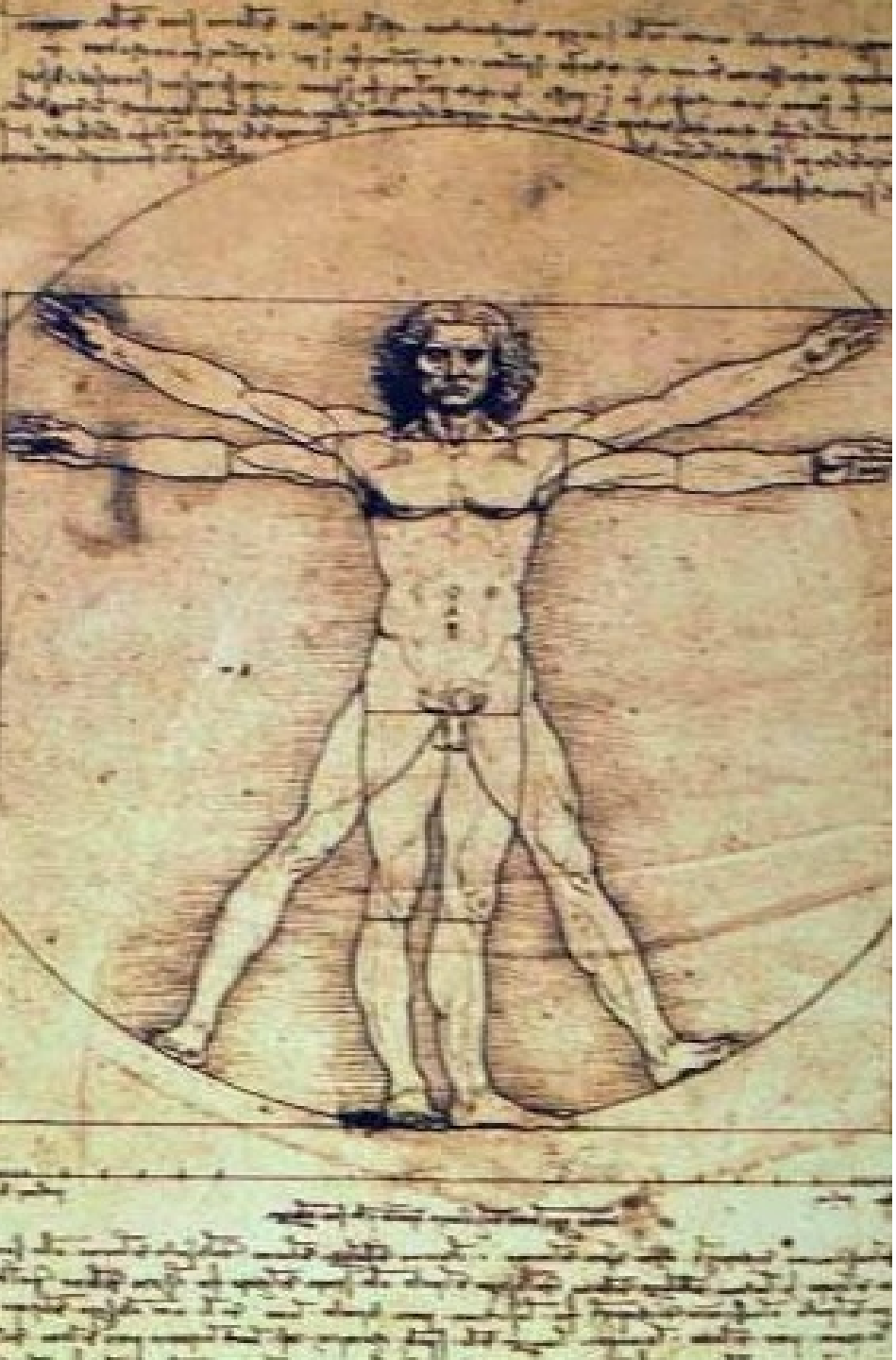

Interactive System
インタラクティブシステム特論(2)

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Hash tag #itsys

Handouts on the web

http://kaji-lab.jp/ja/index.php?people/kaji/interactive

–現在は2018年版がおかれています。徐々に変えていきます。
–Temporary, 2018 Japanese version. Will be replaced progressively.

–**こちらのpdfには動画のリンク先(Youtube等）が埋め込まれているので、紙資料よりも便利。紙資料は配布せず、講義の1時間前までにアップロードします。必要なら事前にダウンロードしてください**

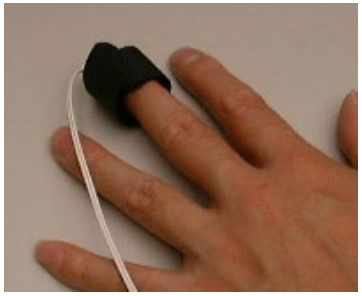
–**From next time, lecture handouts will be online 1 hour before the lecture. Print it if necessary.**

Schedule

- 4/5 講義(lecture)
- 4/12 講義(lecture)
- 4/19 講義(lecture)
- 4/26 講義(lecture)
- 5/10 休講(IVRC説明会 by 小泉先生)
- 5/17 講義(lecture)(休講の可能性あり)
- 5/24 講義(lecture)
- 5/31 講義(lecture)
- 6/7 休講 (6/1 オープンラボ研究室見学(任意))
- 6/14 講義(lecture)
- 6/21 講義(lecture)
- 6/28 講義(lecture)
- 7/5 プレゼンテーション(presentation)1
- 7/12 休講 (6/15 オープンラボ研究室見学(任意))
- 7/19 プレゼンテーション(presentation)2
- 7/26 休講

人間計測手法／Measuring Human





意志から行動までの「どの経路を測るか」で5つの段階
Five layers, *from* our initial will *to* our perception.

- 脳活動計測／Measure brain activity.
- 神経・筋活動計測／Measure nerve activity.
- 自律神経系計測／ Measure autonomic nerve related phenomenon.
- 運動計測／Measure motion.
- 心理物理実験／Ask the user (psychophysics)

Psychophysics

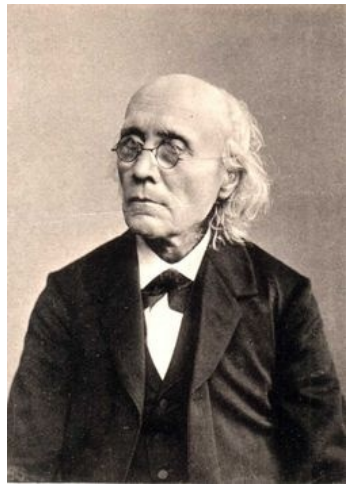
- Measure relationship between subjective sensation and physical stimulation.
  ≒Measure Human's sensing "ability".

- Important value: "Discrimination threshold"
  - Limitation of "difference of two stimuli" **ΔP**, which is perceptible
    ex)
    - P=30g ⇒ ΔP=3g
    - P=3kg ⇒ΔP=300g

- Weber-Fechner's law (1834)
  - **ΔP／P＝Constant**
    Can be applied to most sensation.

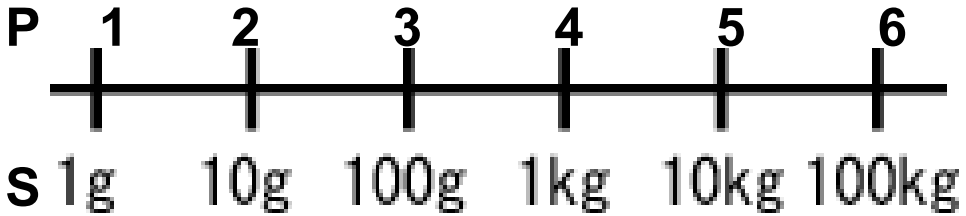
Weber-Fechner's Law

Weber
(1795～1878)



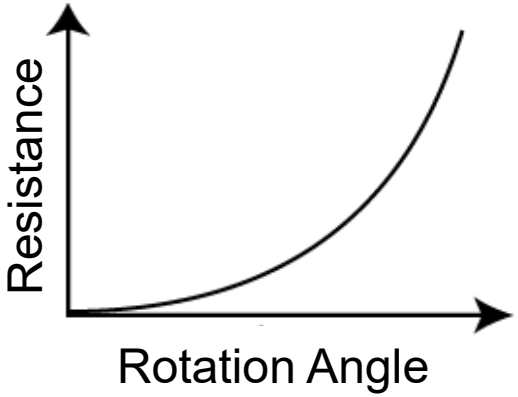
Fechner
(1801～1887)

- P=P(S)
  - P: subjective value of sensation
  - S: physical value of stimulation
  - ΔP = subjective "scale" of sensation
- ΔP/P = Constant
  - Integral of both sides gives **S ∝ logP**

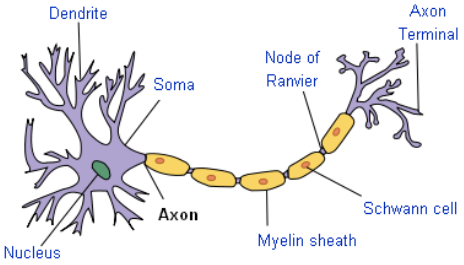


- Conclusion: Our internal "scale" is logarithmic

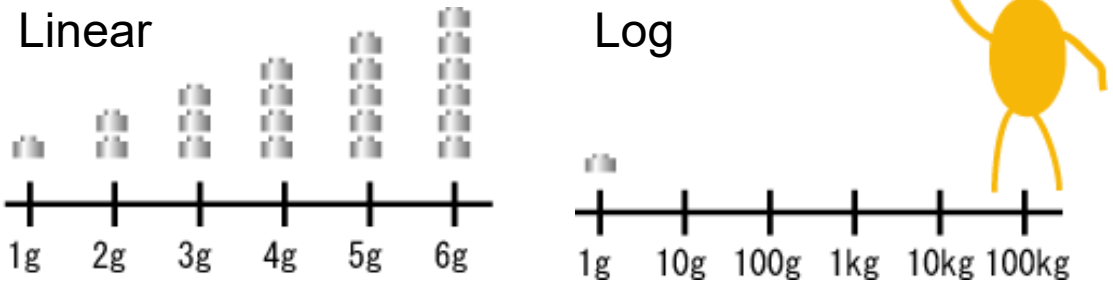
- ex:
  - Audio's rotary volume



Why Log? = Why not Linear?



Our nerve quantimizes the phenomenon by impulses.
When we have only 6 scales...



By using Log scale, we can perceive more phenomena.

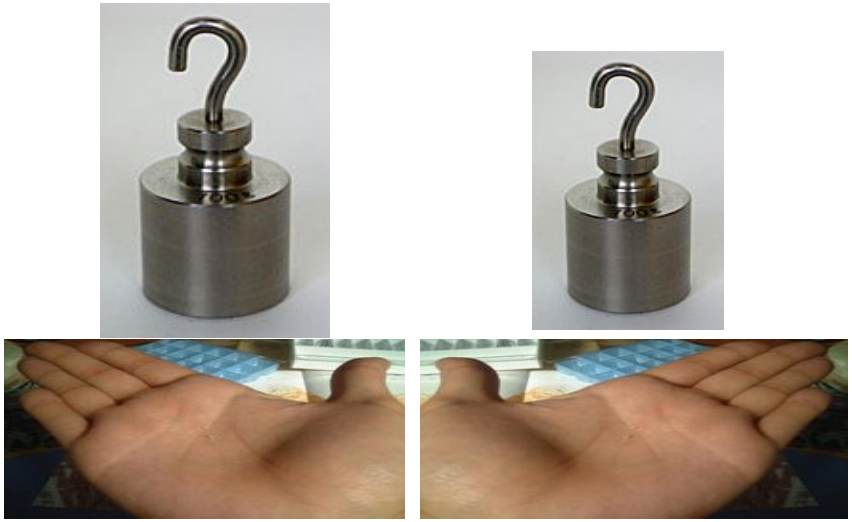
(ex) CCD cam：20dB～30dB
Huma Eye：80dB(Can see stars and sun

Method of Psychophysical experiment

Purposes

- Measure “Discrimination Threshold” (DT), which gives ΔP
- Measure “Point of Subjective Equality” (PSE).
  - Perceive two different stimuli as “same”.

Discrimination Threshold (DT)
＝What is the necessary difference
for discrimination



Point of Subjective Equality (PSE)
= What is the value of left weight, which can be perceved as “same” as the right weight.

Major Methods:

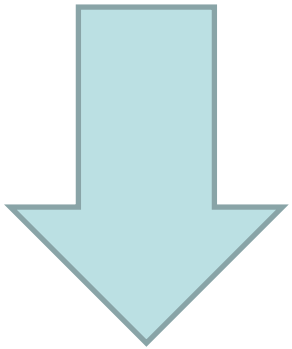
Method of Adjustment, Method of Limit, Method of Constant

●調整法／Method of Adjustment
　被験者が調整する

●極限法／ Method of Limit
　実験者が調整する

●恒常法／ Method of Constant
　調整せず回答の確率分布を見る

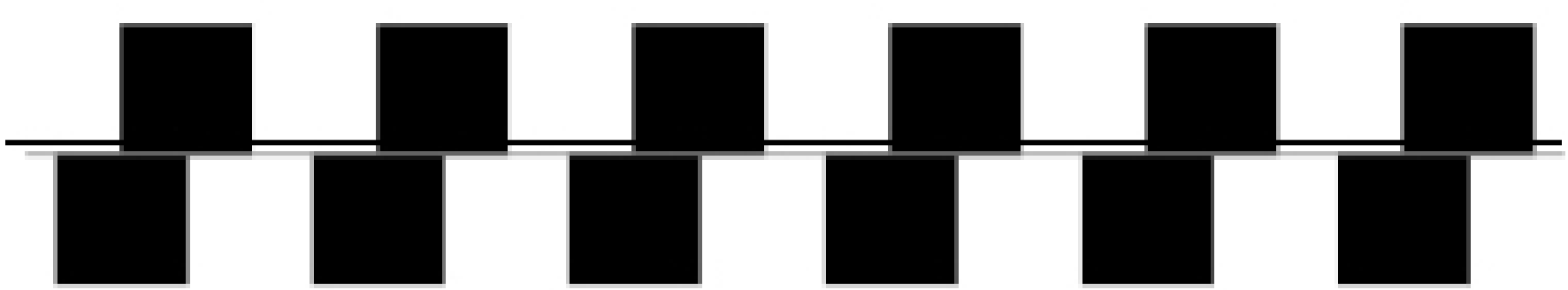
Easy,
Rough



Time Consuming,
Precise

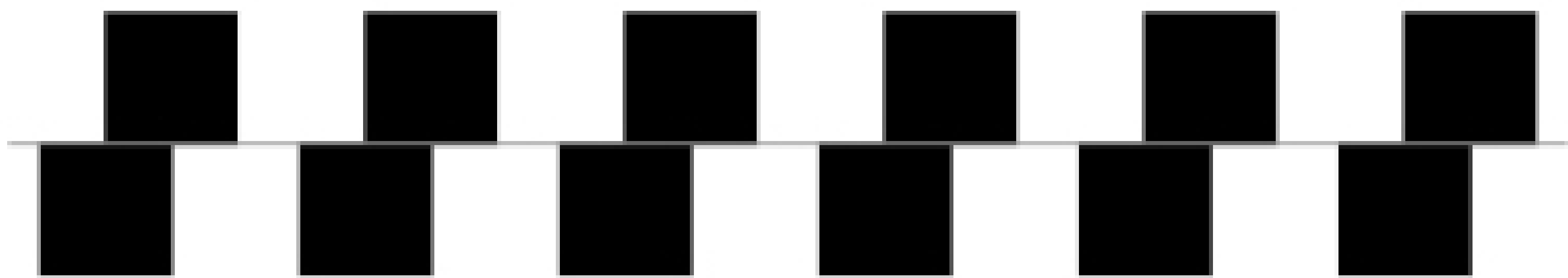
調整法／Method of Adjustment

カフェウォール図形：確かに水平

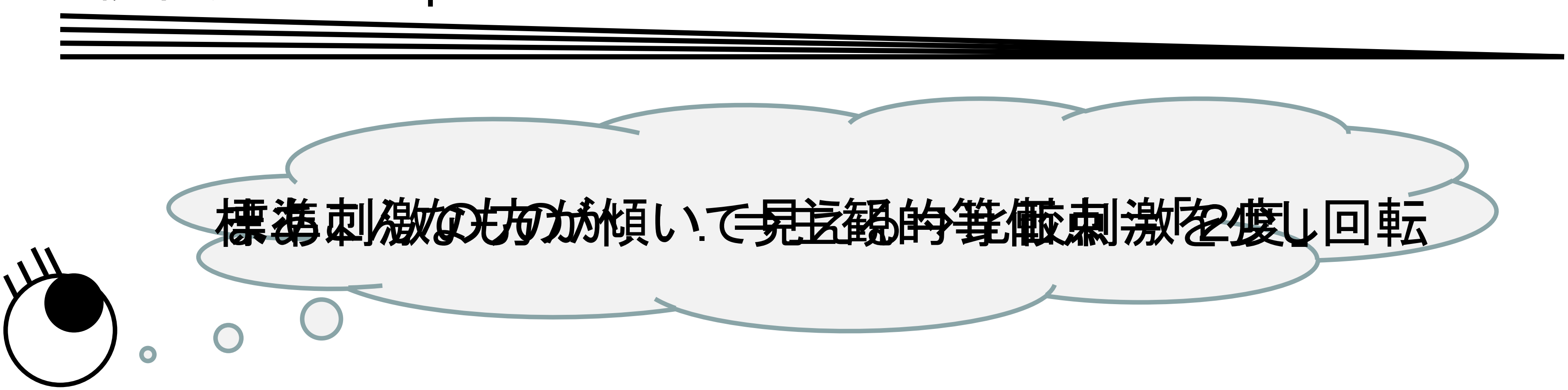


調整法／Method of Adjustment

標準刺激／Standard Stimulus



比較刺激／Comparison Stimulus



極限法／ Method of Limit

ミュラー・リヤー錯視
確かに同じ長さです

極限法／ Method of Limit

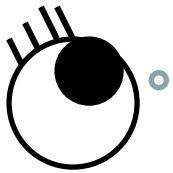
1．下降系列／Descending Series

標準刺激
Standard Stimulus

比較刺激
Comparison Stimulus

比較刺激の方が長い→回答「小」

同じくらい？二件法なので→無理やり回答



このときの比較刺激の長さ＝上閾値／Upper Threshold

極限法／ Method of Limit

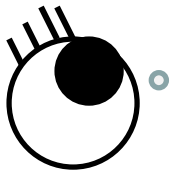
2. 上昇系列／Ascending Series

標準刺激
Standard Stimulus

比較刺激
Comparison Stimulus

比較刺激の方が短かった → 回答「小」

比較刺激の方が長かった → 回答「大」



このときの比較刺激の長さ＝下閾値／Lower Threshold

極限法／ Method of Limit

閾値の計算
Threshold Calculation

標準刺激：長さ1．0

上閾値：0.95

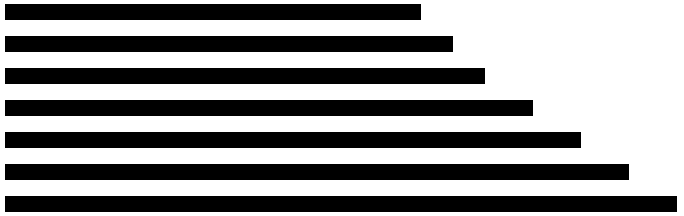
下閾値：0.85

この結果から，
- 主観的等価点(Point of Subjective Equality)は(0.85+0/95)/2 = 0.90
- 弁別域(Discrimination Threshold)は(0.95-0.85)/2 = 0.05

