Principles of **Eye Tracking** and its applications in **Brain Mapping**

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Contents

Introduction

- Eye-tracking is the process of calculating the motion of the eye relatively to the head.
- An eye-tracker is a device for measuring eye positions and eye movement.
- Eye-trackers are used in research mainly on the visual system, in marketing, psychology/psycholinguistics, marketing, product design and as input device for human computer interaction.
- Eye monitoring systems could be classified into two categories: invasive and active vs. non-invasive and passive.

History

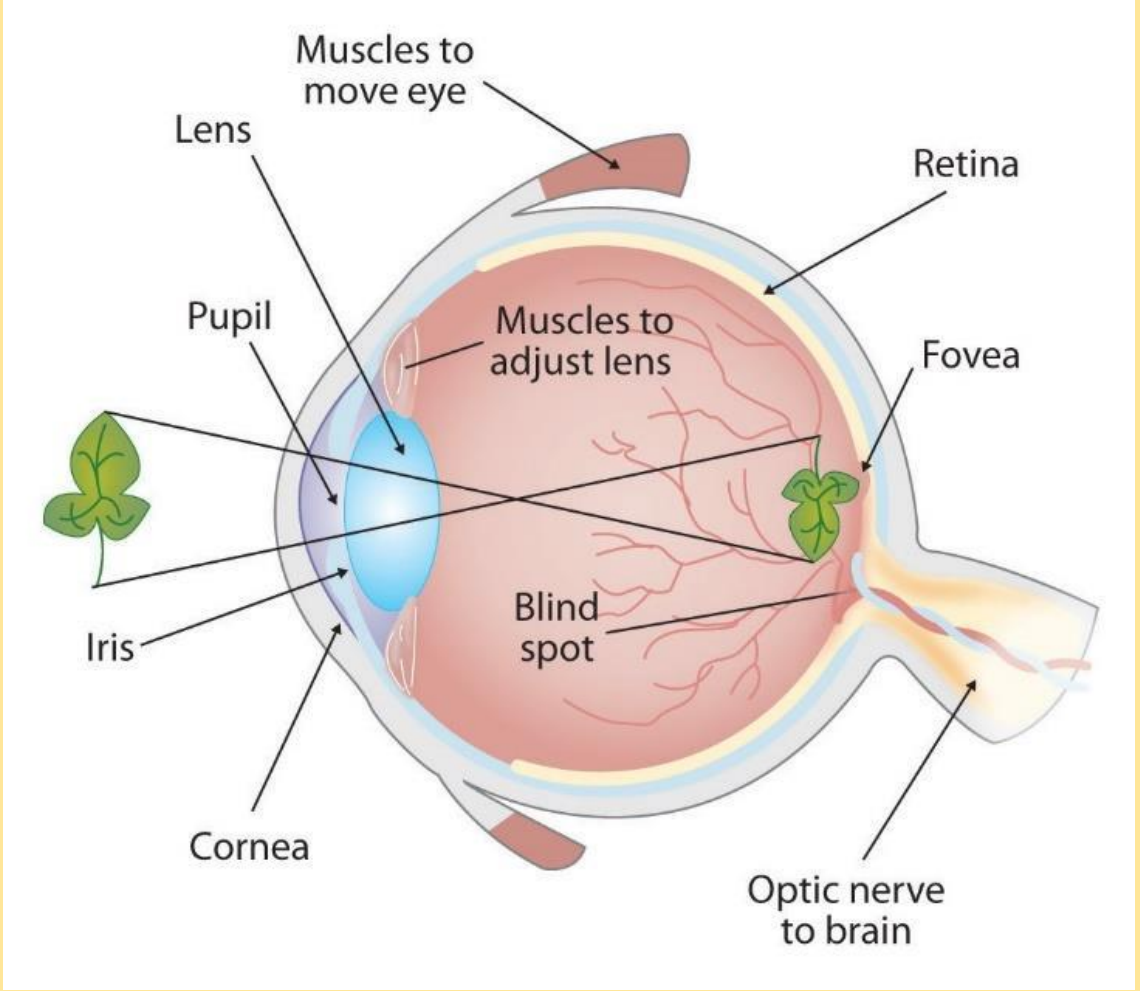
- Scientific study of human eye movements began in the late 19th century.
- In the late 1940s, researchers used cameras to record the eye movements of pilots in the cockpit.
- In an early study of fixational eye movements, Horace Barlow placed a drop of mercury in his eye, while an iron bar pressed his head firmly against a granite slab.

History

- In the magnetic search coil system, a small loop of wire is placed in the eye.
- The electro-oculogram (EOG) is a measurement made using electrodes attached to the skin around the eye region.
- Today, the majority of eye monitoring systems in general use are based on digital images of the front of the eye, captured with a remote video camera and coupled with image processing and machine vision hardware and software.

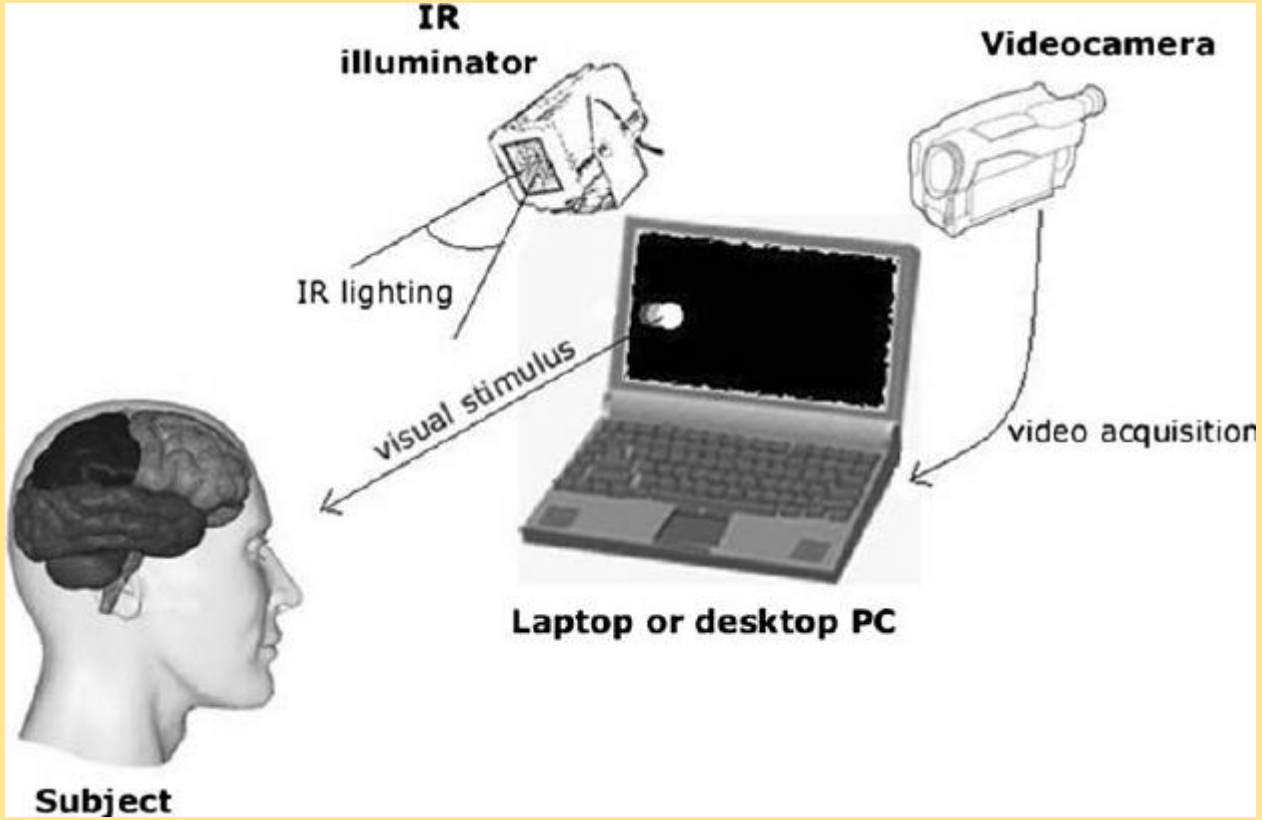
Human Eye Physiology

- at the centre of the fovea there are those called cones (colour sensors)
- There are three kinds of them that are more sensitive in different colours (i.e. red, green, blue)
- The other kind of photoreceptors, called rods cannot “detect” colour and offer grey, peripheral vision as well as the ability to see in mesopic or scotopic conditions (dim light).



Eye-tracking Technologies and Techniques

- The most widely used current designs of eye-trackers are video-based.
- head fixed or head free
- sampling rate: 30, 50, 60, 240, 360, 1000 or 1250 Hz



Details on Eye-Movement Metrics

- **fixations**: When the eye gaze pauses in a certain position
- **saccades**: When the eye moves to another position
- **scanpath**: The resulting series of fixations and saccades
- Most information from the eye is made available during a fixation, but not during a saccade.
- On average, fixations last for around 200ms during the reading of linguistic text and 350ms during the viewing of a scene.

