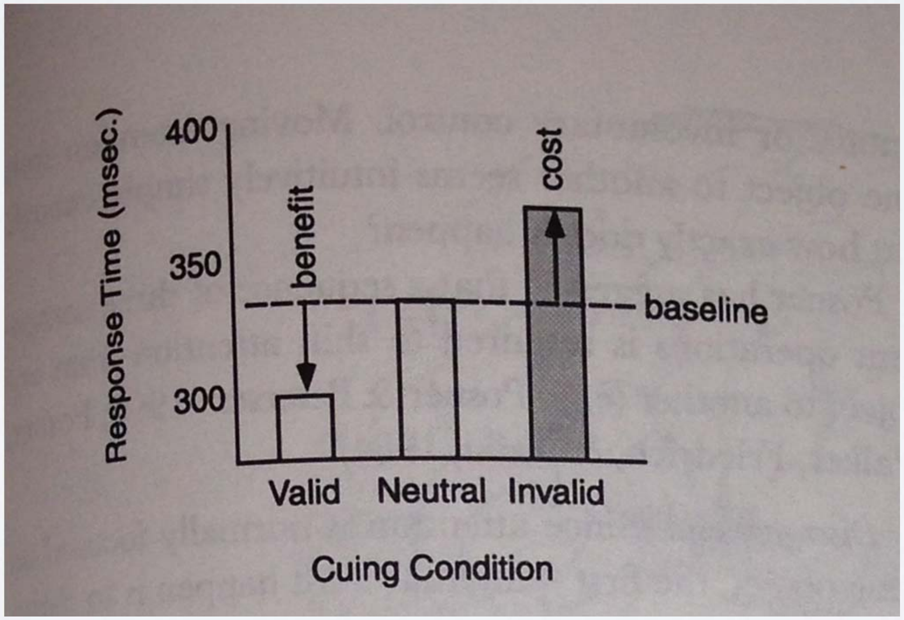
Valid trials - 80% of the time when the flash occurred in the same direction that the arrow pointed. looking for a measurable benefit to having attention already placed in the right area in terms of reaction time

Invalid Trials - 20% of the time when the flash occurred on the opposite side from the arrow.

Results

Valid trials were better than the baseline by 30ms

Invalid trials were worse than the baseline by 30 ms



Additional Tests

Another test was done to measure how long it takes to fully shift attention

Time between cue and flash varied such that if the interval was small enough then there would be not cost or benefit from the cueing

Inferred that is takes about 400ms to fully shift attention

Voluntary v. Involuntary Shifts in Attention

Push cues - like the arrows, require the subject to "push" their attention to a new area

Pull cues - put the arrow on the far side of the area requiring attention so that attention is pulled towards the cued area

The same trials were performed with push cues and pull cues

Costs and Benefits

Pull cues produce benefits without costs

Pull cues work faster - when the cue-to-cost interval was changed, it was found that an equivalent shift of attention took 100ms as opposed to 200ms-400ms

Pull cues cannot be ignored - when the likelihood was lowered to 50%, subject where able to ignore push cues, whereas pull cues could not be ignore even when the subject was actively trying to ignore them

Three Components of Shifting Attention

The spotlight metaphor - the area where the attention is focused is “illuminated” with a spotlight so that it stands out and can be processed more effectively

When a spotlight moves along a path it illuminates items along that path. Evidence suggests that attention works the same way.

a spotlight cannot be separated into two distinct areas much like the area of attention cannot be split

metaphor fell apart with size.

Eriksen and Eriksen thought that the attentional spotlight is 1 degree of visual angle but it is obvious that when looking at larger objects, the attentional spotlight gets larger

Zoom Lens Metaphor

Likens attention to the operation of a zoom lens which allows the field to get larger and smaller depending on what is in view

Space-Based v. Object Based Approaches

The idea that attention selects an object or group of objects rather than a space(spotlight)

Object based theories can, under certain conditions, account for attentional selection of several discontinuous regions

The spotlight and zoom lens metaphors require a contiguous region of space

Duncan’s Object Based Theory

Attention is allocated to objects rather than to regions of space,

Easier for subjects to detect two different properties of the same object rather than two properties of different objects that lie within the same region of space.