つまり，この「矢印の錯視」によって，
- 長さが0.9に縮んで見えることと，
- 長さの弁別能力が0.05程度であることが分かった．

恒常法／ Method of Constant

標準刺激
Standard Stimulus

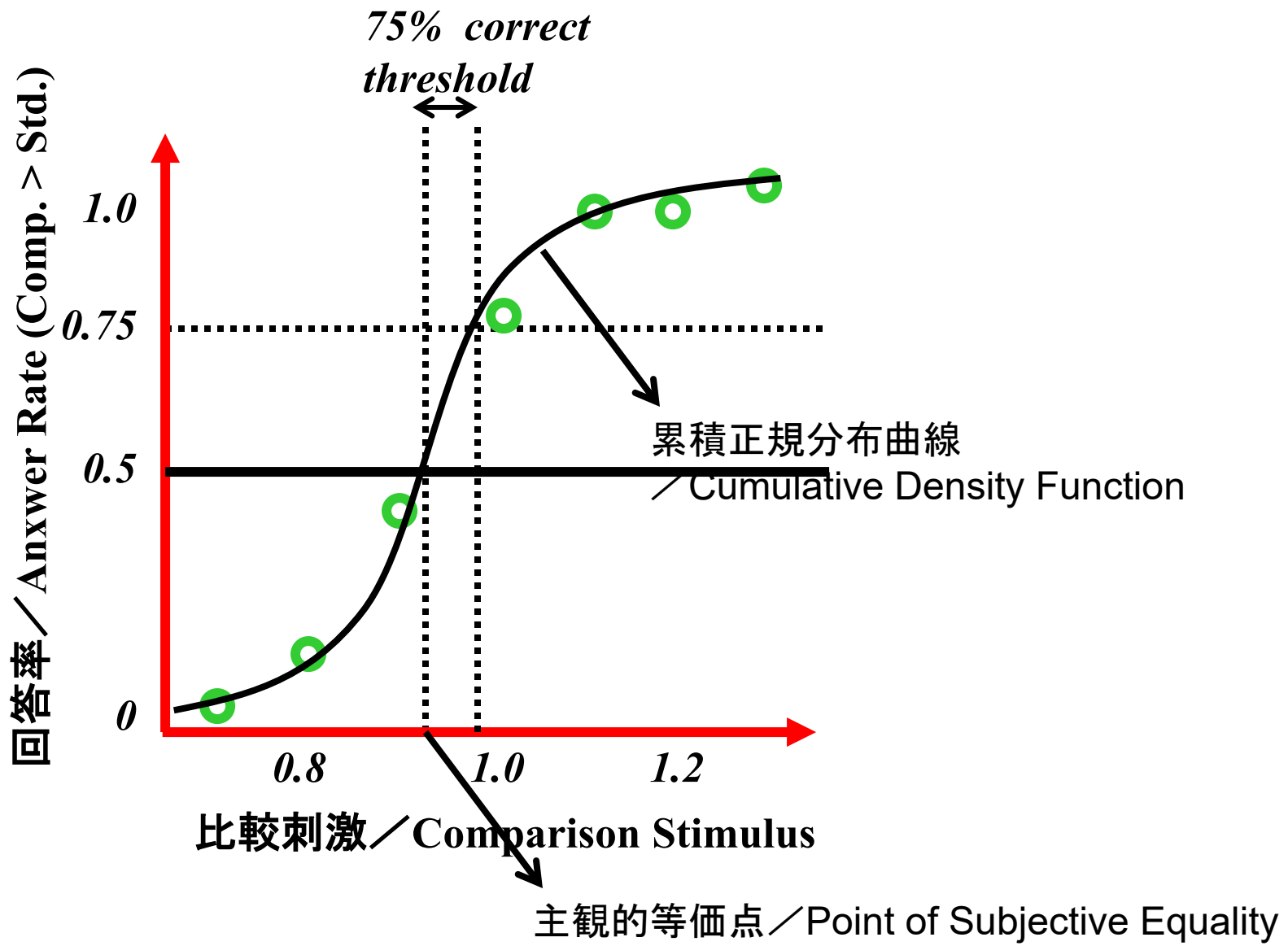


比較刺激
Comparison Stimulus

1. 比較刺激を複数用意する（例では7個）
2. 一個の比較刺激あたりの実験回数を例えば20回とする
3. 合計7×20=140回、「ランダムに」比較し、強制二択させる

比較刺激	「比較刺激の方が長い」	「比較刺激の方が短い」
0.7	1	19
0.8	3	17
0.9	9	11
1.0	15	5
1.1	17	3
1.2	19	1
1.3	20	0

恒常法／ Method of Constant



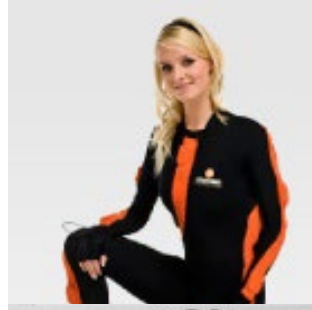
Summary

Measurement of Human perception is neccesary for interactive system design.

- 脳活動計測／Measure brain activity.
- 神経･筋活動計測／Measure nerve activity.
- 自律神経系計測／ Measure autonomic nerve related phenomenon.
- 運動計測／Measure motion.
- 心理物理実験／Ask the user (psychophysics)

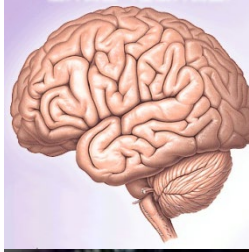
<u>They can be used both as a **evaluation tool**, and **part of an interactive system**</u>



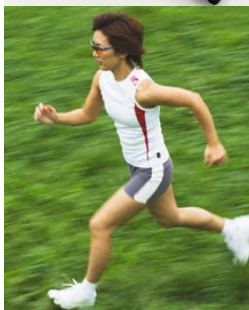




Outline of the lecture

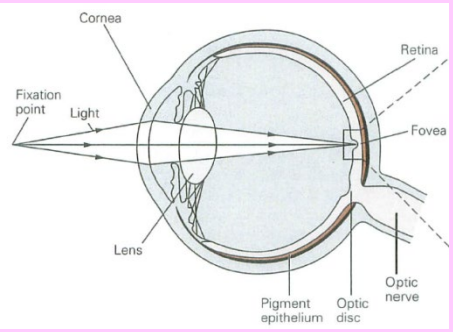
1. 人間計測手法／Measuring Human
2. 視覚／Human Vision System
3. 視覚センシング／Visual Sensing
4. 視覚ディスプレイ／Visual Display
5. 聴覚、聴覚インタフェース／Auditory Interface
6. 触覚、触覚インタフェース／Tactile Interface
7. 力覚、力覚インタフェース／Haptic Interface
8. 移動感覚インタフェース／Locomotion Interface

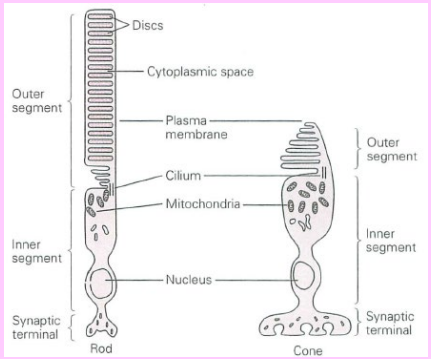


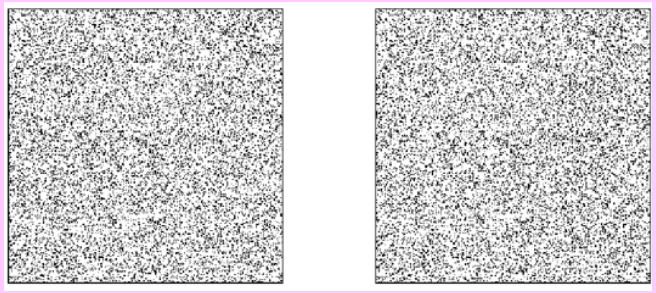


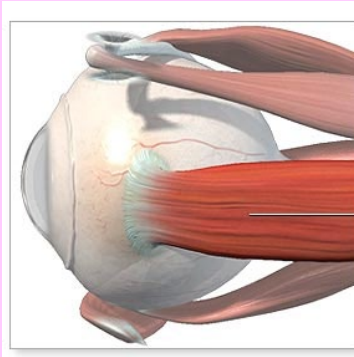



TODAY's TOPIC



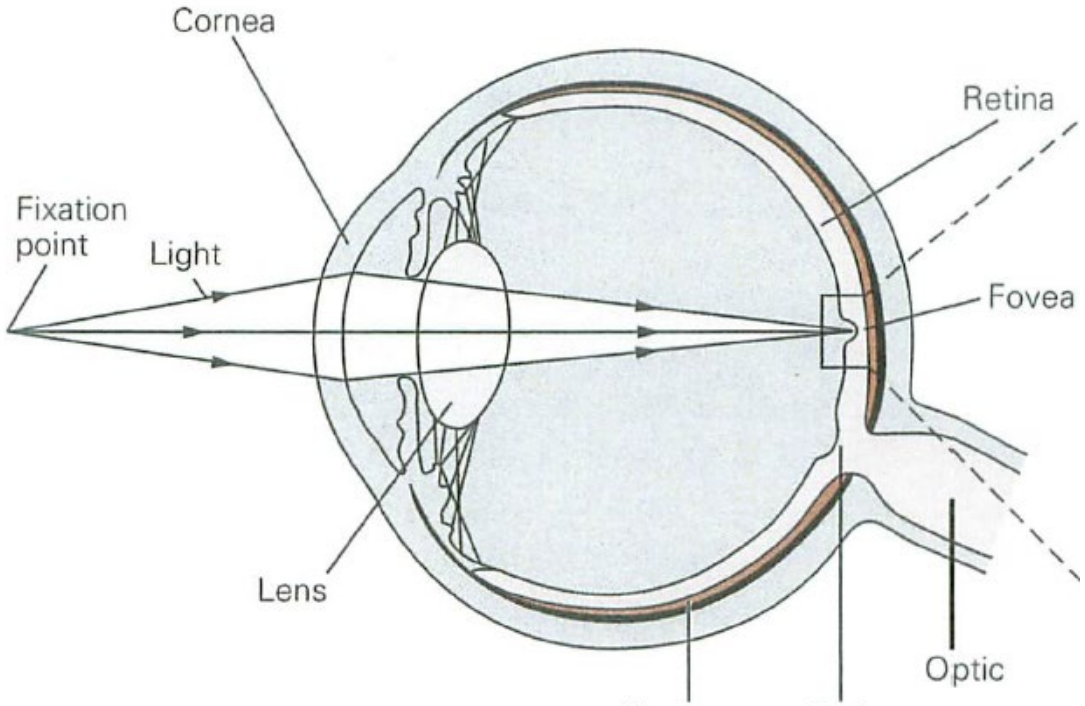




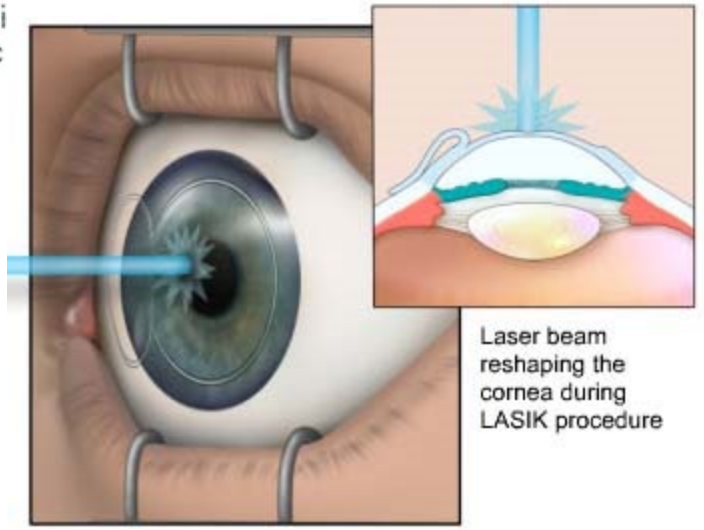


- 目の構造／Eye structure
- 目のセンサ／ Eye sensors
- 奥行き知覚／Depth perception
- 眼球運動／Eye movement

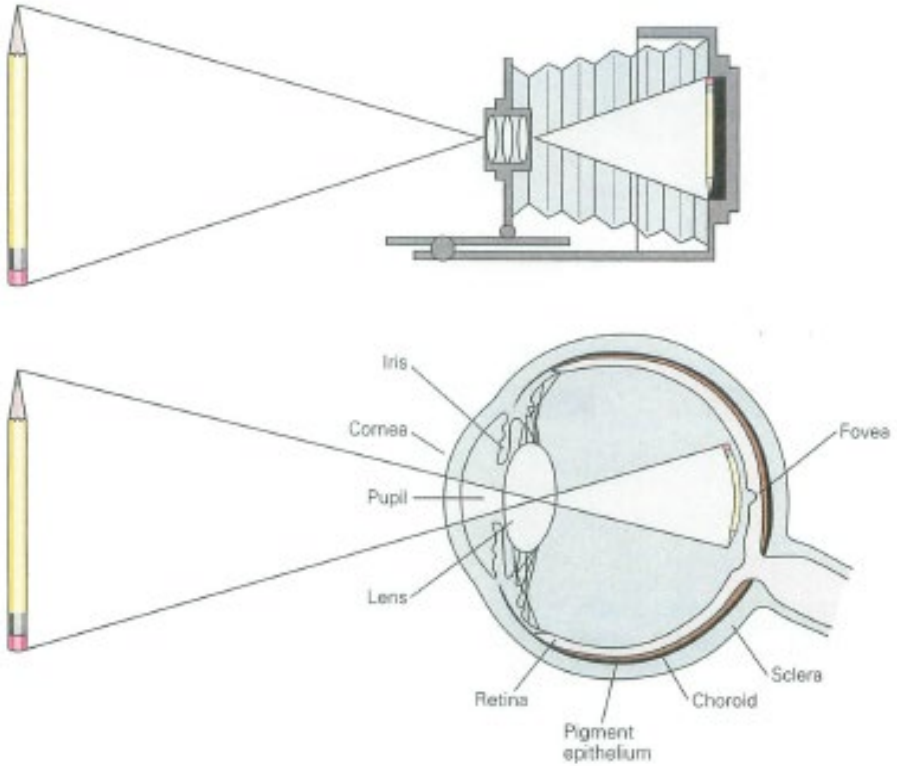
眼の構造／Eye Structure



- 角膜／Cornea: surface lens
  - LASIK: Laser in Situ Keratomileusis
- 水晶体／Lens: Internal lens.
  - Focal length is adjustable by deformation.
- 虹彩／Iris: Adjust amount of light.
- 網膜／Retina: Light sensor



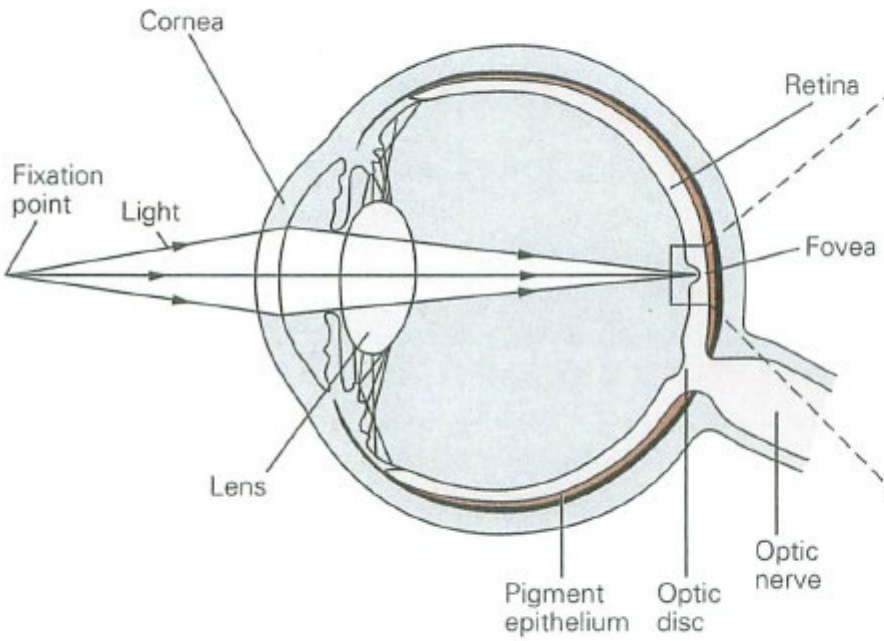
カメラとの比較／Comparison with Camera

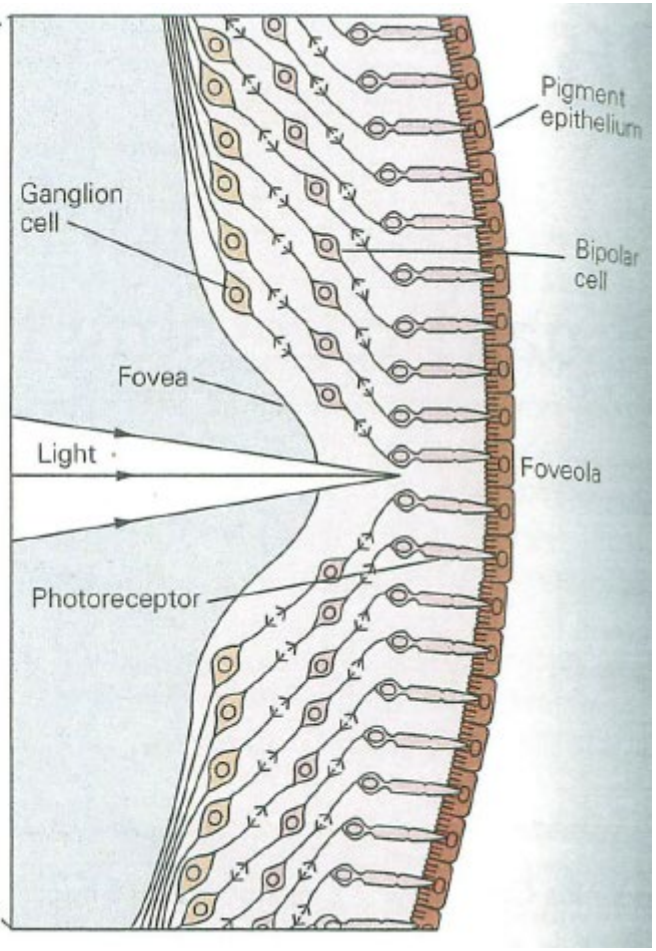


- レンズ／Lens
  Camera: 1
  Eye: 2
- 虹彩／Iris: same
- センサ／Sensor
  Camera: Film or CCD
  Eye: Retina

- Difference = Focal length adjustment(焦点調節)
  - Camera: Shift lens
  - Eye: Deform lens

網膜／Retina = Optical Sensor





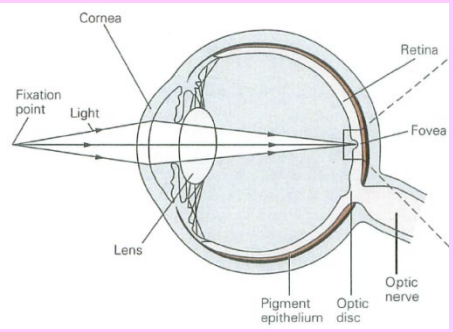
- 中心窩／Fovea: Center of vision. Very high spatial resolution.
- Optic nerve: Nerve from retina to brain.