Details on Eye-Movement Metrics

- **Number of fixations**: More overall fixations indicate less efficient search
- **Fixations per area of interest**: More fixations on a particular area indicate that it is more noticeable, or more important
- **Fixation duration**: Longer fixation duration indicates difficulty in extracting information, or it means that the object is more engaging in some way.
- **Gaze**: The sum of all fixation durations within a prescribed area. It is best used to compare attention distributed between targets. It can also be used as a measure of anticipation in situation awareness.

Details on Eye-Movement Metrics

- **Fixation spatial density**: Fixations concentrated in a small area indicate focused and efficient searching.
- **Repeat fixations**: Higher numbers of fixations off-target after the target has been fixated indicate that it lacks meaningfulness or visibility.
- **Time to first fixation on-target:** Faster times to first-fixation on an object or area mean that it has better attention-getting properties.
- **Percentage of Participants fixating an area of interest:** If a low proportion of participants is fixating an area that is important to the task, it may need to be highlighted or removed.

Details on Eye-Movement Metrics

- **On-target (all target fixations):** Fixations on-target divided by total number of fixations. A lower ratio indicates lower search efficiency.
- **Number of saccades**: More saccades indicate more searching.
- **Saccade amplitude**: Larger saccades indicate more meaningful cues, as attention is drawn from a distance.
- **Regressive saccades**: Regressions indicate the presence of less meaningful cues.
- **Saccades revealing marked directional shifts:** Any saccade larger than 90 degrees from the saccade that preceded it shows a rapid change in direction. This could mean that the user's goals have changed or the interface layout does not match the user's expectations.

Details on Eye-Movement Metrics

- **Scanpath duration**: A longer-lasting scanpath indicates less efficient scanning.
- **Scanpath length:** A longer scanpath indicates less efficient searching
- **Spatial density:** Smaller spatial density indicates more direct search.
- **Transition matrix**: The transition matrix reveals search order in terms of transitions from one area to another.
- **Scanpath regularity:** Once “cyclic scanning behaviour” is defined, deviation from a “normal” scanpath can indicate search problems due to lack of user training or bad interface layout.

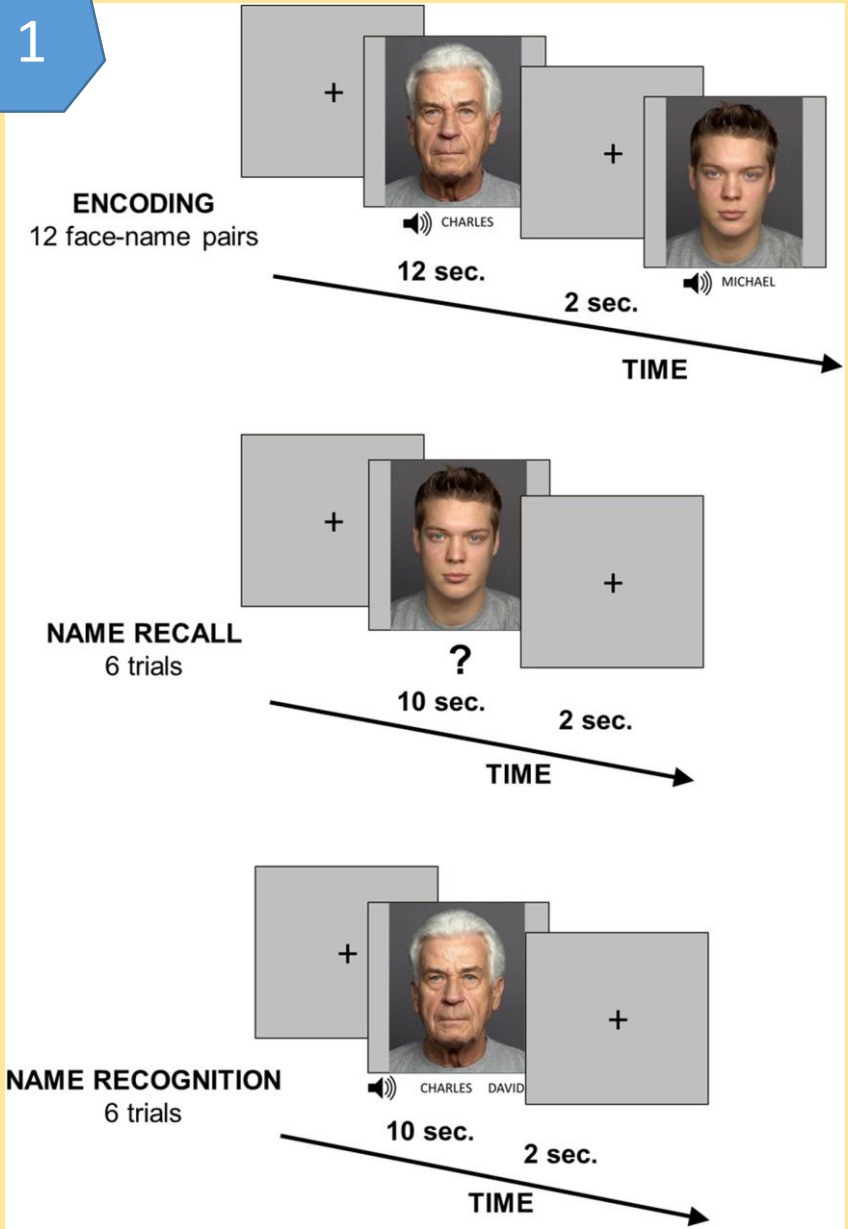
Details on Eye-Movement Metrics

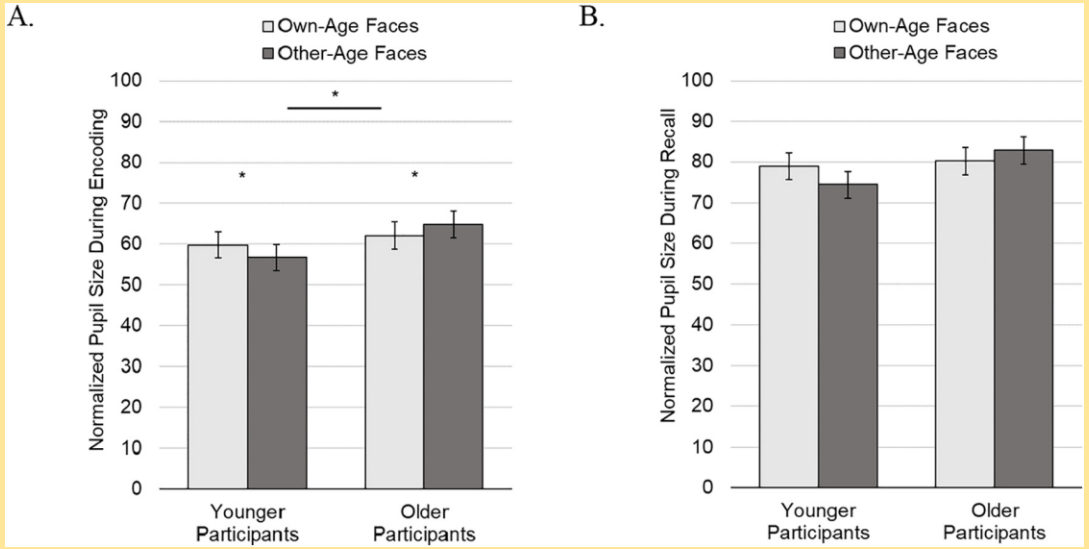
- **Spatial coverage calculated with convex hull area**: Scanpath length plus convex hull area define scanning in a localised or larger area.
- **Scanpath direction**: This can determine a participant's search strategy with menus, lists and other interface elements.
- **Saccade/fixation Ratio:** This compares time spent searching (saccades) to time spent processing (fixating). A higher ratio indicates more processing or less searching.
- **Blink rate:** A lower blink rate is assumed to indicate a higher workload, and a higher blink rate may indicate fatigue.
- **Pupil size**: Larger pupils may also indicate more cognitive effort.