Subjects had to report on one or two different attributes. When two attributes were tested, they could belong to the same object or different objects.

Results showed that if the attributes belonged to different objects, subjects were worse at detecting the second property than the first. But if they belonged to the same object then no such difference was obtained.

Conclusion for Object v. Space

Object based theories are much more supported

Array of dots, given several to focus on, subjects could track up to five once they all start moving around.

Often the theories are referred to as mutually exclusive but it is possible that they both apply at different levels of the visual system

Selective Attention to Properties

The Stroop Effect

When an object is attended to, certain properties are always processed even if the observer is trying to ignore them.

Experiment:
Reading the color of the ink rather than the color that the word spells

Does not work the other way around (read color spelled out despite color of ink)

Interference is greatly reduced when the subject must press buttons instead of saying the colors out loud

Integral v. Separable Dimensions

Separable dimensions - pairs of dimensions are separable if people can selectively attend to one or the other at will, without interference from the unattended property. Example of separable dimensions is the color and shape of an object

Integral Dimensions - pairs of dimensions are integral if people cannot selectively attend to one without also perceiving the other. Example: the saturation and lightness of a color. These dimensions are processed together.

Examples

Unidimensional variation condition - subjects are asked to classify the stimuli according to the value of one dimension while the other is held constant. Used as the baseline and show that discriminating shape takes longer than discriminating lightness

Correlated variation condition - subjects are told to classify the stimuli according to the value on just one dimension, but the other dimension varies in a correlated fashion.

Orthogonal variation condition - subjects have to classify according to a single specified dimension, but this time the other dimension varies independently.
neither orthogonal nor correlated variation showed an improvement/decrease in discriminating lightness.

More Complex Dimensions

Asymmetrically Integral Dimensions - are pairs of dimensions in which one property can be selectively attended to then exclusion of the other, but the reverse is not true. ie. the first property is separable fro the second but the second is integral with the first.

Configural Dimensions - are pairs of properties that combine to produce a new emergent property, such as symmetry or closure. ex. left and right facing parenthesis, () or)(

Distributed v. Focused Attention

Distributed Attention - subject is prepared to view a target in a certain place. Processing occurs in parallel over the whole visual field.