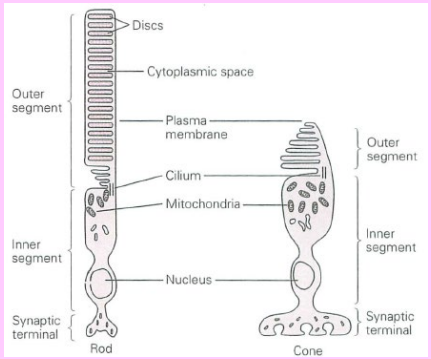
  Optic nerve is in front of the retina. (transparent)
- 盲点／Optic disc (blind spot): Hole that optic nerve axons exit.

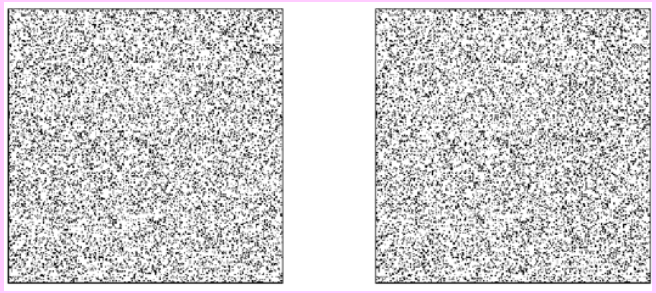
盲点／Blind Spot

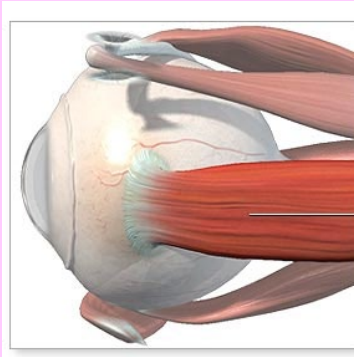
- Close your right eye, and gaze ‘+’ with your left eye.
- Move the paper back and force, and find ‘●’ disappears.
- You also find the line connected.

TODAY's TOPIC









- 目の構造／Eye structure
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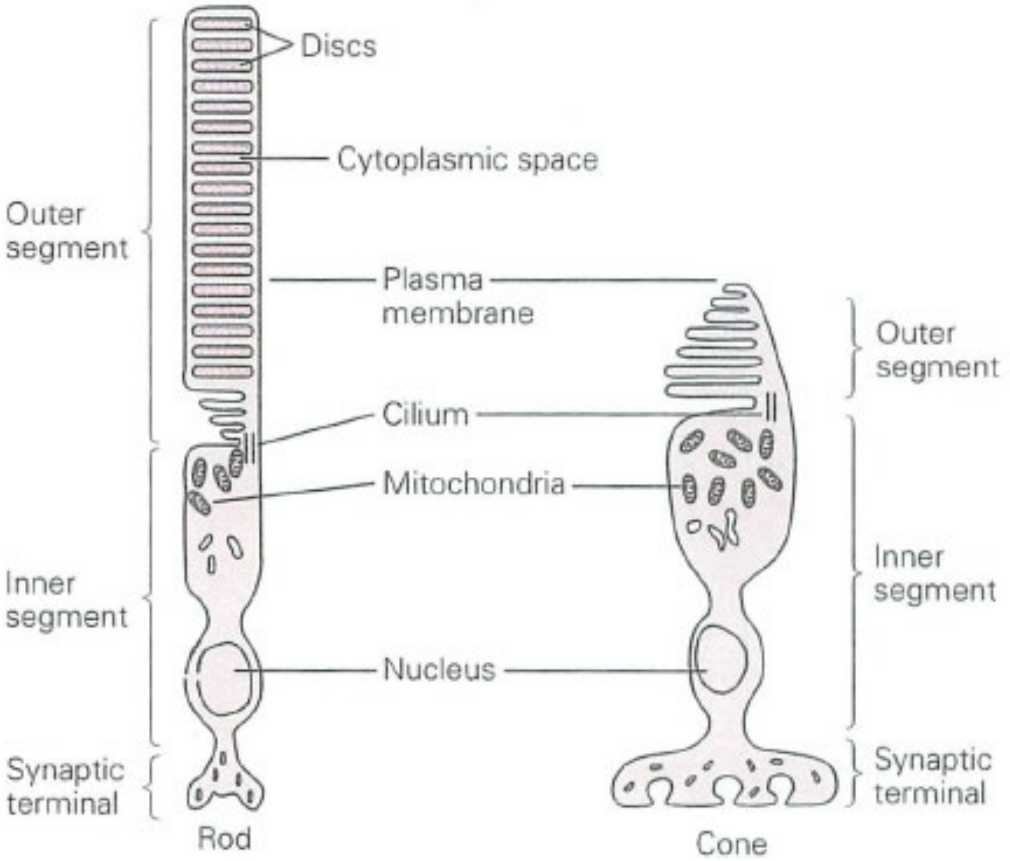
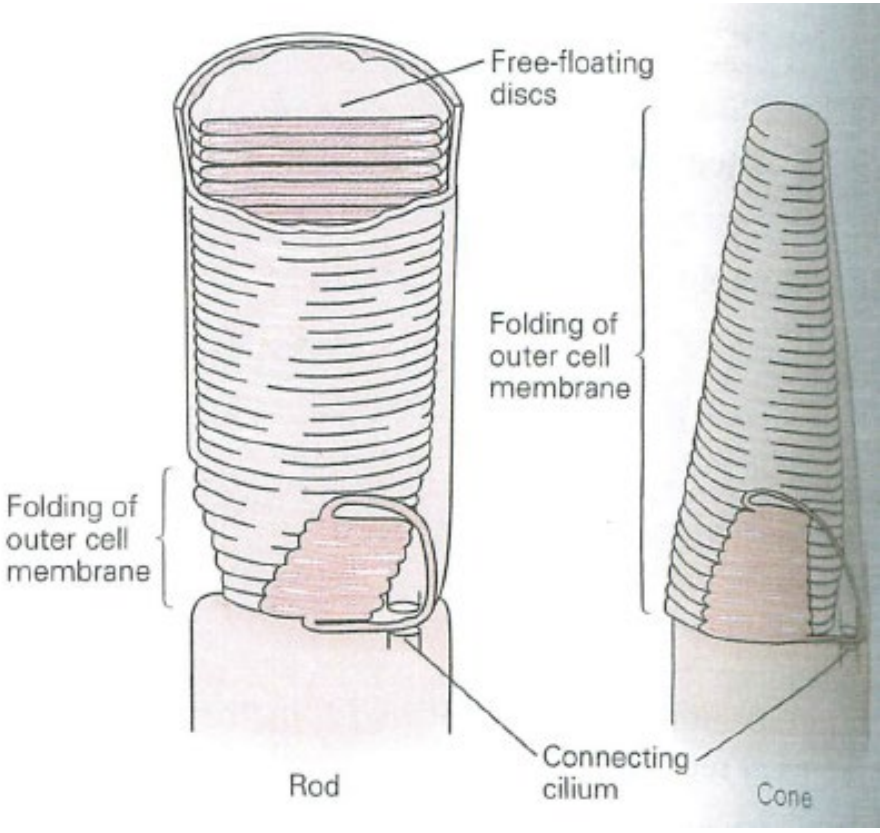
網膜の視細胞／Optic cells in the retina

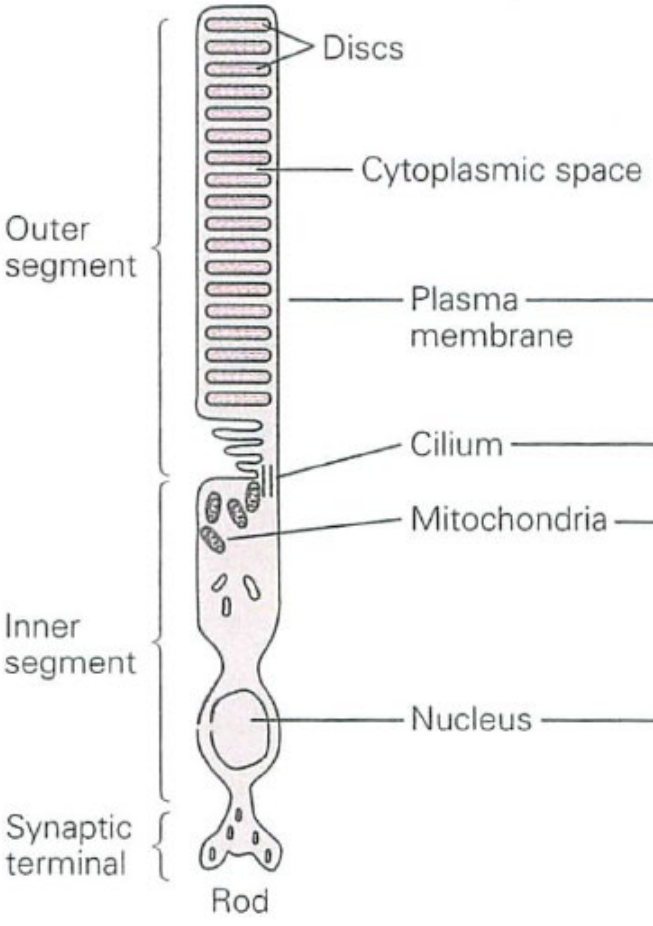




- Rod Cell (桿体細胞) and Cone Cell (錐体細胞)
  - Light to electric conversion is done at outer segment.
  - Channels composed of protein is opened by the light.
  - Rod cell has longer outer segment.

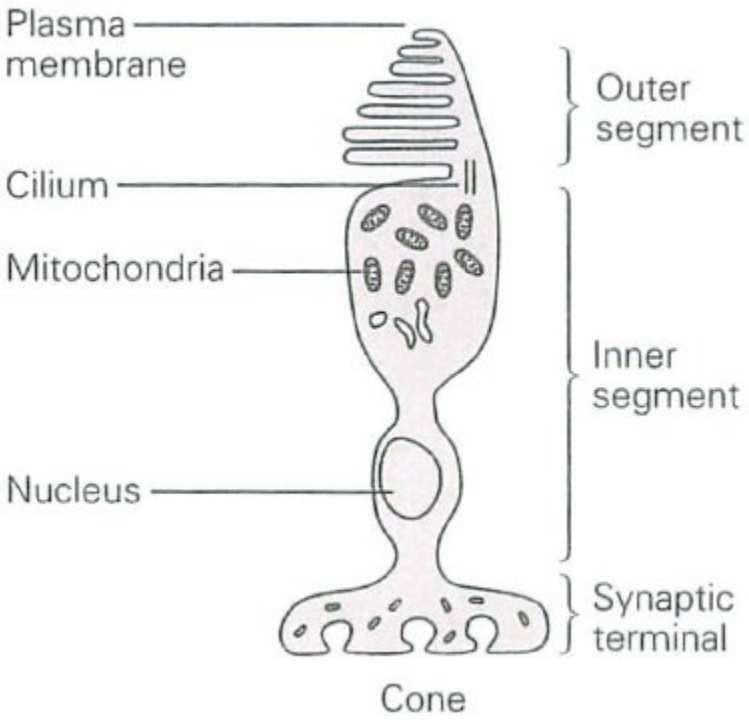
桿体細胞／Rod cell

- Black and White sensor.
- Plays major role when dark
- High sensitivity (x100 cone cell)
  - Can capture single photon
- One eye has 130,000,000 cells.
- Slow response.

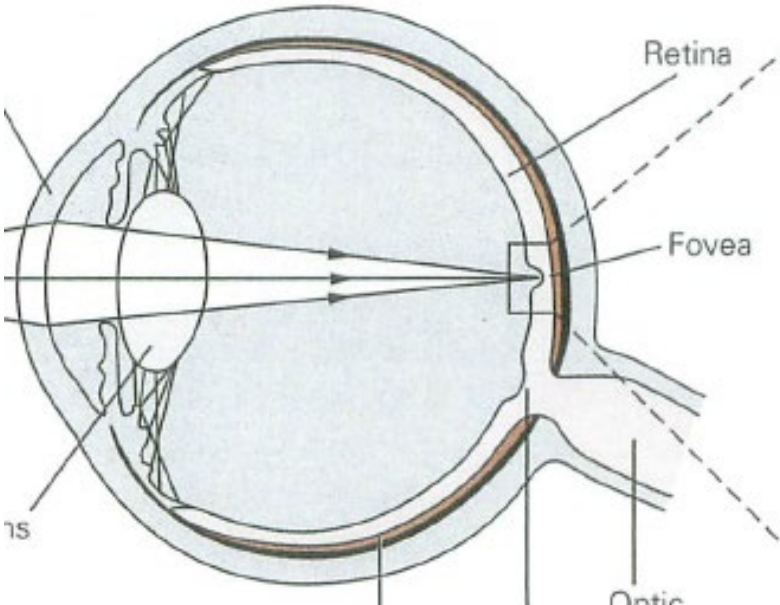


錐体細胞／Cone cell

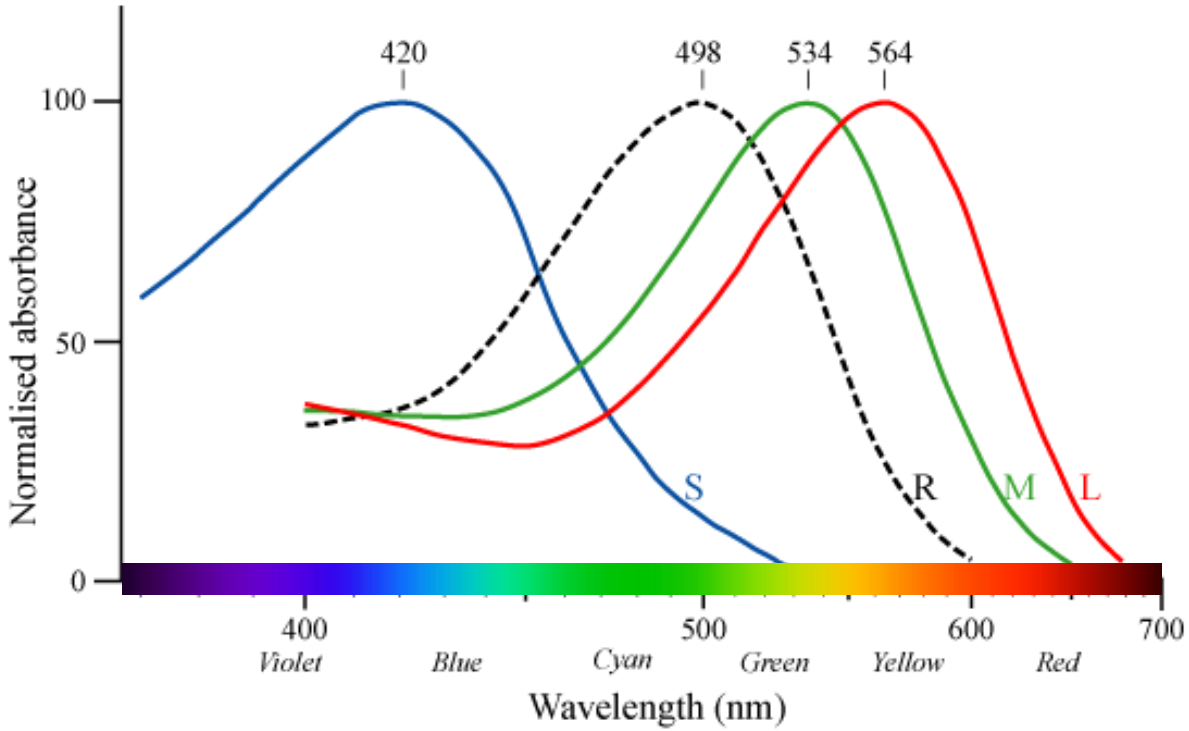
- Color sensing
  - Three types (L,M,S)
  - Caused by different proteins in the channel.
- Play major role when bright.
- Has lower sensitivity.
- One eye has 7,000,000.
- Clustered at fovea (中心窩).
- Fast Response.

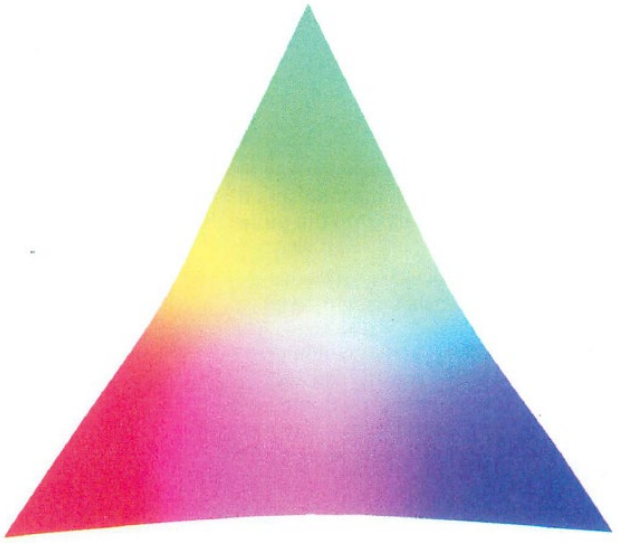


Cone



桿体細胞･錐体細胞／Rod cell & Cone cell





- Rod cell: black & white sensor. center = 498nm.

  Green Laser Pointer is the best for presentation.