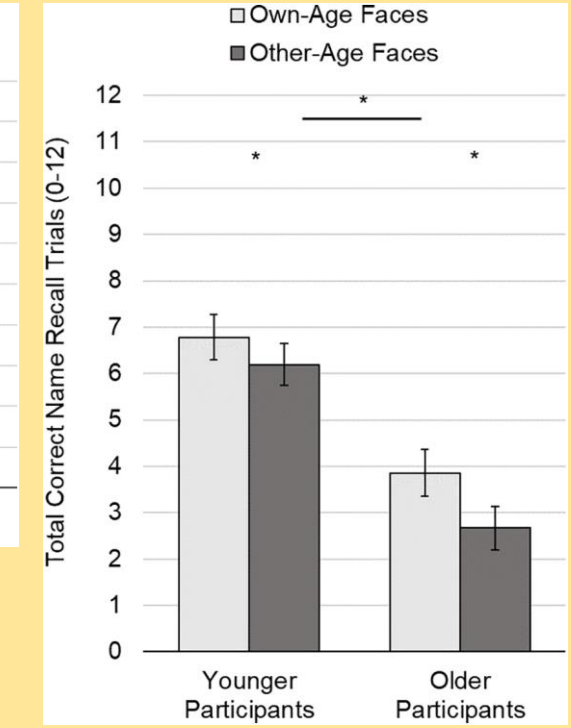
Eye-tracking Applications

- Commercial Applications
  - web usability
  - advertising
  - sponsorship
  - package design
  - automotive engineering
- cognitive science
- psychology
- human computer interaction (HCI)
- medical research
- language
- Sport

1







- Successfully learning and remembering people's names is a challenging memory task for adults of all ages

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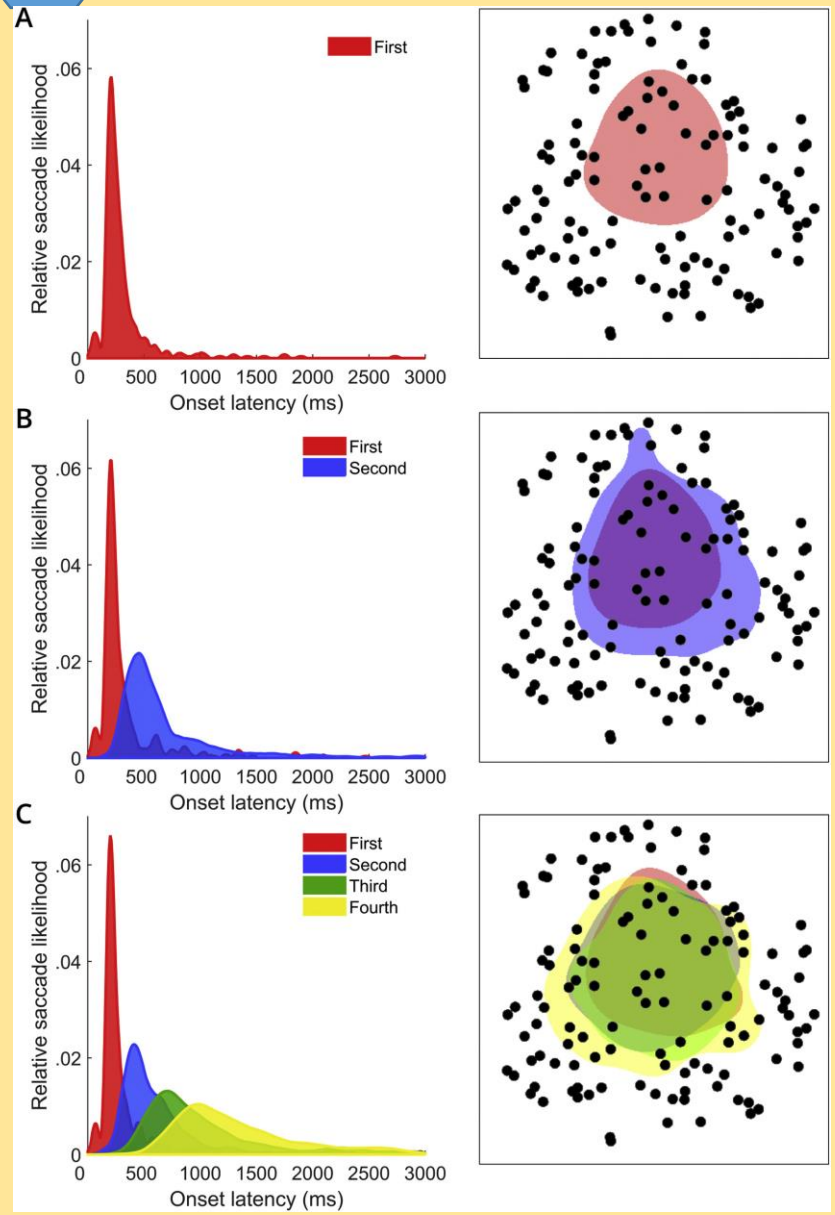
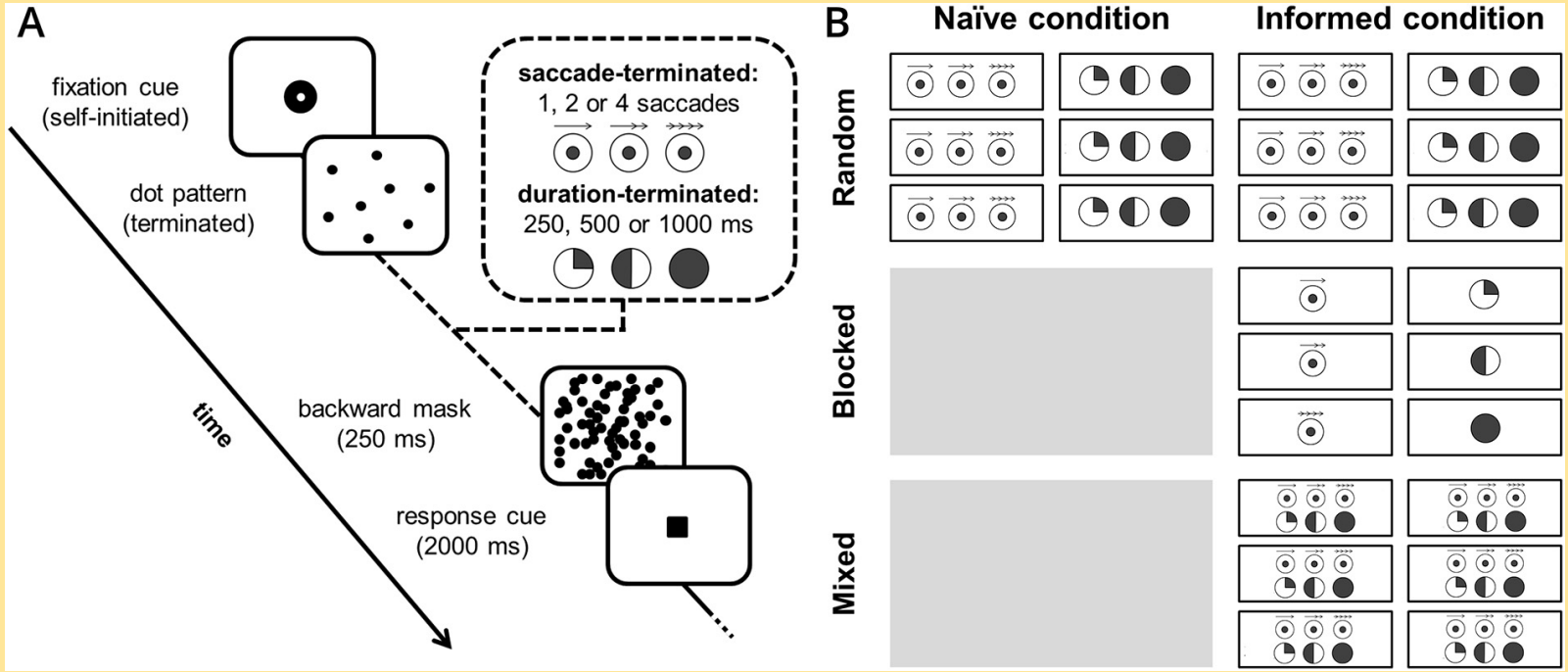




- We typically generate multiple saccadic eye movements when enumerating sets of objects.

- Many questions in cognitive psychology center on how language influences the ways in which we perceive and reason about information in the world around us.