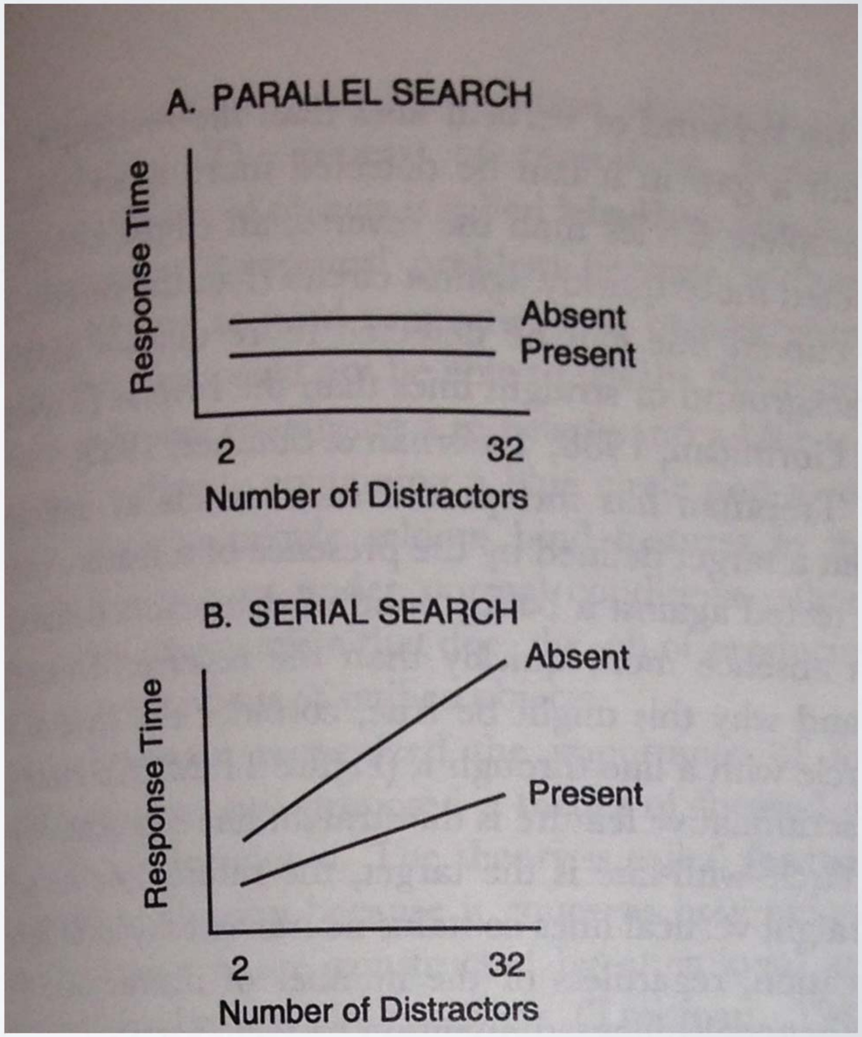
Focused Attention - when a single object is chosen for perception. This is serial processing because once the object has been chosen there is a sequence of attentional fixations in the same region

Visual Pop Out

In a field of similar objects, the one that has a different size, shape, or orientation will pop out without any extra processing

1. Expected that the time to find the different object would be constant if the objects were evaluated in parallel

2. Expected that the time to find the different object would be linear as the number of objects increased if they were evaluated in serial



Does the Relationship Work in Reverse?

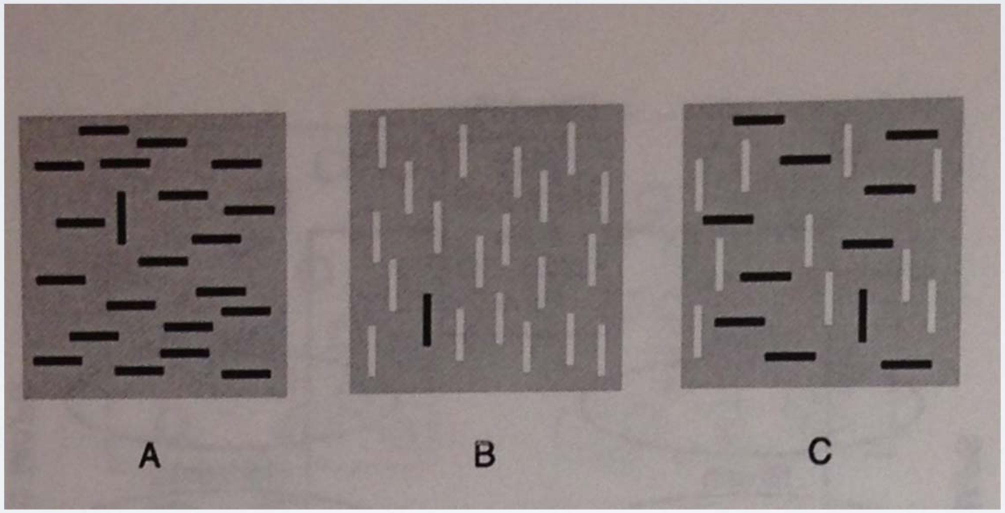
Feature Integration Theory

Binding:
Physiological evidence supports the idea that the visual field is split up and sent to different areas for processing of different properties and then put together for the final result. We see a red line, not redness and a line. These properties are bound together.