- Cone cell:Three types

  S:420nm, M:534nm, L:564nm

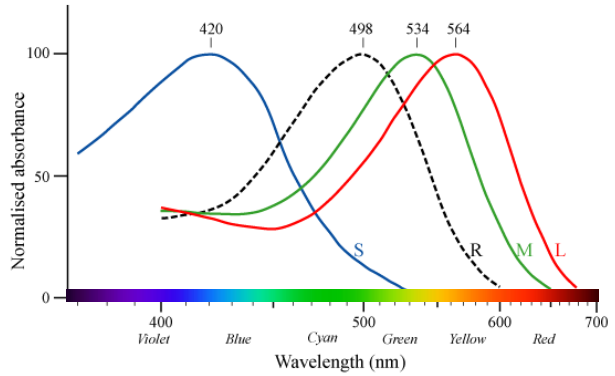
  Color perception is based on the combination of the three.

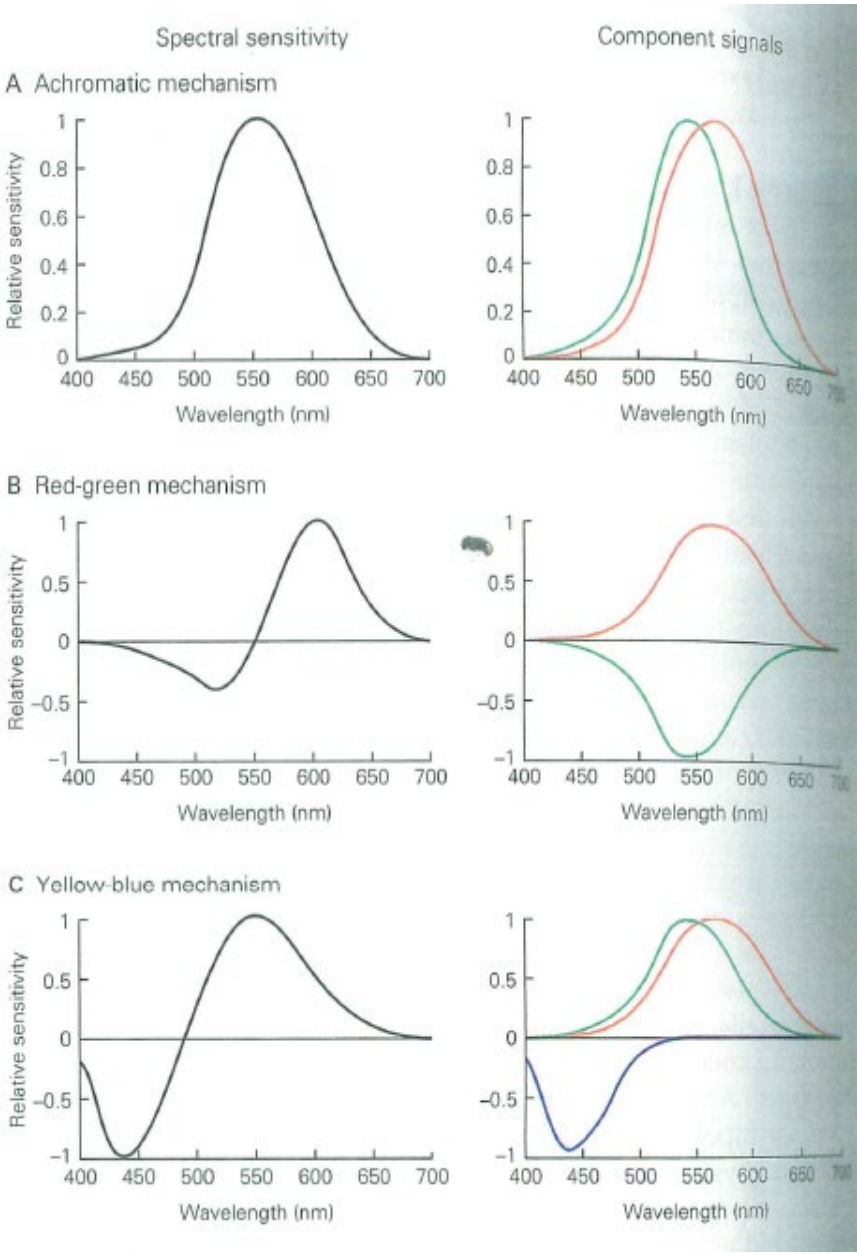
色知覚メカニズム／Brain color perception ≠ R,G,B

Take differentials and compose another 3 axis.

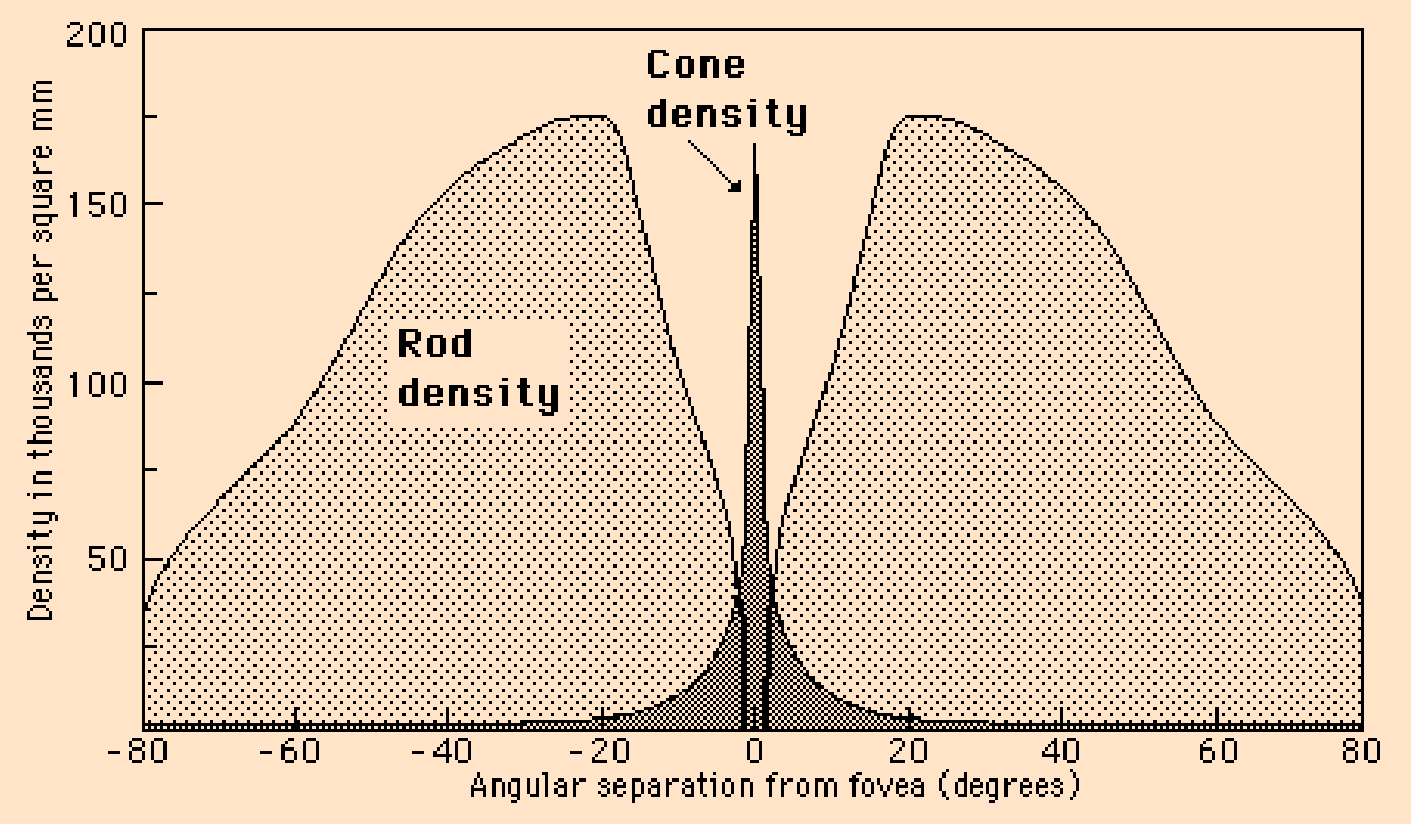
- L+M（+S）（Blightness）
- M-L（Red-Green axis）
- S -(L+M)(Blue-Yellow axis）

- They are the basis of “complementary color”(補色)
  - there is no such thing as “reddish green”



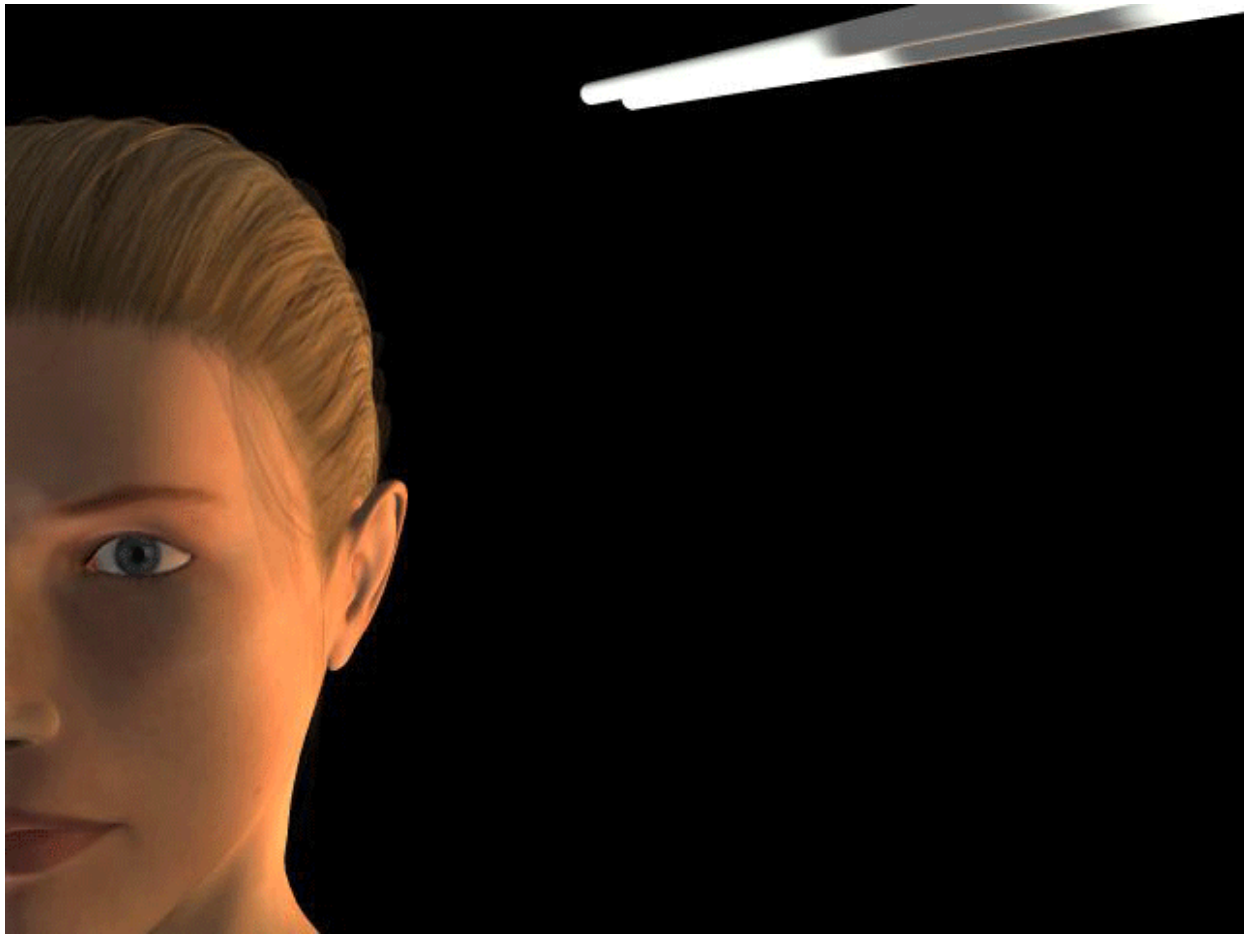


桿体・錐体の分布／Distribution of the cells.



- Cone cell = central vision (中心視)
  - ✓Peripheral vision is almost color blind
- Rod cell = peripheral vision (周辺視)
  - ✓You can see stars better by peripheral vision

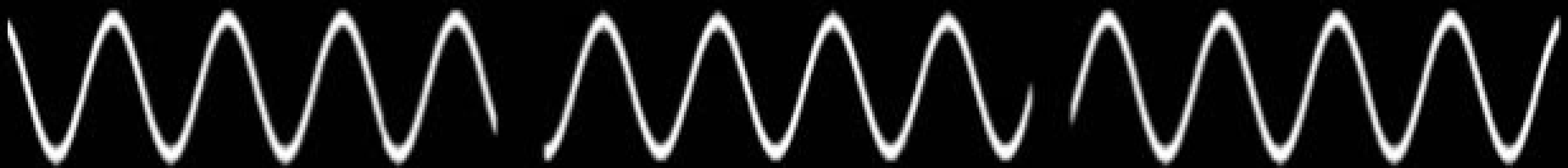
周辺視野への情報呈示（1）



●周辺視野への呈示は環境に覆われている事，すなわち臨場感を呈示するために不可欠

●周辺視野のほうが時間的解像度は高い⇒運動呈示

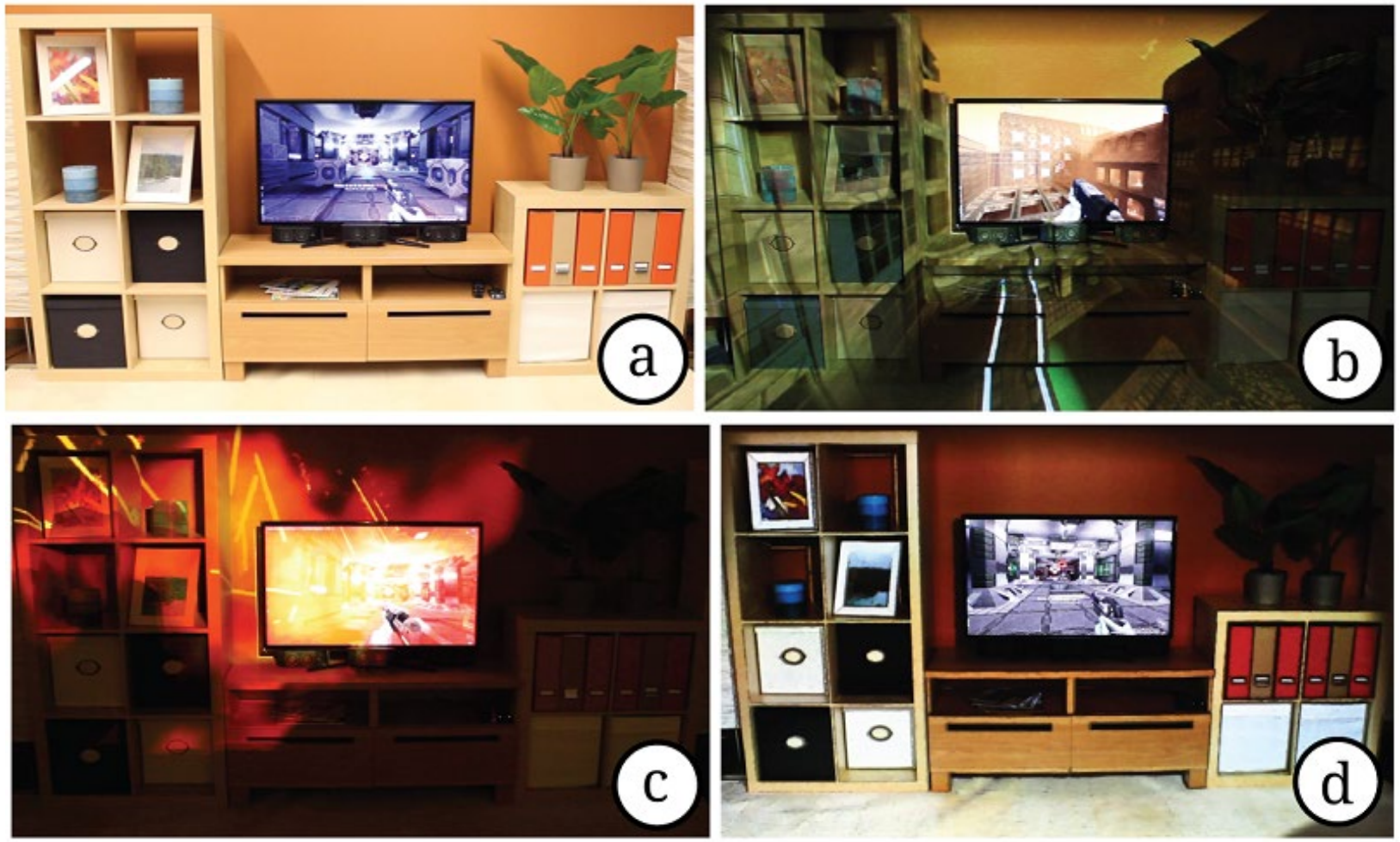
周辺視野への情報呈示(1)



We prepare three luminance wave patterns, each of which has a different phase lag (0°, 120°, 240°).

Y. Okano, S. Fukushima, M. Furukawa, H. Kajimoto, "Embedded Motion", SIGGRAPH Asia 2010, Poster, Korea.

周辺視野への情報呈示(2) IllumiRoom



Brett R. Jones: IllumiRoom: Peripheral Projected Illusions for Interactive Experiences,CHI2013

http://www.youtube.com/watch?v=re1EatGRV0w

Augmenting the Field-of-View of Head-Mounted Displays with Sparse Peripheral Displays, CHI2016
Robert Xiao, Hrvoje Benko

HMDに低解像度のLEDを並べて周辺視野を拡張する.

(CHI2018)ExtVision: Augmentation of Visual Experiences with Generation of Context Images for a Peripheral Vision Using DNN
Naoki Kimura, Jun Rekimoto

- 周辺視野へのコンテンツ拡張をニューラルネットワークによって行う.