Search event

0° rotation

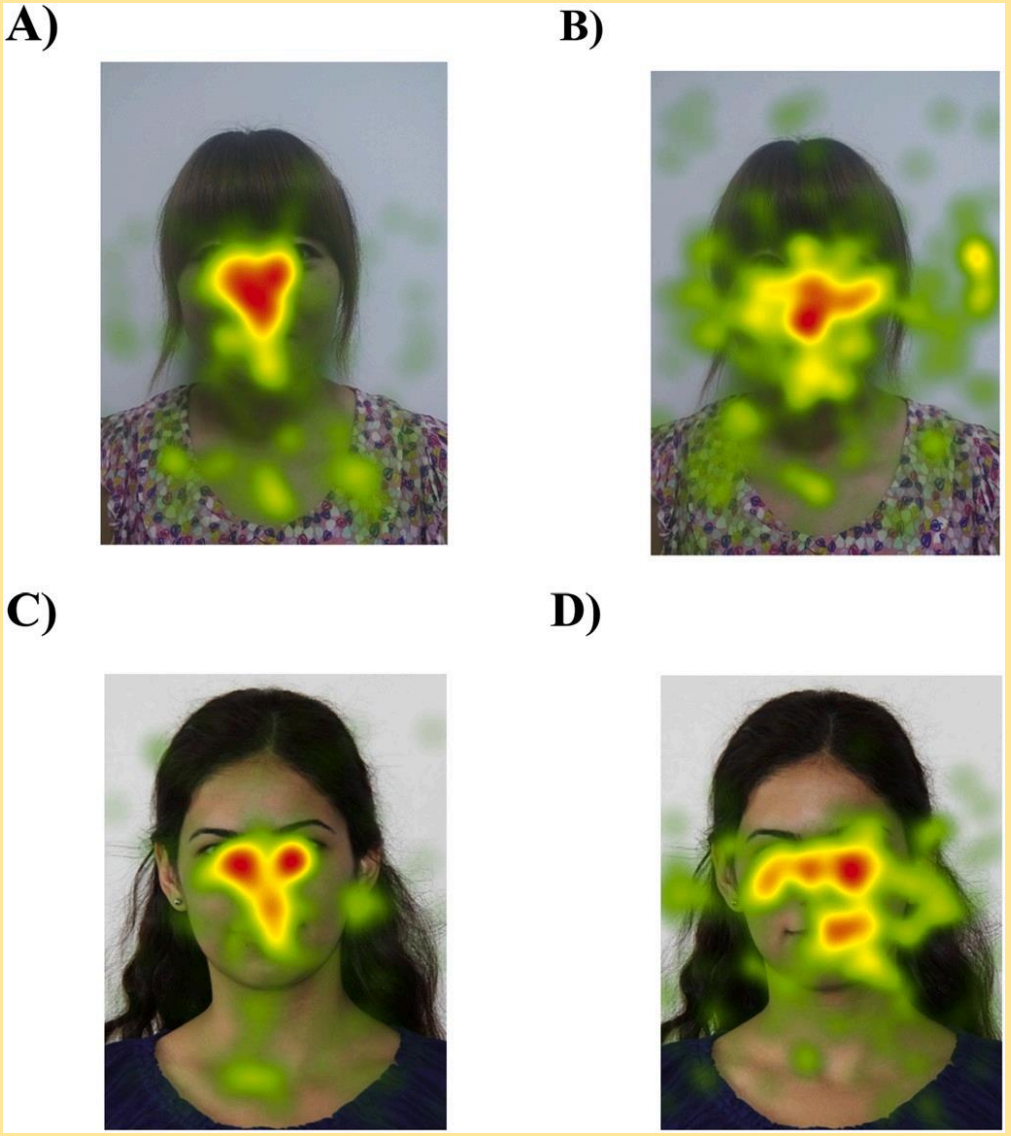
+90° rotation

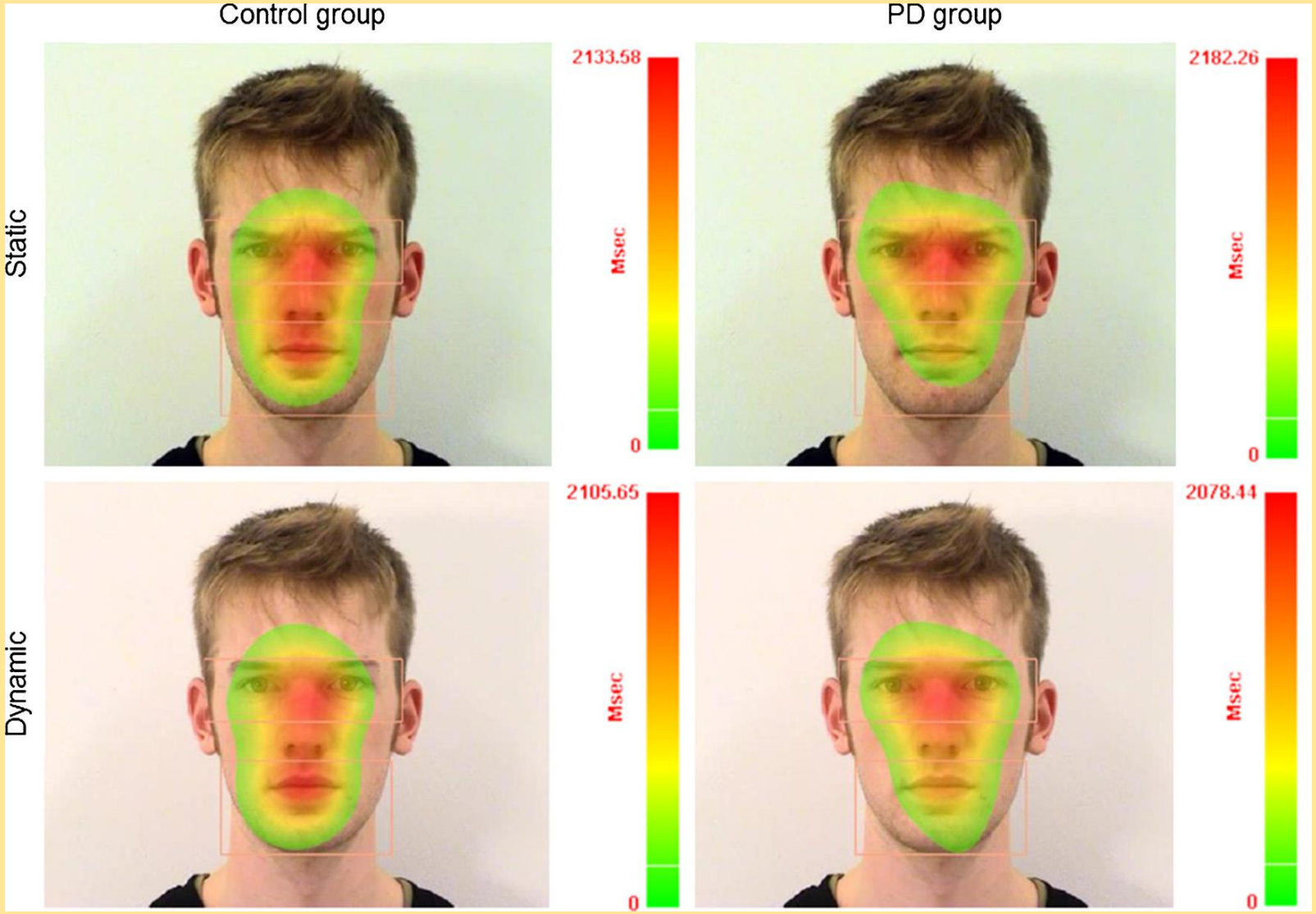
Hiding event

180° rotation

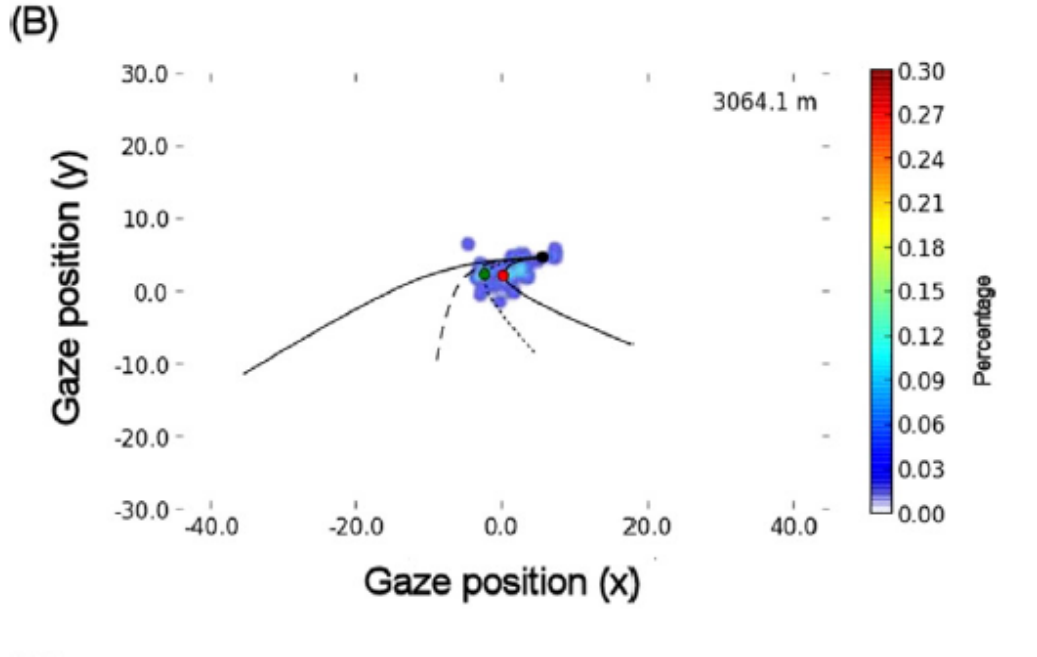
-90° rotation

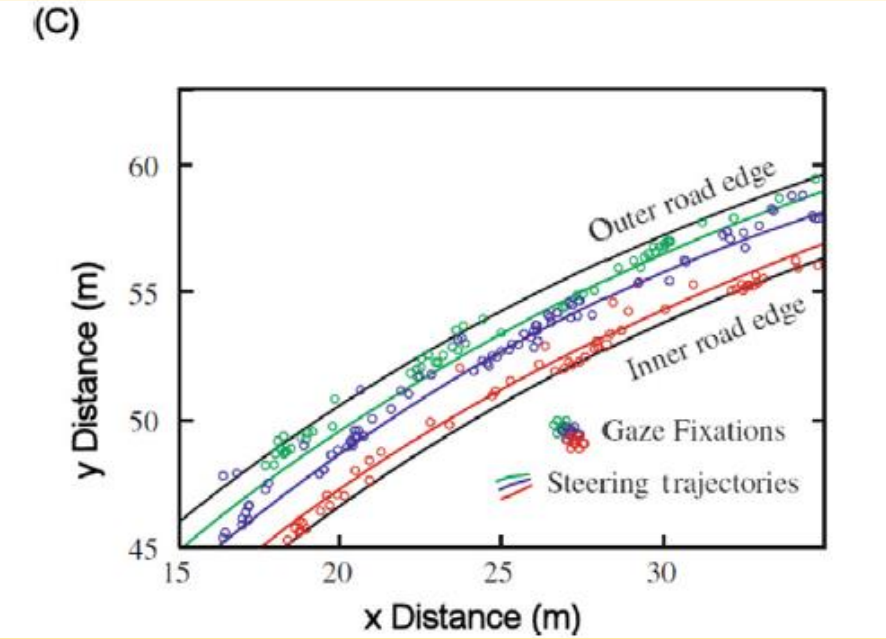
- The differences map of two kinds of facial stimuli in two groups.
- A) showed the hotspot map in TD children when gazing own-race face and
- B)showed the hotspot map in children with ASD when gazing own-race face;
- C)showed the hotspot map in TD children when gazing other-race face and
- D)showed the hotspot map in children with ASD when gazing other-race face