Anne Treisman came up with the feature integration theory - stems from the feature maps. These maps separate color from orientation but the question is, how do they get put back together again?

Predictions

Conjunction Search - targets defined by the conjunction of two features do not pop



Texture Segregation

Illusory Conjunctions

If attention is spread over a region including several different objects then the features may not be correctly conjoined

Flashed a red X, a blue S, and a green T between two black numbers and then another image to eliminate the after image
Illusory conjunctions such as a red T or a blue X occurred 39% of the time.

Supports feature integration theory in that when having to focus on several different objects, it is not always possible to put the feature back together again

Problems with Feature Integration Theory

When depth is added the theory breaks down

A red square in the near depth plane
green distractor squares in the near plane and red distractor squares in the far plane

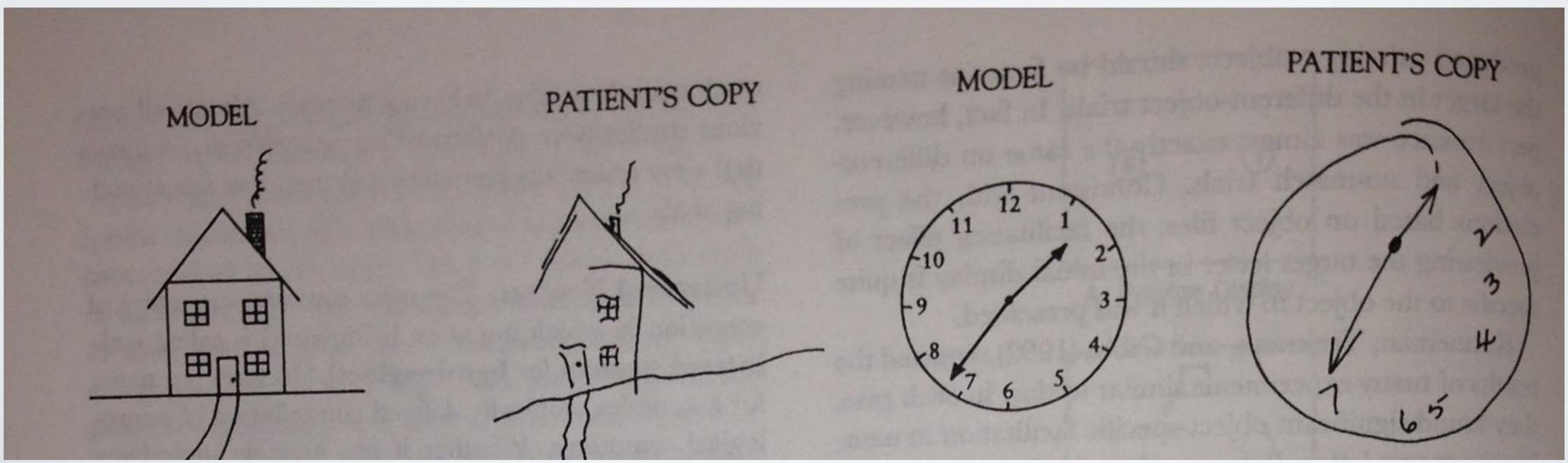
The initial red square pops out despite it being a conjunction of red and square

Physiology of Attention

Unilateral Neglect - associated with brain injuries in the parietal lobe of the right hemisphere

Patients systematically fail to notice objects on the opposite side of the world from their brain injury

Even draw picture from memory differently



Balint's Syndrome

Patients can only focus on one object at a time and often have trouble moving their concentration without blinking.

Symptoms:

Ocular apraxia - inability to change fixation from one object to another

Simultagnosia - inability to perceive more than one object at a time

Spatial disorientation - inability to orient and localize objects correctly, including both their egocentric direction and their depth

Optic Ataxia - the inability to reach out and touch an object in space

This syndrome supports the idea that the visual system is object based