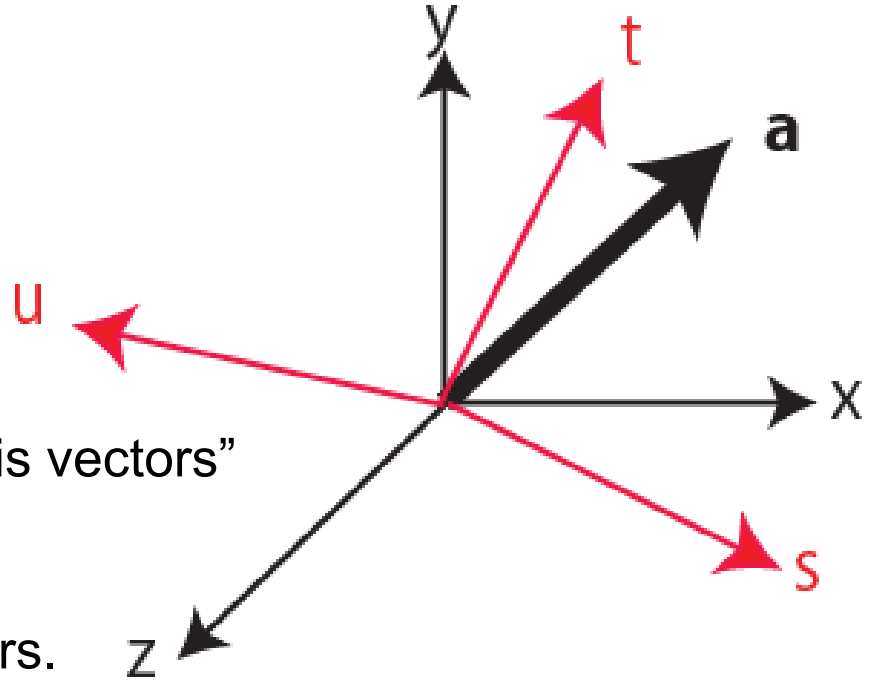
色知覚は空間解像度が低い
Color process has very low resolution

Flowers

Black & white

Color only

RGB and YCbCr(YUV)



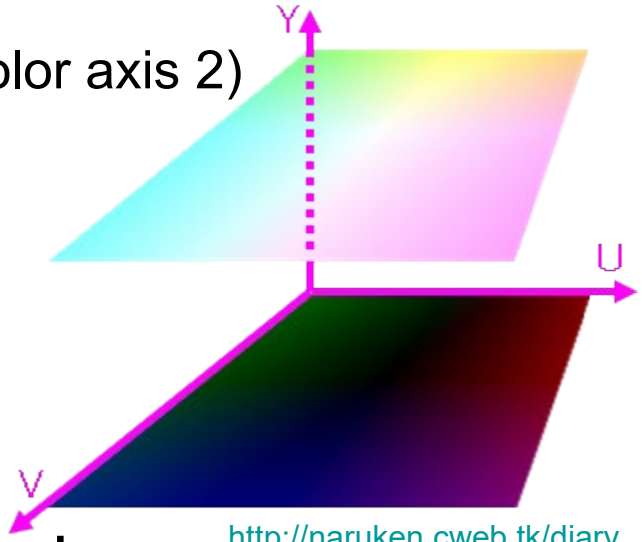
RGB: corresponds to 3 cone cells.

Mathematics tells us...
ANY 3 independent vectors can be “basis vectors”
(orthogonality not required)

RGB = One type of 3 independent vectors.
There are infinite ways.

YCbCr (YUV): Y(blightness), Cb(color axis 1), Cr(color axis 2)
Similar to brain’s color perception.

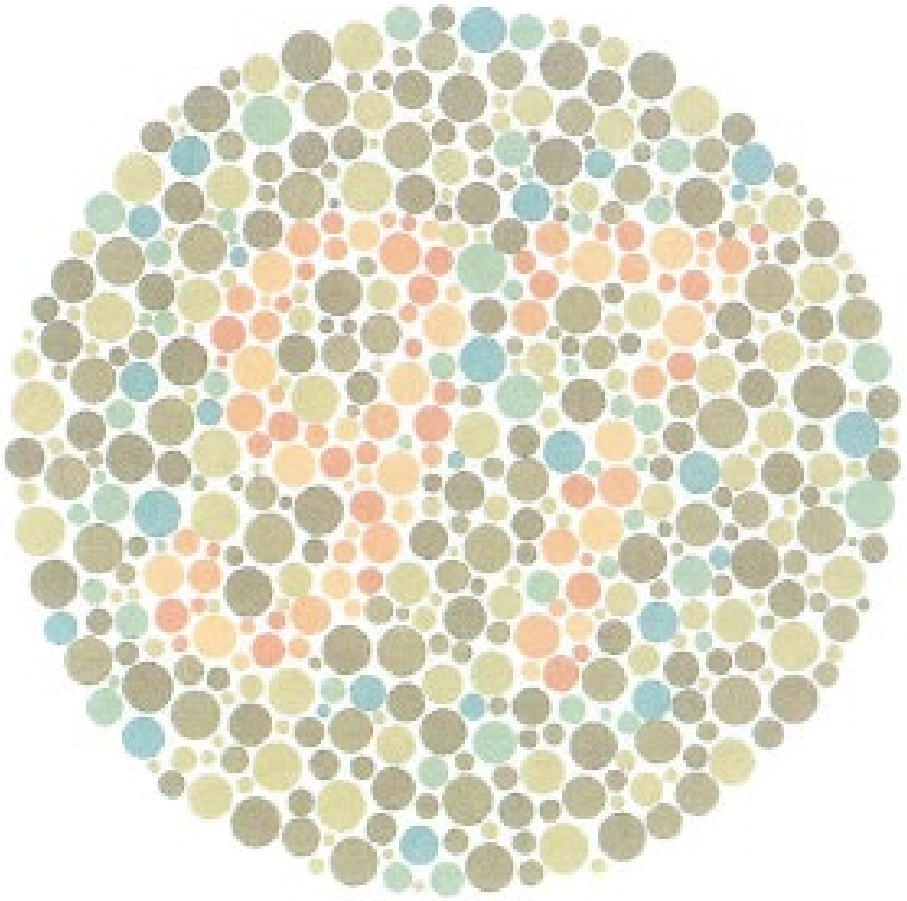
$$Y = 0.257R + 0.504G + 0.098B + 16$$
$$Cb = -0.148R - 0.291G + 0.439B + 128$$
$$Cr = 0.439R - 0.368G - 0.071B + 128$$



Used in JPEG image compression

http://naruken.cweb.tk/diary/diary.cgi?key=ircf2007

色盲／Color blindness



- One to three types of cone cells lacks.

(CHI2018) ChromaGlasses: Computational Glasses for Compensating Colour Blindness
Tobias Langlotz, Jonathan Sutton, Stefanie Zollmann, Yuta Itoh, Holger Regenbrecht

ChromaGlasses: Computational Glasses for Compensating Colour Blindness

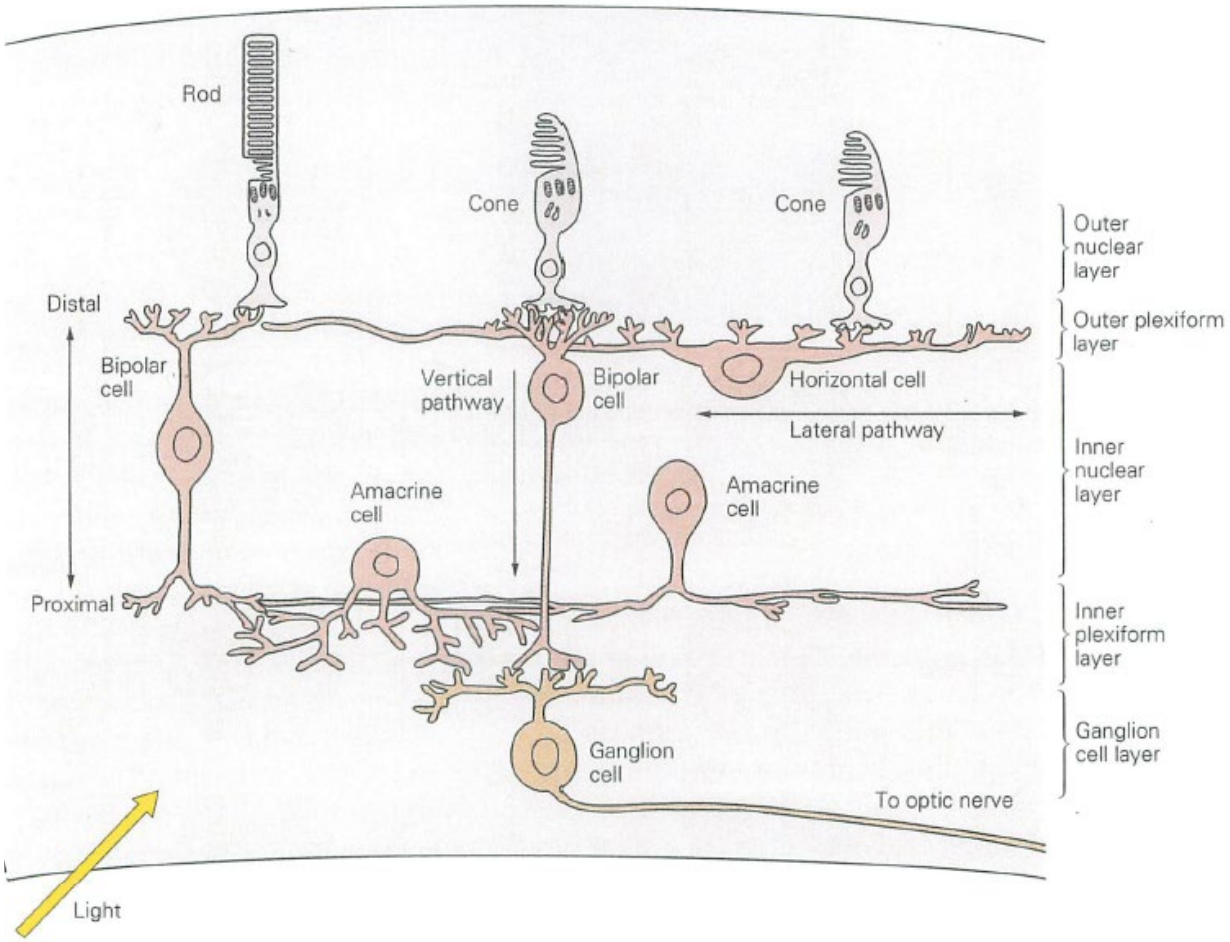
Tobias Langlotz, Jonathan Sutton, Stefanie Zollmann, Yuta Itoh, Holger Regenbrecht

Accepted for ACM CHI 2018

UNIVERSITY of OTAGO
Tokyo Tech

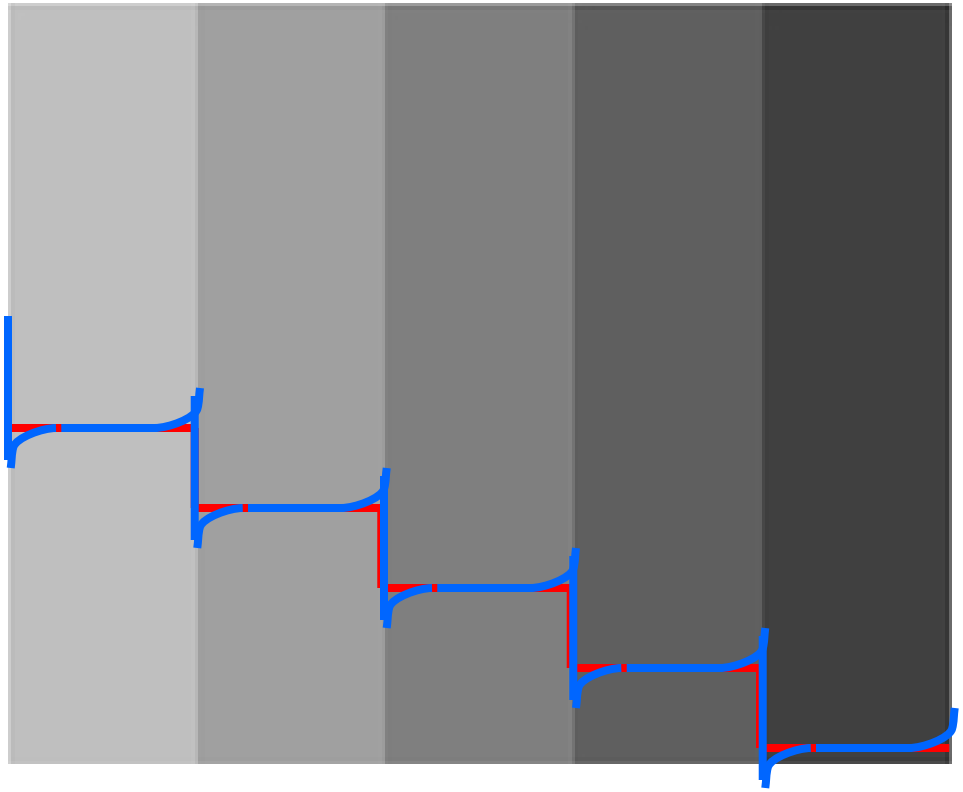
- 色盲の人が色を区別できるようにするARシステム.

網膜での情報処理／Retinal image processing



- Sensors: About 200,000,000 / eye
- Nerve axons to the brain: about 1,000,000 / eye
- Retinal image process: 200 cells⇒1 output

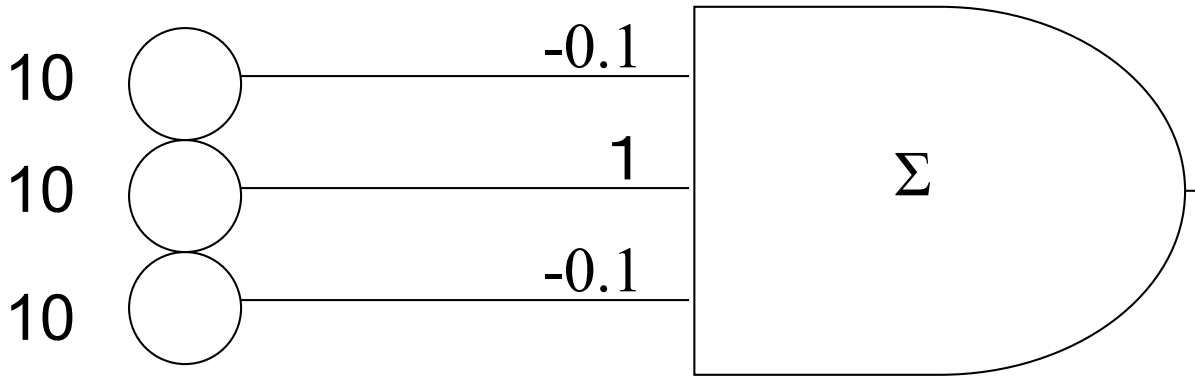
Key to the retinal process: “Mach belt” illusion



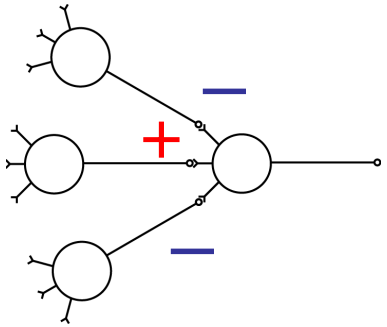
Subjective perception

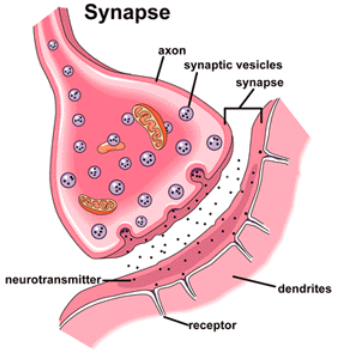
Physical value

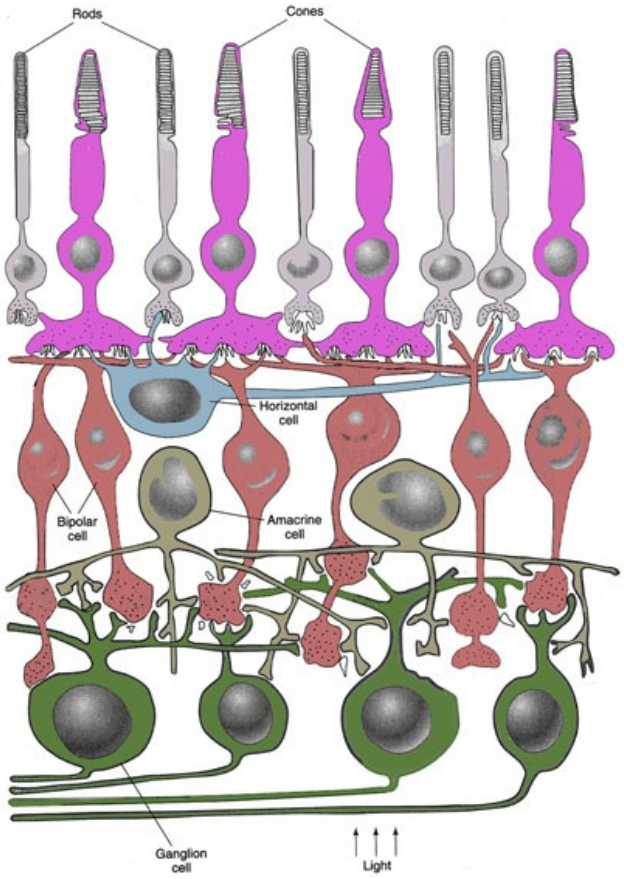
側抑制／Lateral inhibition（1/3）



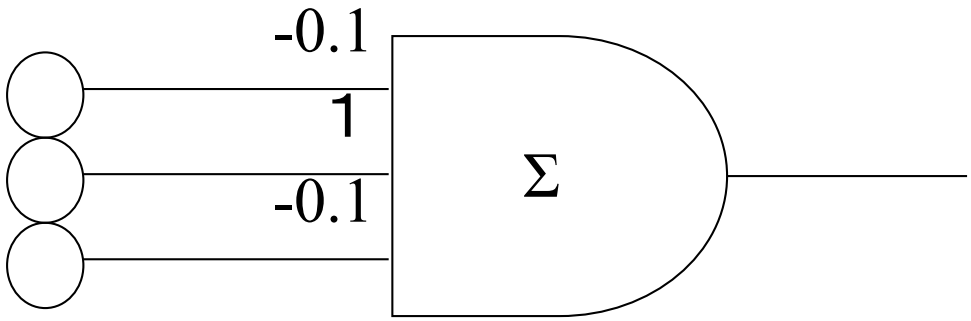
- Synaptic calculation
- Central input: +(plus)
- Surrouinding input: -(minus)