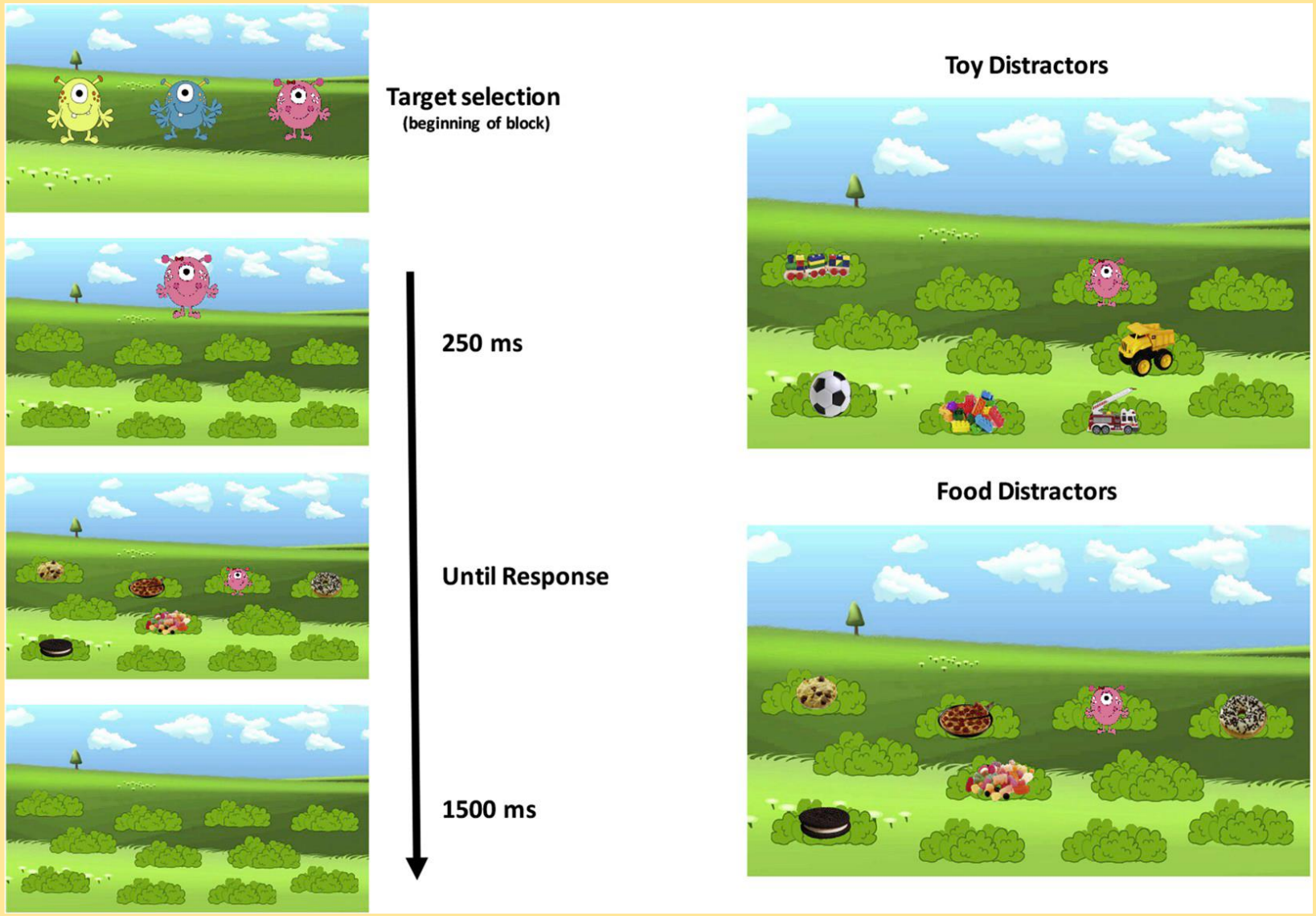


- There is a reduction of facial expression in Parkinson's disease (PD), which may influence the ability to use motion to recognise emotions in others.

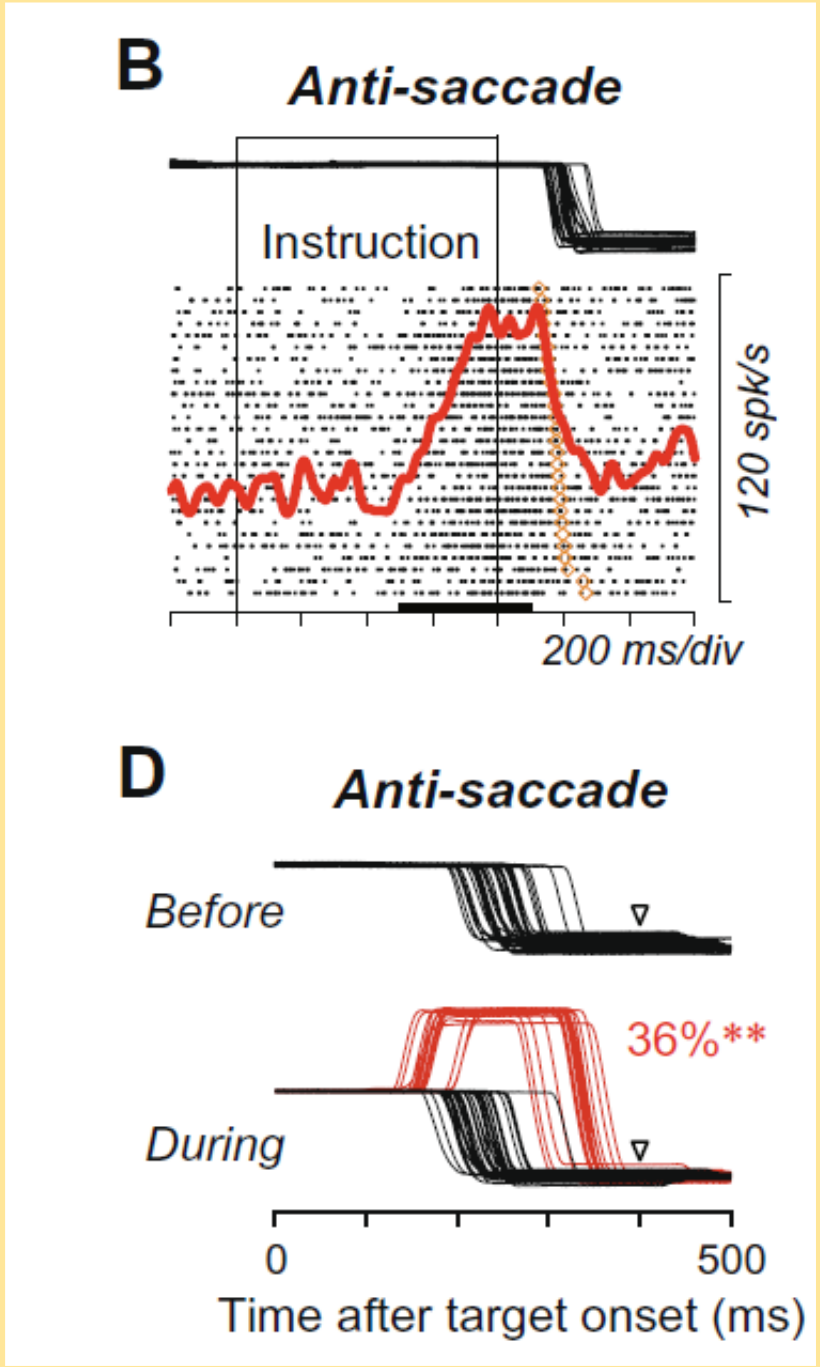


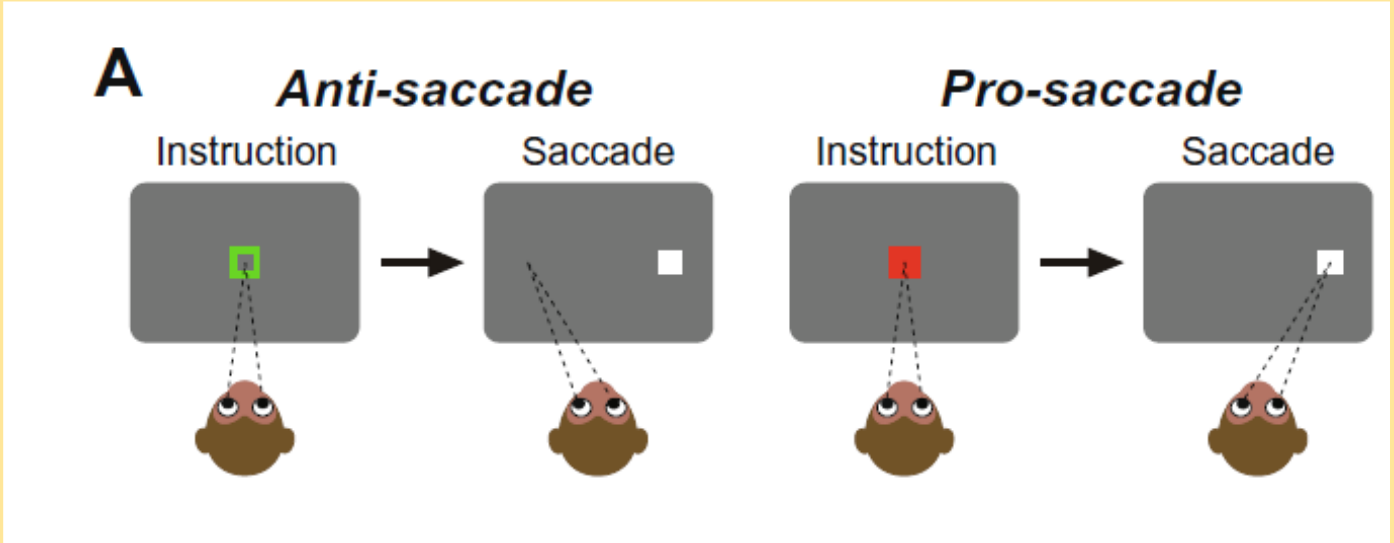


- Sensory ecology studies the ways species sample information from their environment and how they use this information to interact with the world around them.

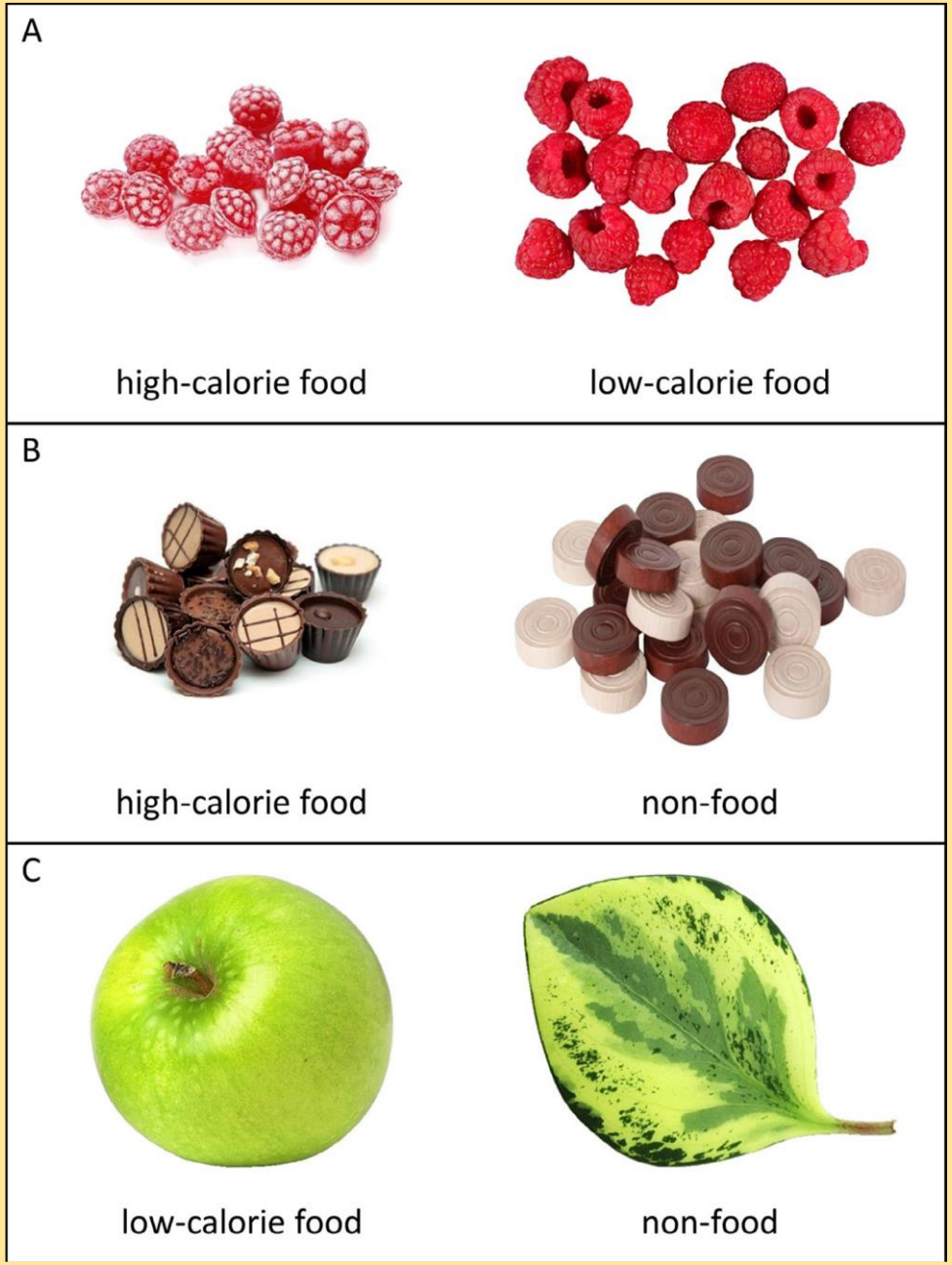


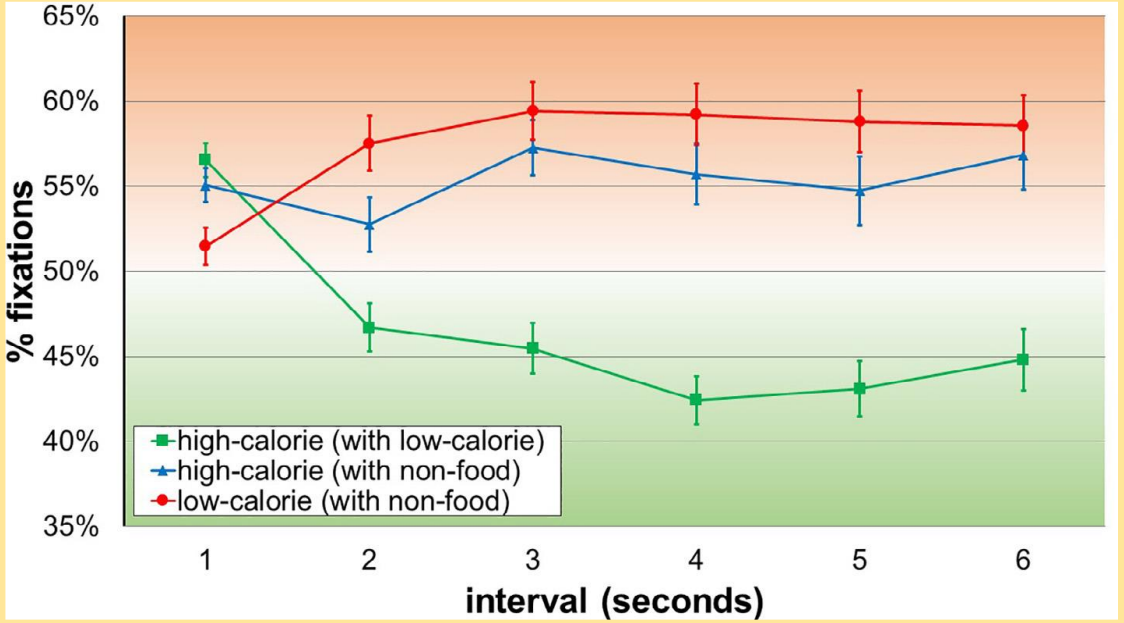
- Attentional bias to food cues may be a risk factor for childhood obesity, yet there are few paradigms to measure such biases in young children.