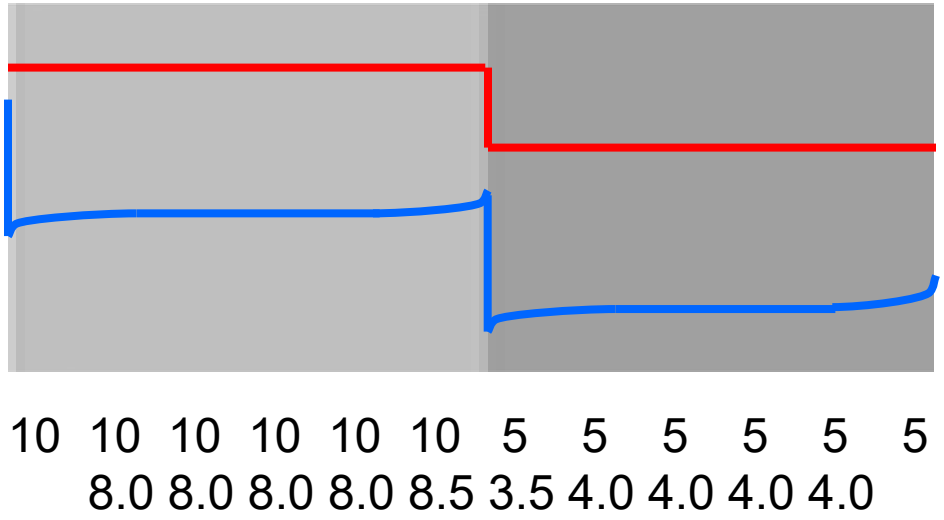




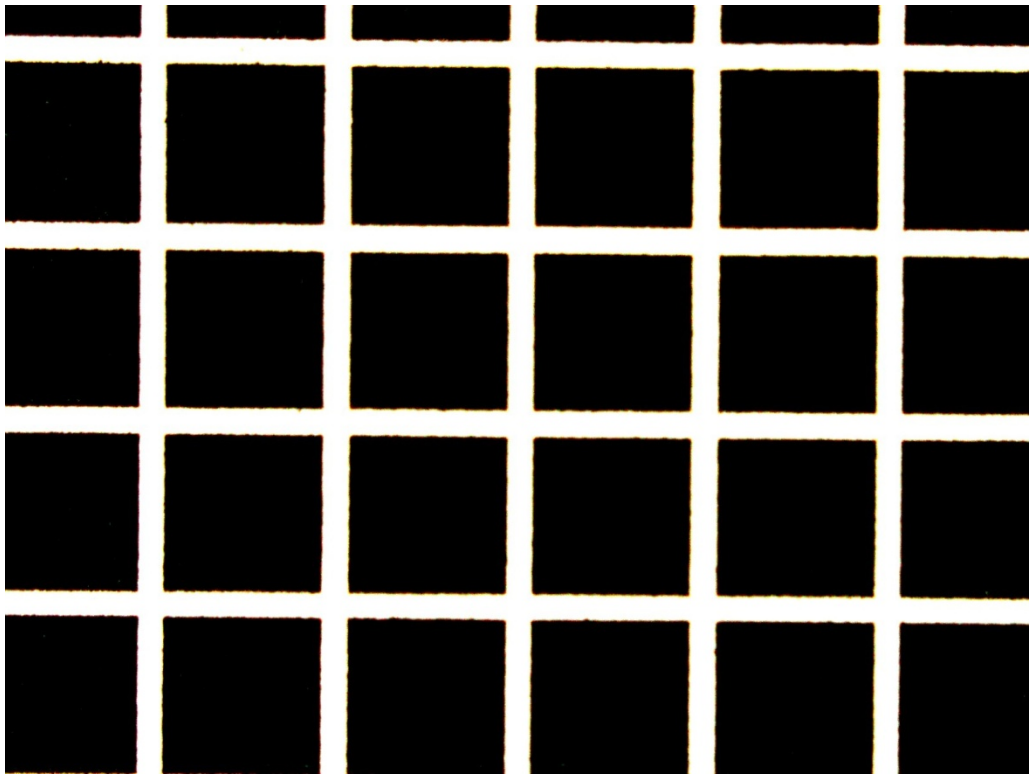


側抑制／ Lateral inhibition（2/3）





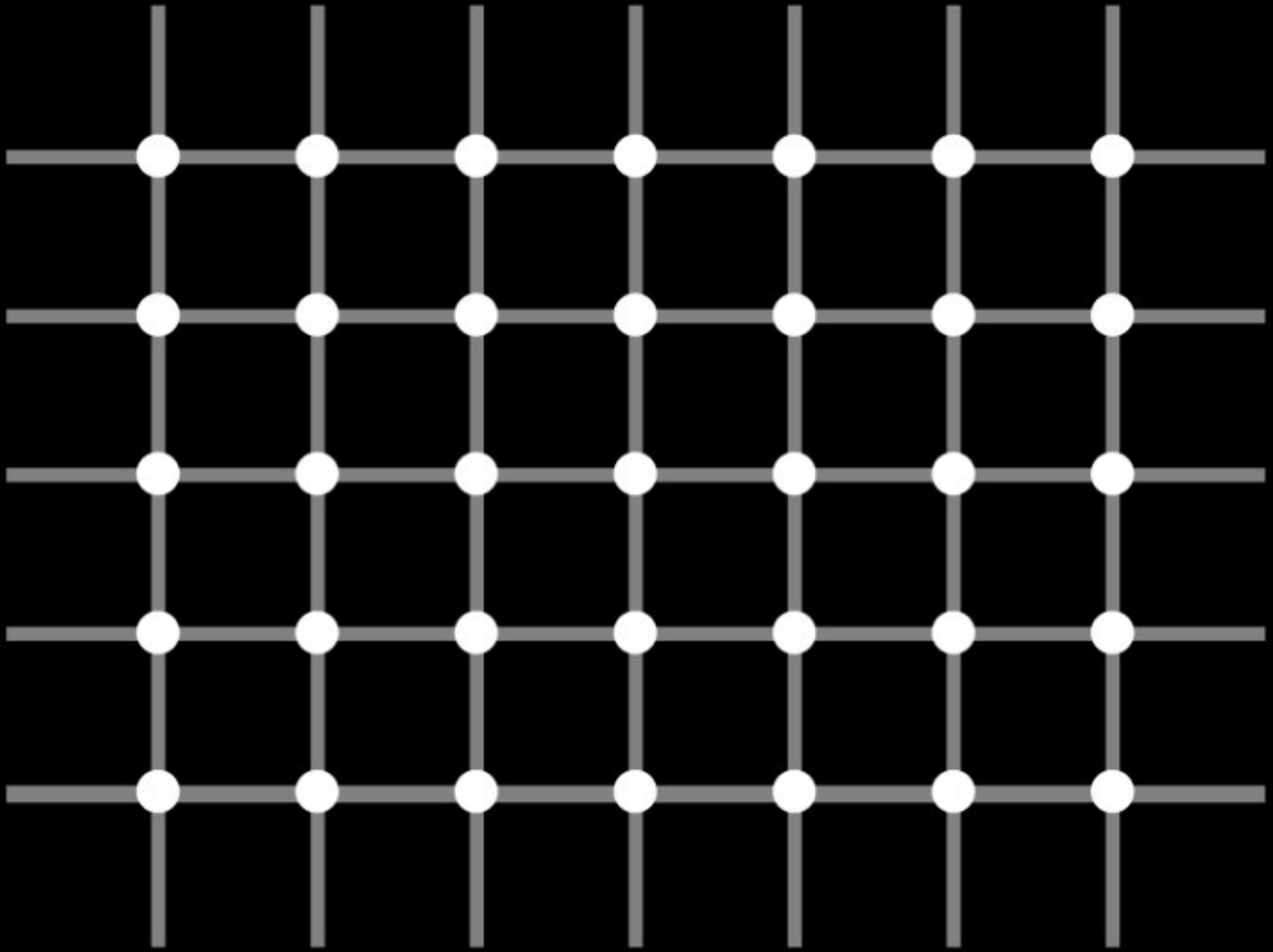
側抑制／ Lateral inhibition(3/3):
Harman grid illusion



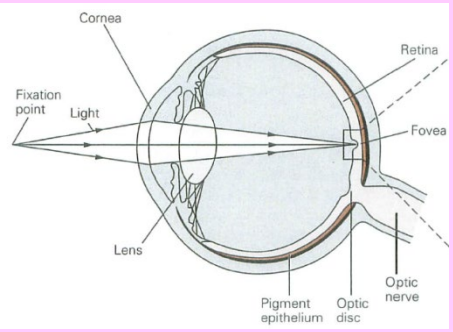
(1) 周辺視／peripheral vision: the cross point becomes dark, due to lateral inhibition

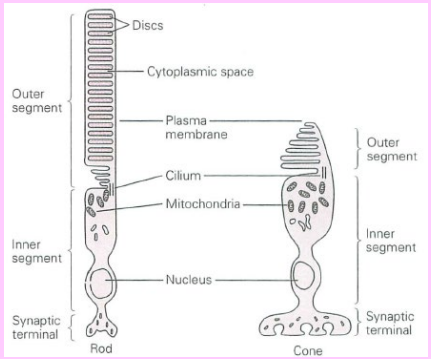
（2）中心視／central vision: No such effect

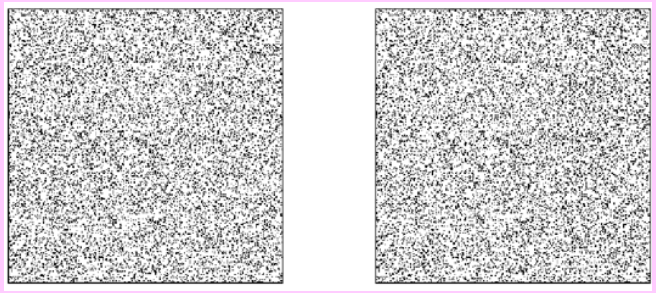
⇒The peripheral vision “compress” larger field.

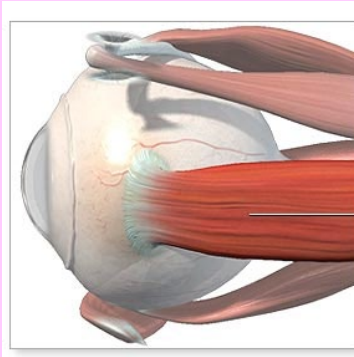


TODAY's TOPIC





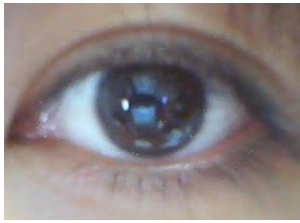




- 目の構造／Eye structure
- 目のセンサ／ Eye sensors
- 奥行き知覚／Depth perception
- 眼球運動／Eye movement

奥行き知覚の鍵／Depth perception cues

- 単眼性／With single eye
  - 経験／Experience
  - 焦点調節／Accommodation
  - 運動視差／Motion Parallax

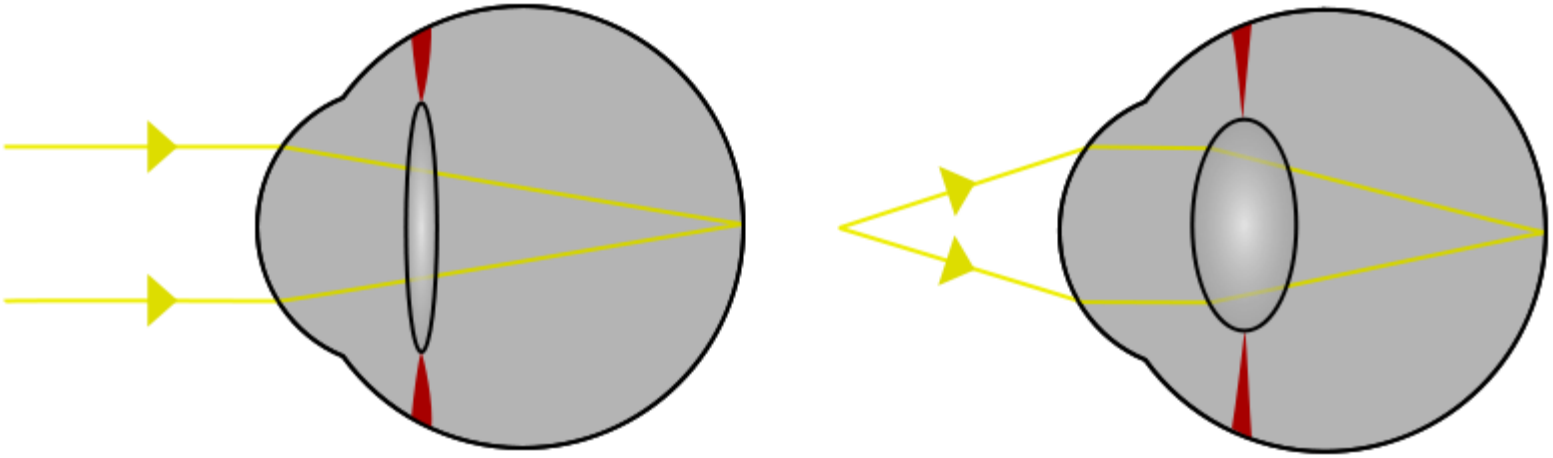


- 両眼性／With two eyes
  - 輻輳角／Vergence eye movement
  - 両眼視差／Binocular disparity

Depth cue(1) 経験／Experience

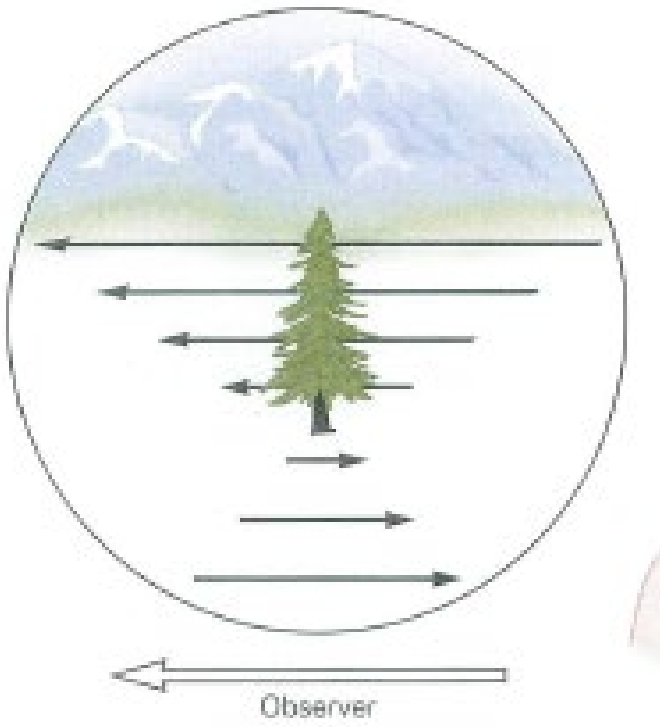
- 重なり（遮蔽）／Occlusion
  - Occluded (shielded) objects are more distant than occluding (shielding) objects.
- 遠近法／Perspective
  - Near= Large, Bottom, Clear
  - Far = Small, Top, Blur
- 記憶／Memory
  - Knows the physical size

Depth cue(2) 焦点調節／Accommodation: Changing the power of the lens



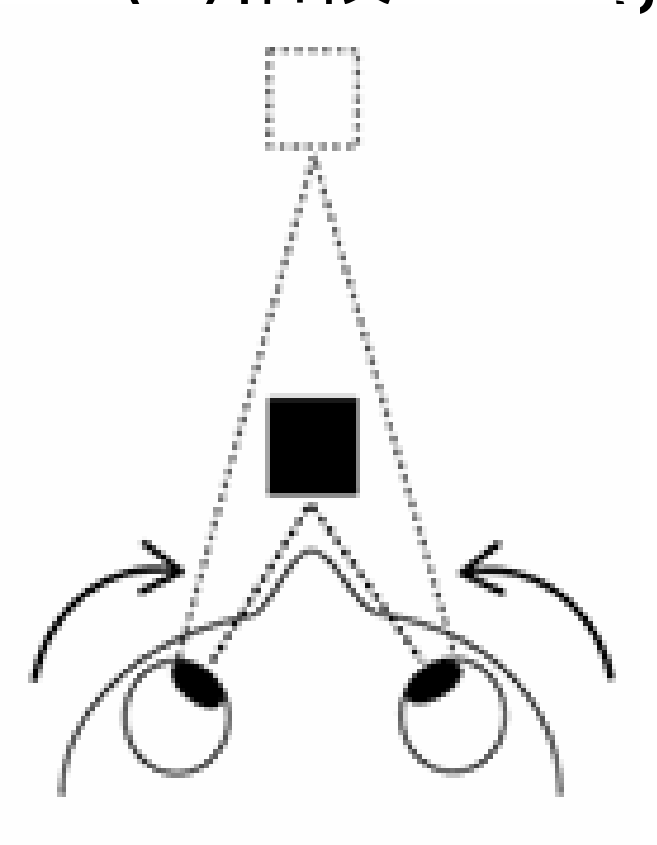
- Automatic focus adjustment by lens deformation
- The adjustment itself works as depth cue.
  - works at close range.

Depth cue(3) 運動視差／Motion Parallax



- When the head moves...
  - Near: Moves in the opposite direction.
  - Far: Does not move, or moves in the same direction.

Depth cue(4)輻輳／Vergence eye movement



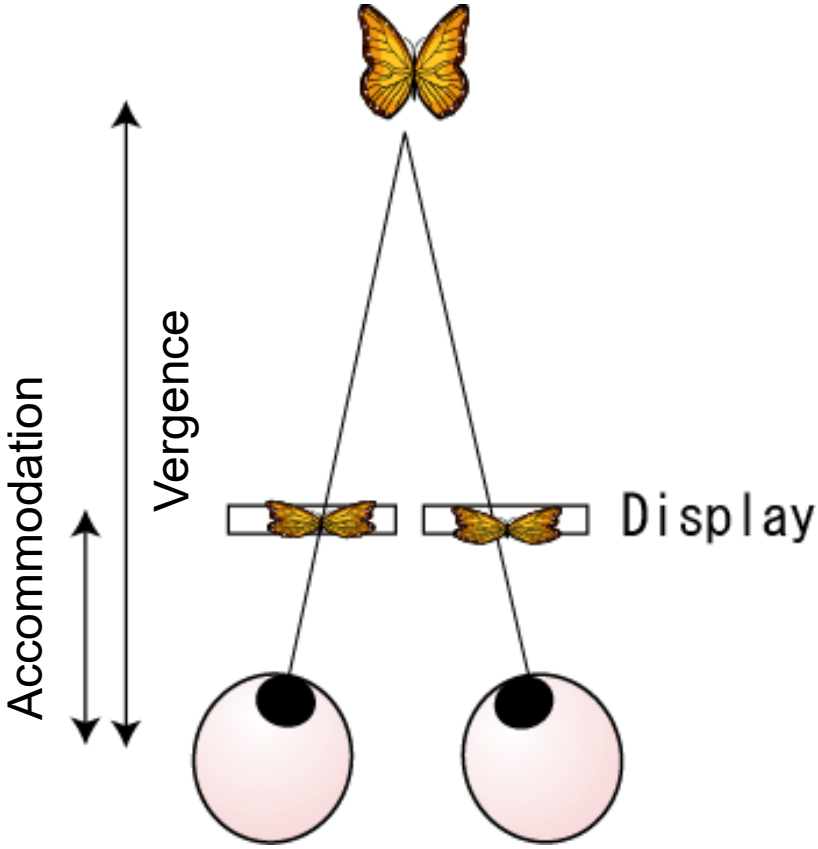
- The eyes converge (move inward) and diverge (move outward) by distance.