- The cerebellum is thought to have a variety of functions because it developed with the evolution of thecerebrum and connects with different areas in the frontoparietal cortices



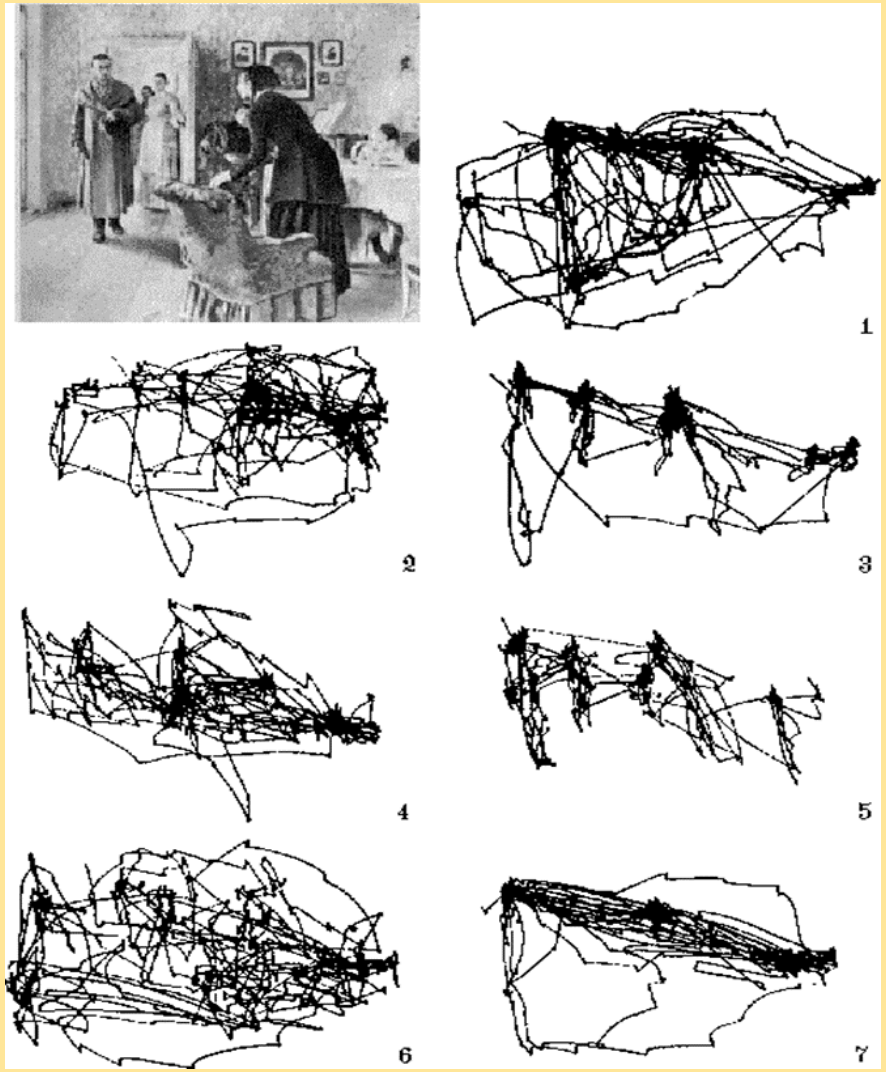


- Previous eye-tracking research has demonstrated that high-calorie food cues capture visual attention, particularly in individuals with overweight and weight concerns.

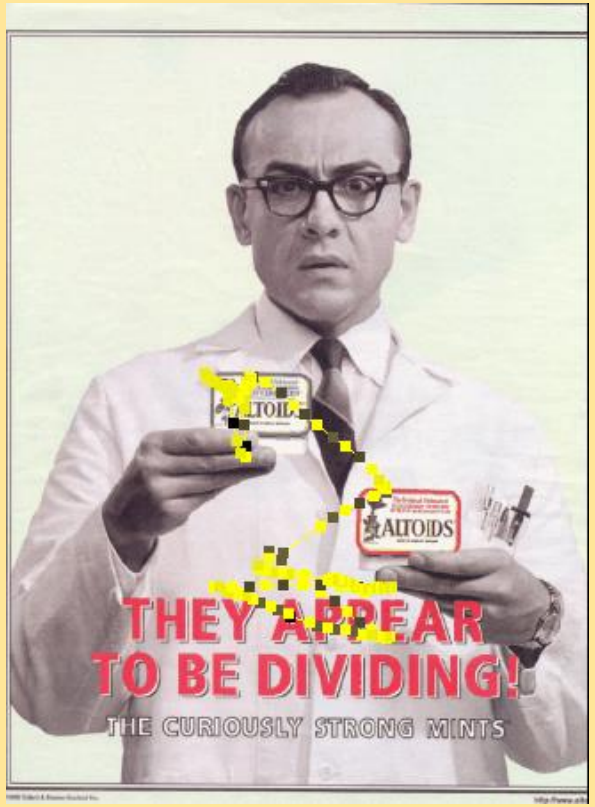
Scanning path

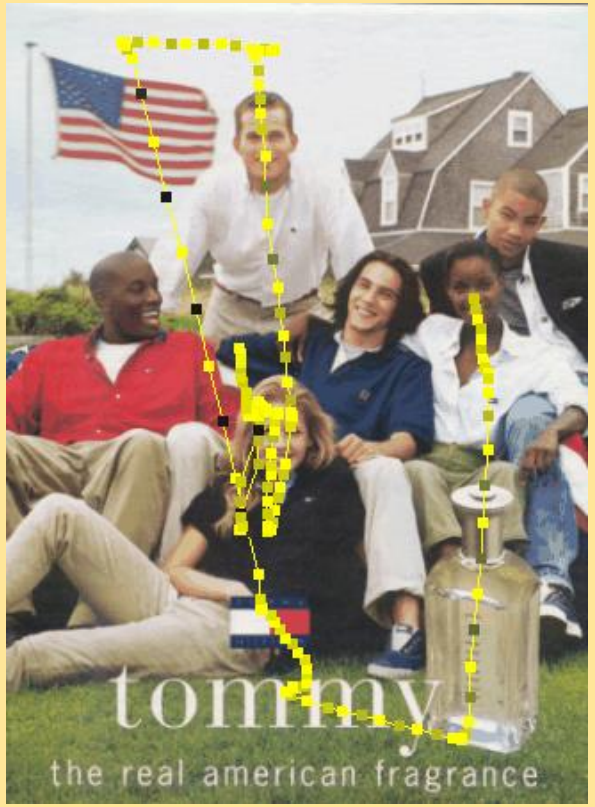
Presents the sequence of perceiving individual areas.

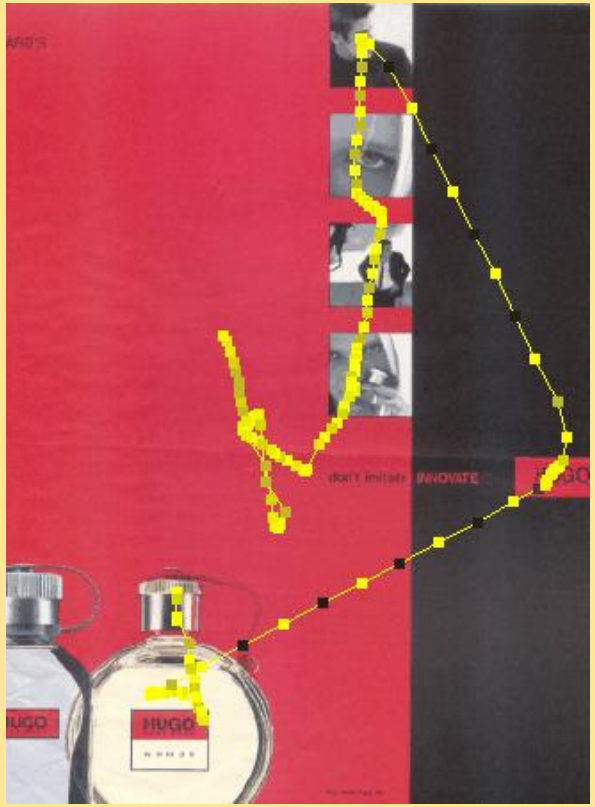
It allows to specify whether the elements crucial for the Client are perceived first. It helps to identify elements distracting from the main contents.



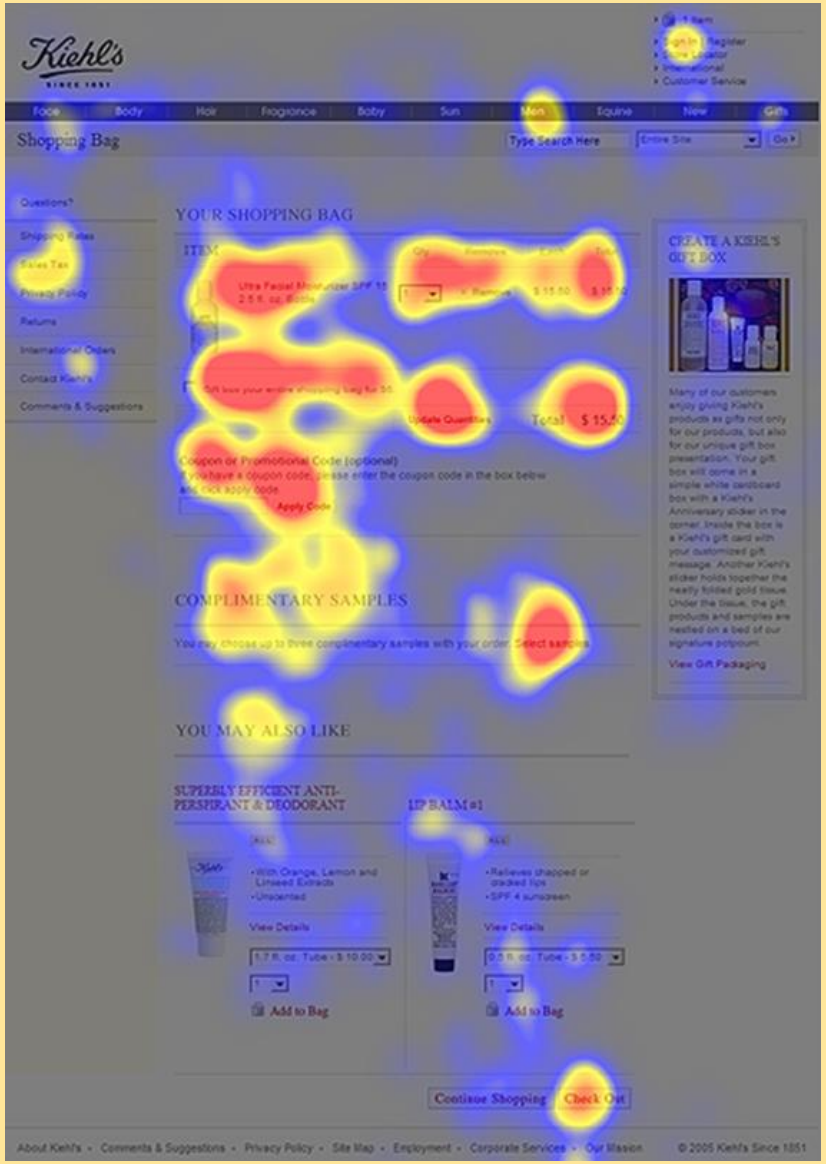
- Yarbus' early scan path recording:
- 1: examine at will
- 2: estimate wealth
- 3: estimate ages
- 4: guess previous activity
- 5: remember clothing
- 6: remember position
- 7: time since last visit