輻輳 - 調節矛盾の問題
Vergence-accomodation conflicts

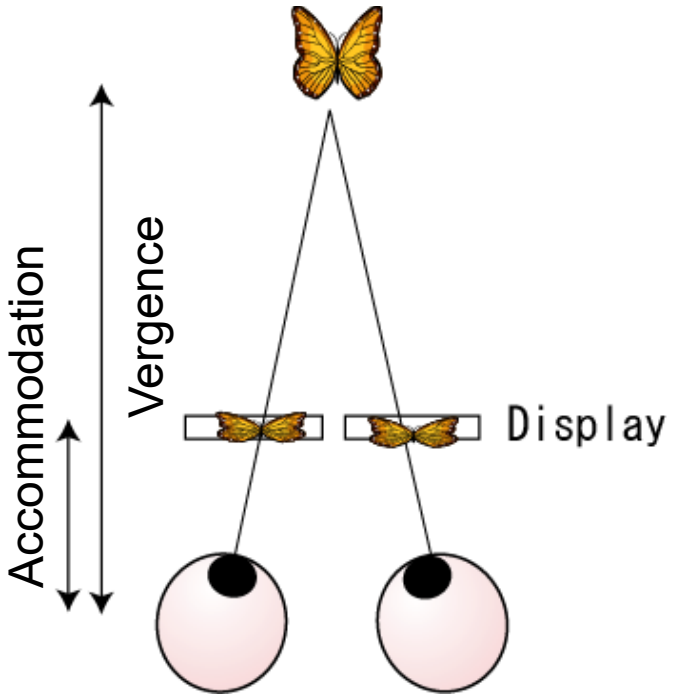
- Accommodation & vergence are slightly coupled.

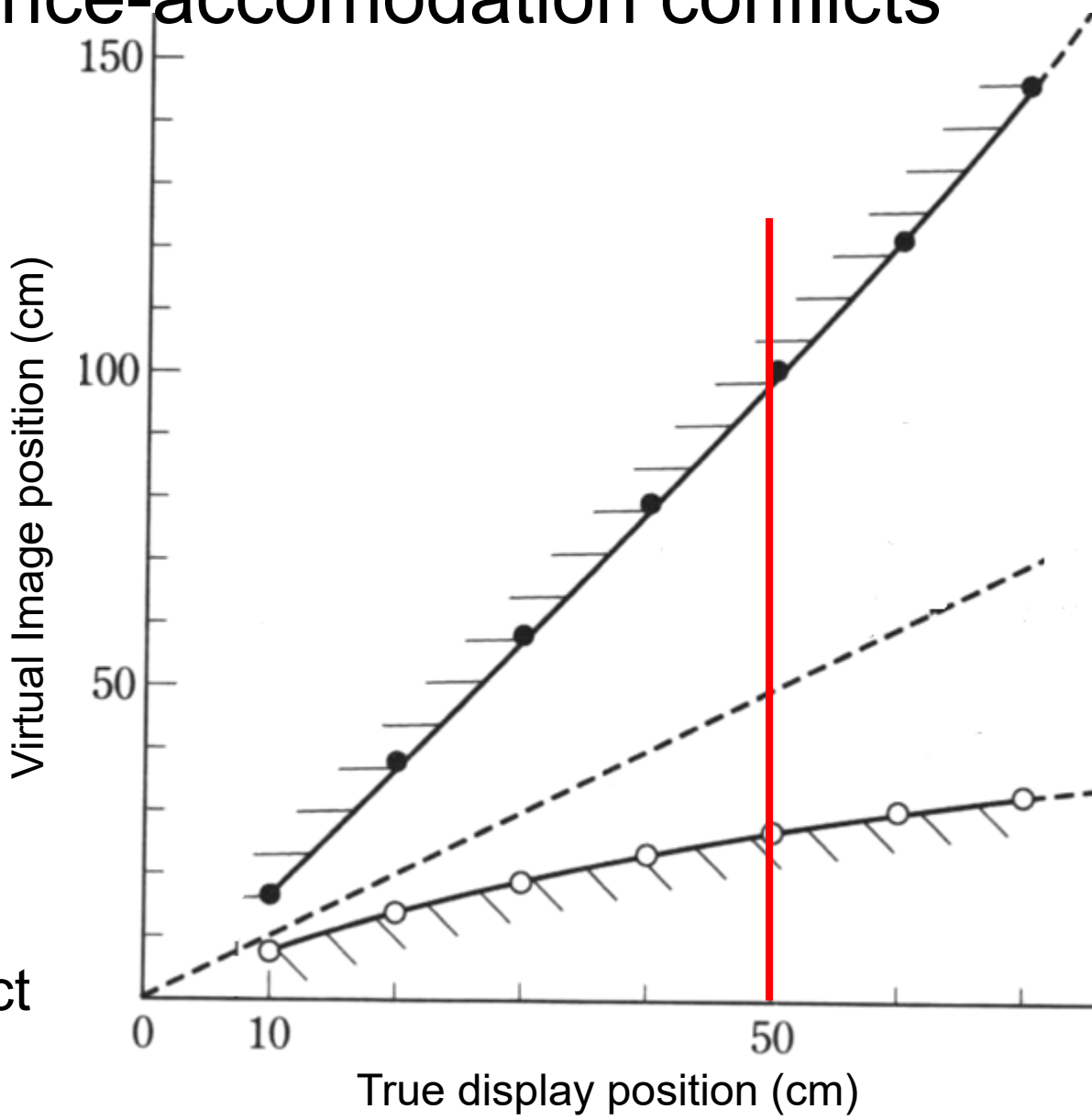
- Stereo display problem:
  - Accomodation=constant
  - Vergence = variable

  ⇒Severe Fatigue



輻輳 - 調節矛盾の許容範囲
Tolerance of vergence-accomodation conflicts

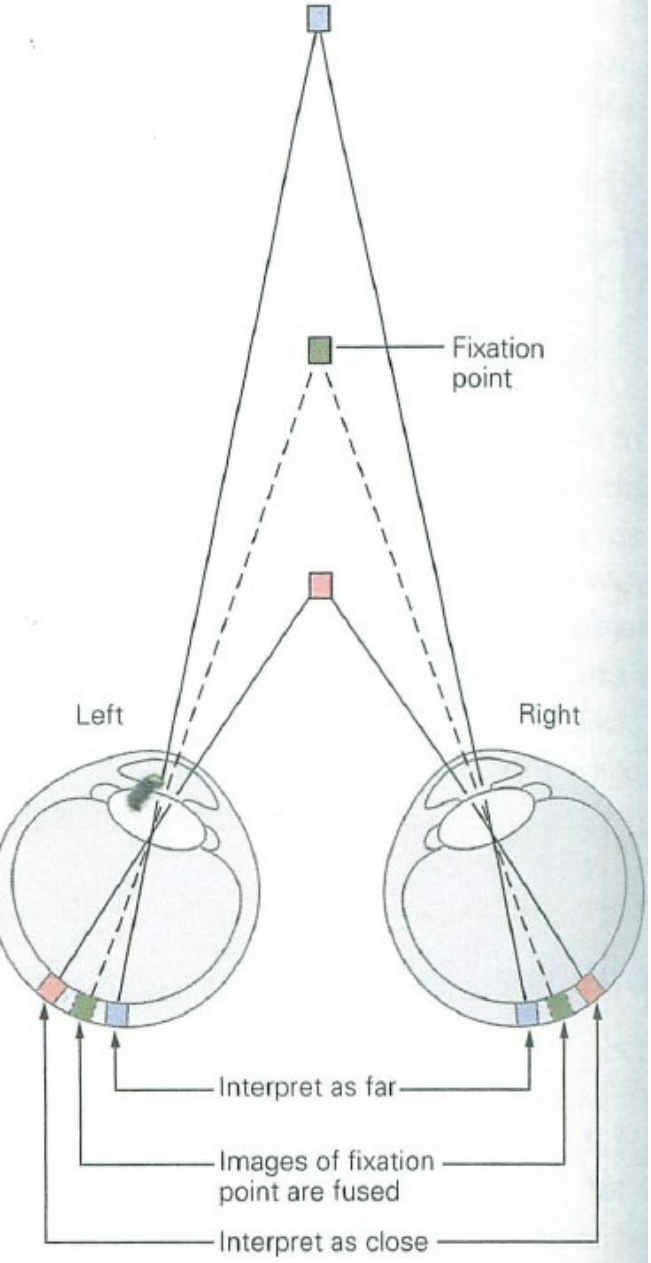


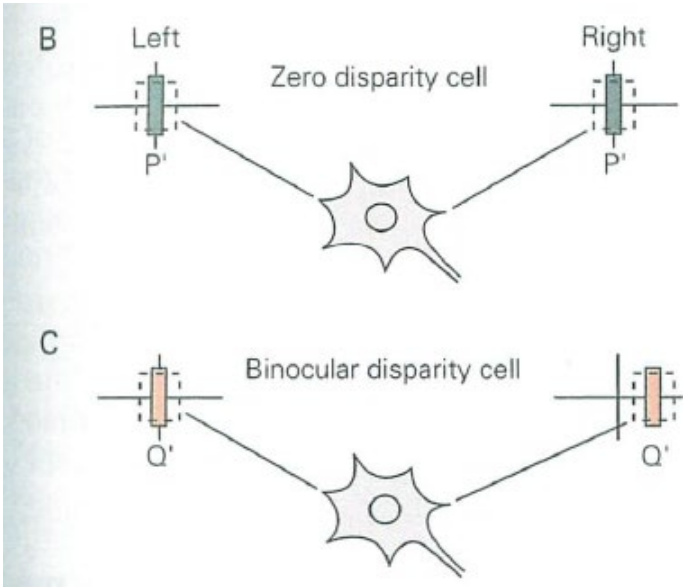


(ex) Display with 50cm away from the eyes:

25cm to 1m virtual object can be displayed.

Depth cue(5) 両眼視差／Binocular disparity

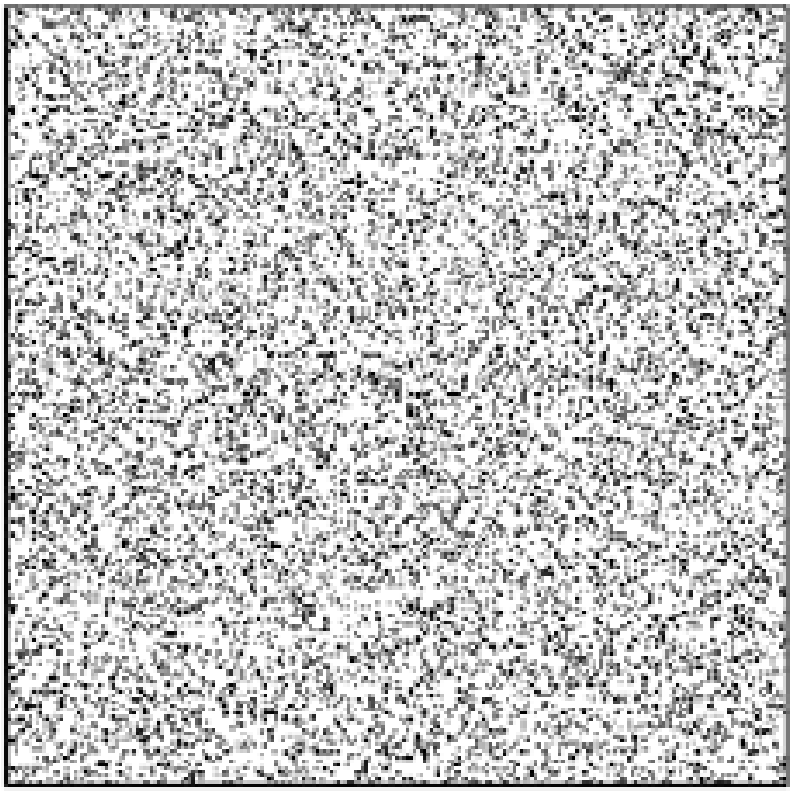


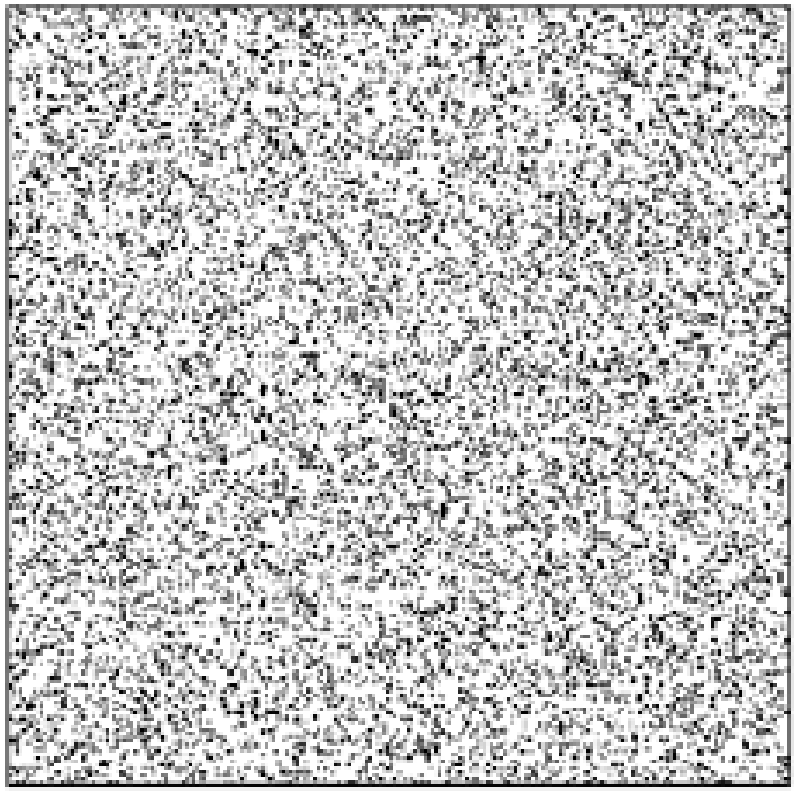


- Dispality = image shift
  - Vergence: single point.
  - Binocular disparity: whole field of view.
- Most important for VR system

Stereogram

ランダムドット・ステレオグラム
Random dot stereogram (RDS)





- Proof of “pure disparity can be distance cue”.
  Before the RDS, “experience” was thought to play major role.
- Found and used during Vietnam War.

Novel Optical Configurations for Virtual Reality: Evaluating User Preference and Performance with Focus-tunable and Monovision Near-eye Displays

Robert Konrad, Emily Cooper, Gordon Wetzstein, CHI2016

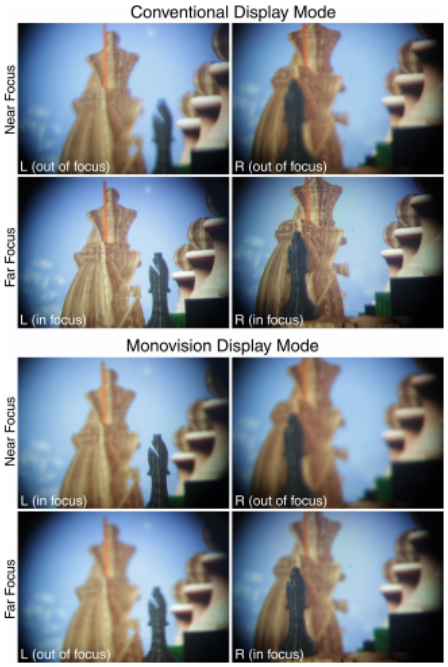
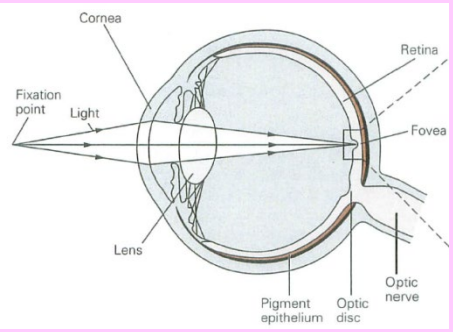
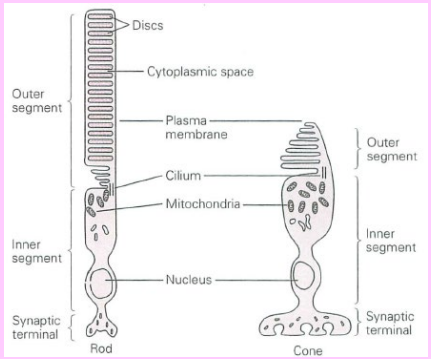


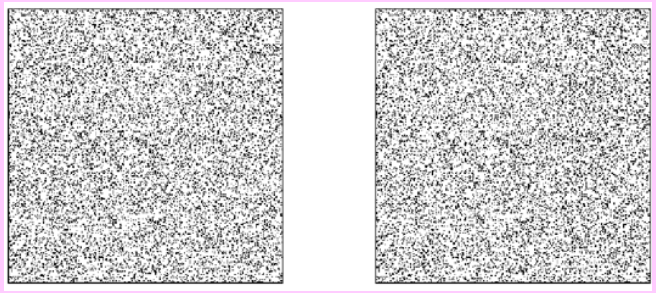
Figure 1. Focus-tunable near-eye display with different rendering modes. In the top panels, we illustrate via photographs how the images seen by each eye in a typical near-eye display are only focused properly when the eyes are focused at a relatively far distance (lower row). When the eyes focus near, to match objects simulated to be near, both eyes' images are blurry (upper row). Monovision is an alternative display mode where the lenses of the two eyes have different focal lengths, allowing for each eye to accommodate at a different distance. The bottom panels illustrate this mode. When the camera is focused relatively far, the left eye's image is out of focus and the right eye's image is sharp (lower row). When the camera is focused near, the relationship reverses. We asked whether this display mode could improve visual comfort and performance.