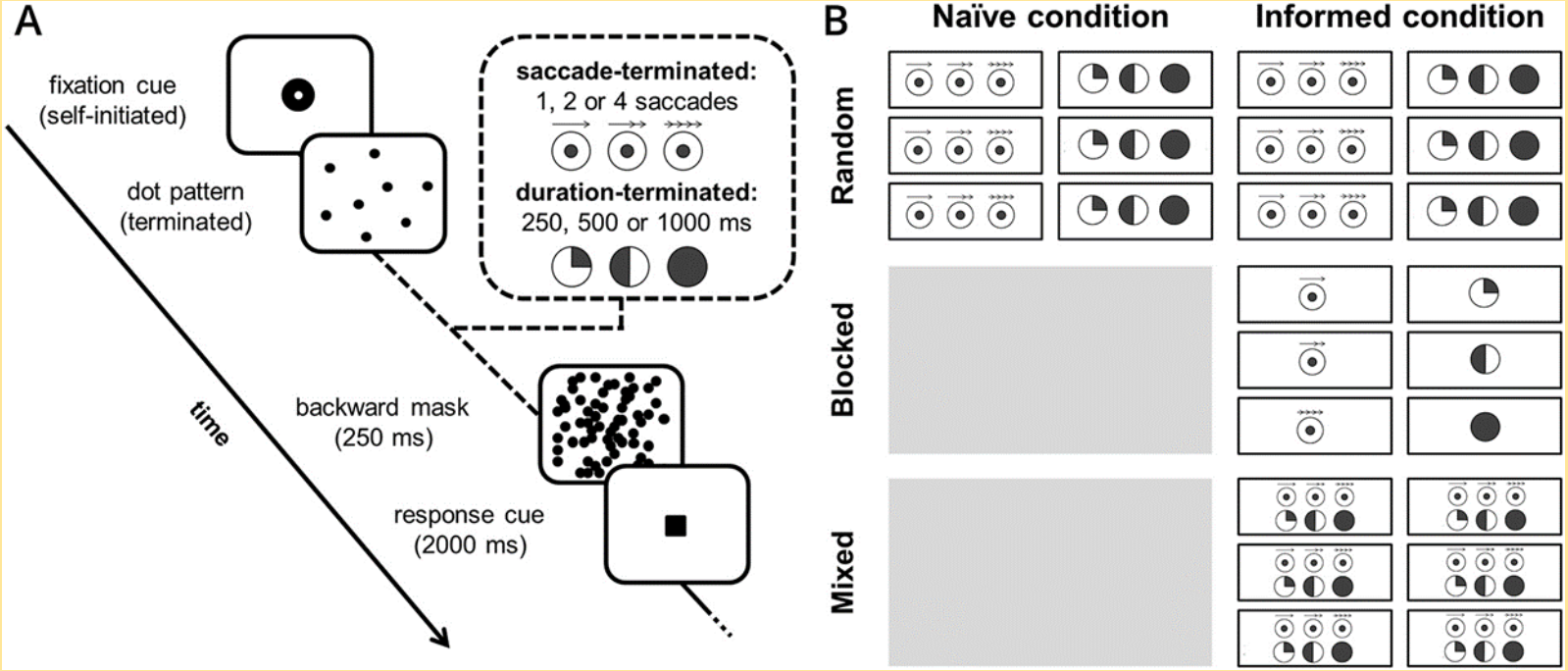
- Scanpaths over printed magazine ads



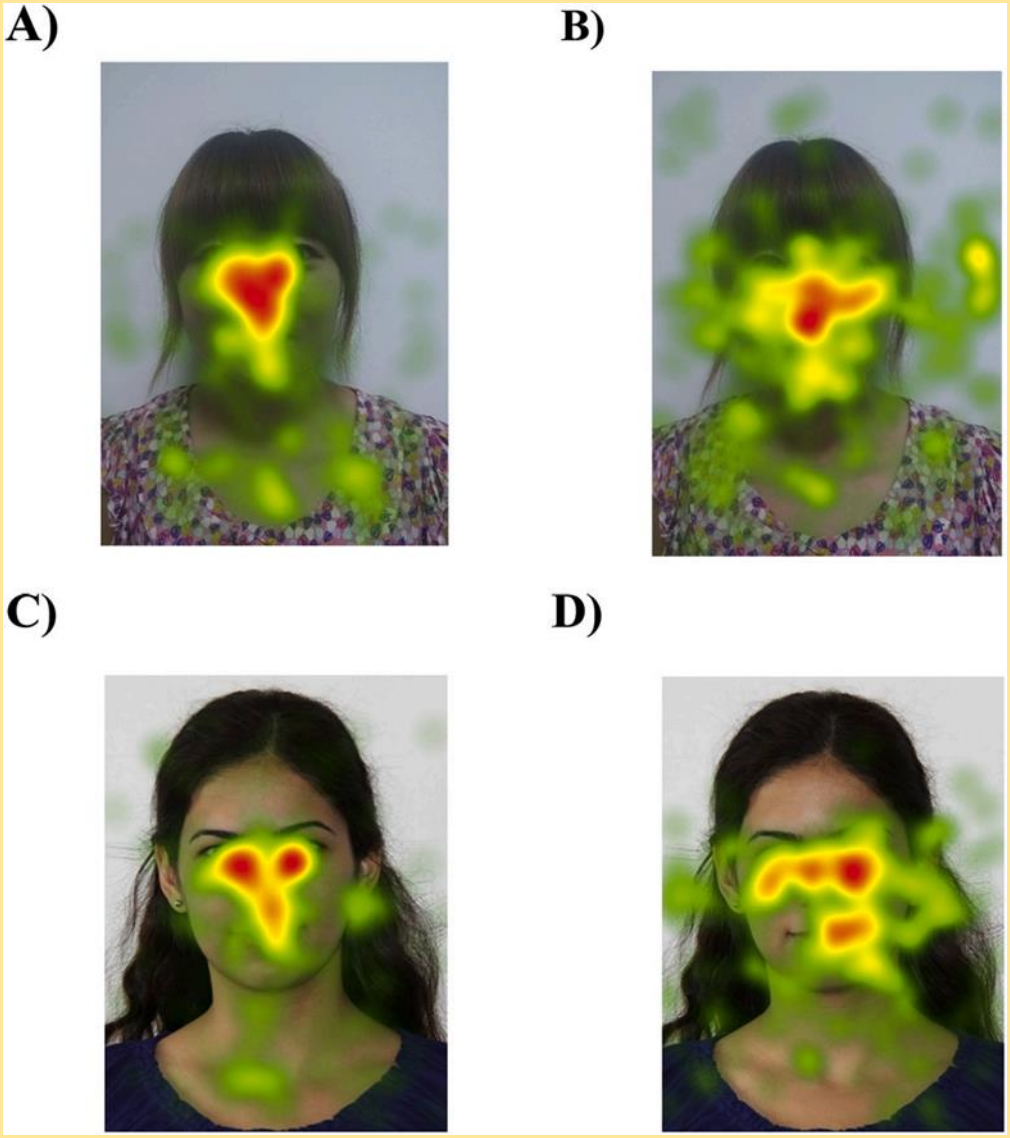
- Most people view websites in a “F” shaped flow.
- First they scan the page at the top, from left to right.
- Then the eyes go back to the left and down the page.
- They again scan to the right and back along the same pattern.

Any Question?

Question 1


A
fixation cue
(self-initiated)
dot pattern
(terminated)
saccade-terminated:
1, 2 or 4 saccades
duration-terminated:
250, 500 or 1000 ms
backward mask
(250 ms)
response cue
(2000 ms)
time
B
Naïve condition
Informed condition
Random
Blocked
Mixed

Question 2



Thanks.

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