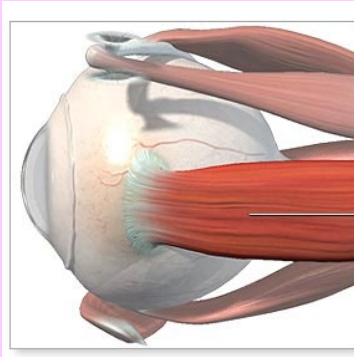
HMDの輻輳調節矛盾を解決する複数の手法を比較．液体レンズによって焦点距離を動的に変える方法がもっともよい結果だが，monovisionとして知られる，右目と左目をそれぞれ異なる焦点距離にしたもの（老眼への対処として知られる）でも近い結果を得た．

TODAY's TOPIC



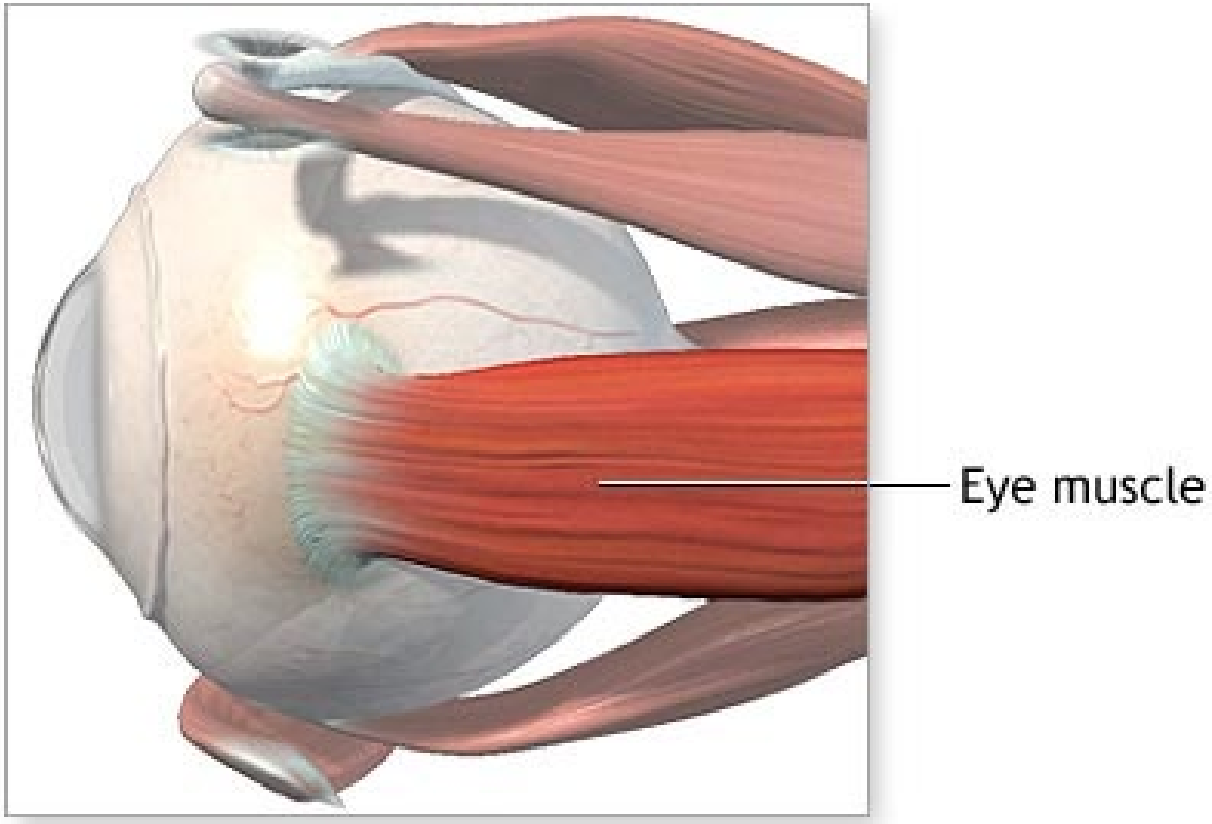






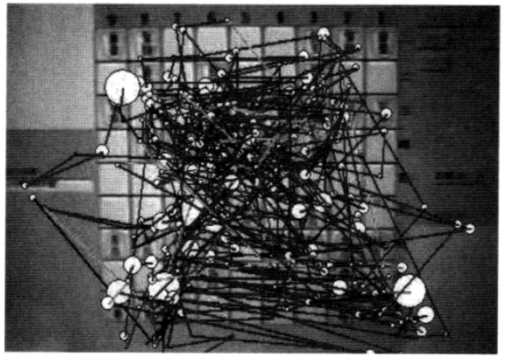
- 目の構造／Eye structure
- 目のセンサ／ Eye sensors
- 奥行き知覚／Depth perception
- 眼球運動／Eye movement

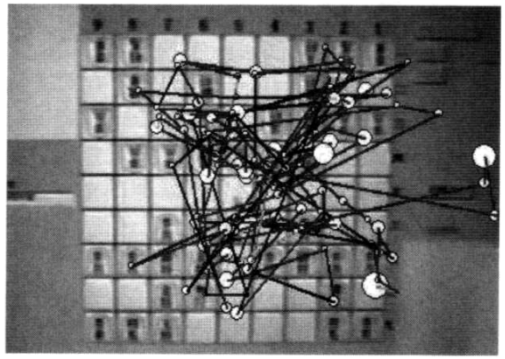
Eye movement

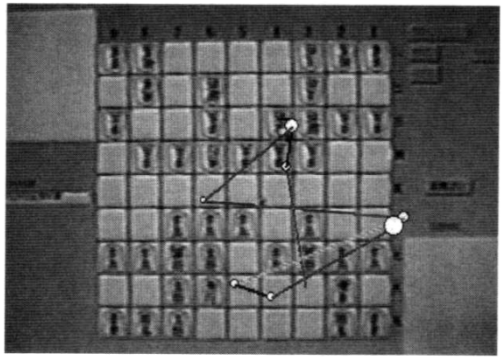


- 6 muscles (3 pairs) rotate eyes.

Eye movement: 入力手段として／As an Interface


初級者の視線の動き

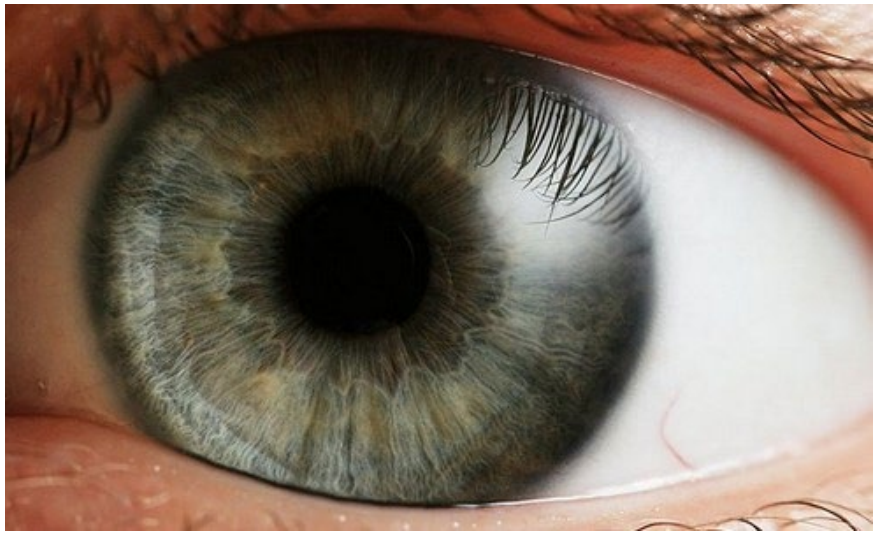

中級者の視線の動き


羽生さんの視線の動き

EyeSwipe: Dwell-free Text Entry Using Gaze Paths, CHI2016
Andrew T. N. Kurauchi, Wenxin Feng, Ajjen D. Joshi, Carlos H. Morimoto, Margrit Betke

眼球運動によるキーボード入力その2．単語の最初と最後の文字はしっかりと見る．途中の文字は近傍をかするように見る．あとは登録単語辞書を使う

How to measure Eye movement

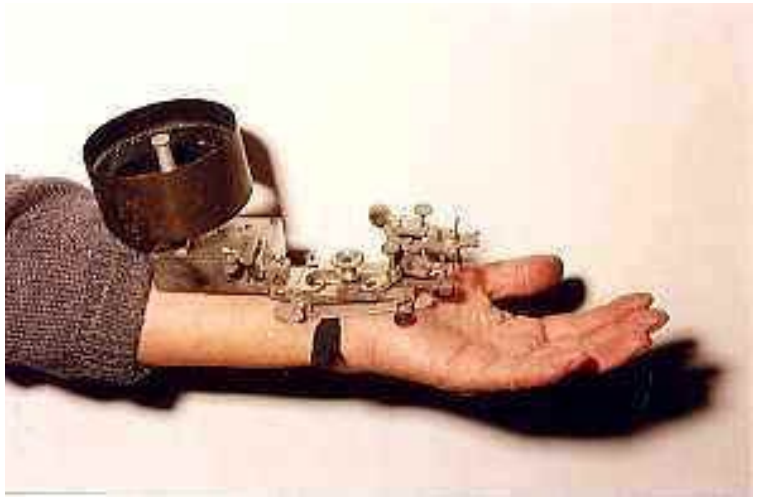


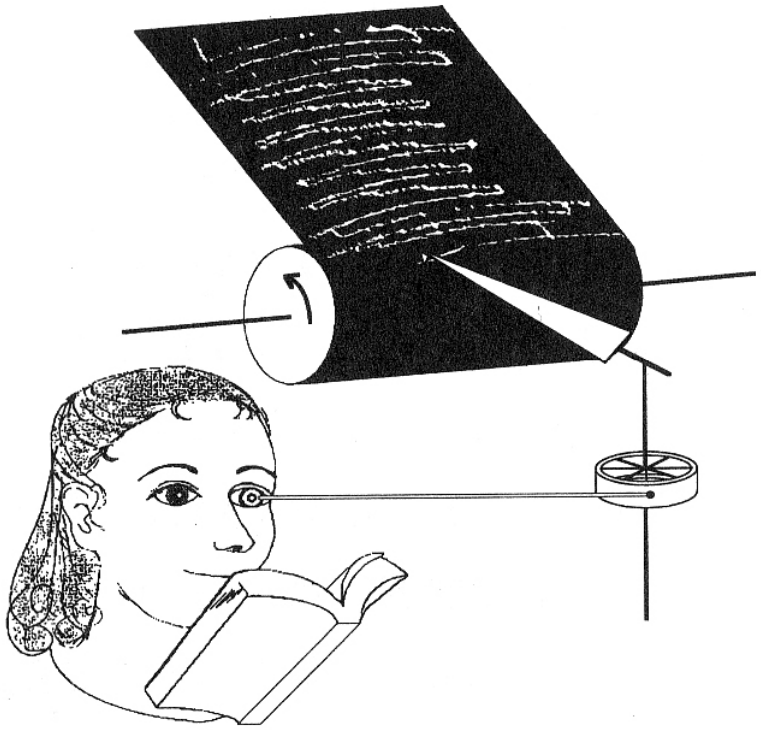
- アナログ測定／Analog measurement
  - コンタクトレンズ／Contact Lens
  - 眼底電位／ Electrooculography
  - 強膜反射／ Limbus Tracking Method

- 画像処理／Computer Vision
  - パッシブ・アクティブな方法／Passive・Active Methods

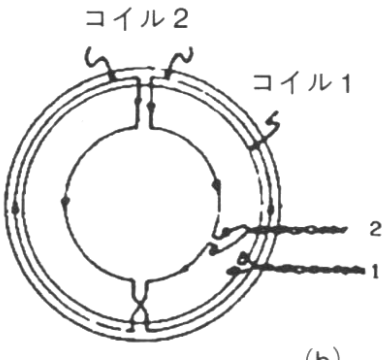
コンタクトレンズ／Contact Lens

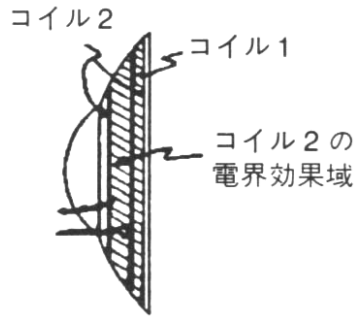
- カイモグラフ(Kymograph)



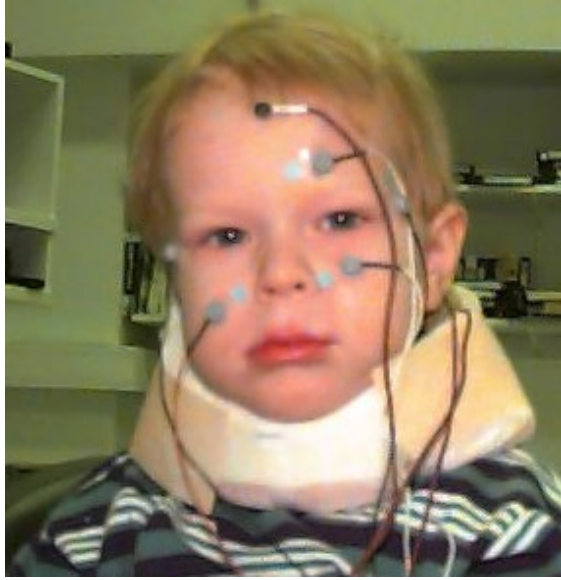


- バリエーション
  - オプティカル・レバー法
    コンタクトレンズに微小ミラー装着
  - サーチコイル法
    コンタクトレンズにコイルを埋込

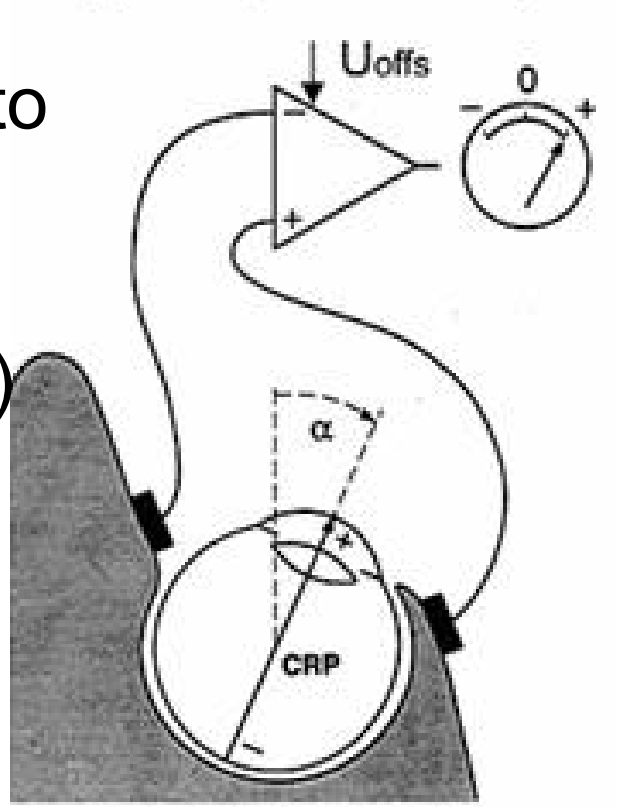




眼底電位
Electrooculography, EOG

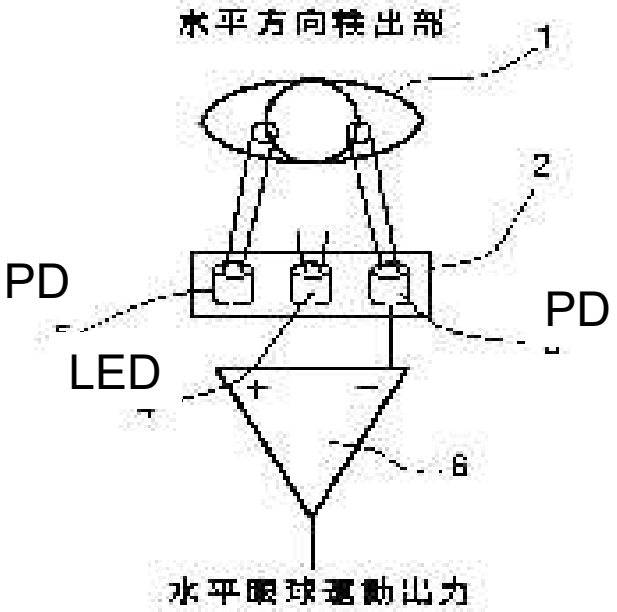


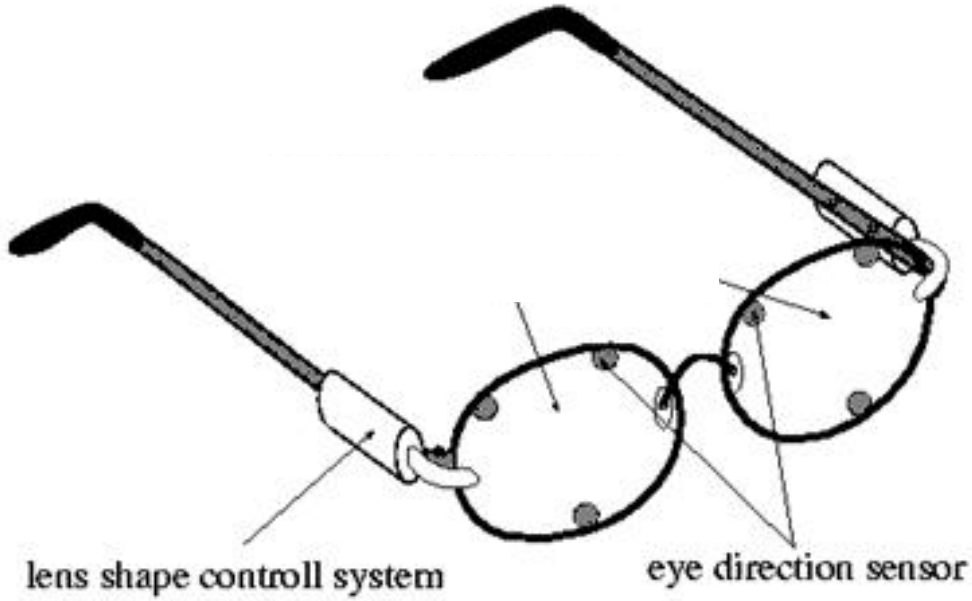
- Horny coat(角膜) has ~1mV positive voltage to Retina(網膜)
- Electrodes(電極) around eyes.
  ⇒Measured voltage is proportional to eye rotation.
- Has wide range (velocity, frequency)
- Accuracy not so good (1 deg~)



強膜反射／ Limbus Tracking Method

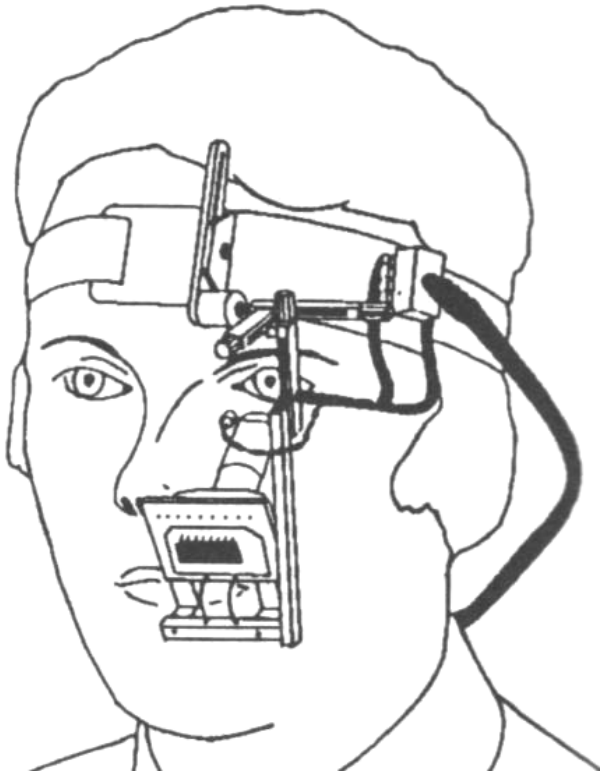
- Emit IR light to the eye, measure reflected light.
  黒目と白目の境界に赤外線照射。反射光計測
- Received light：White part > Black part.
- Good for horizontal eye motion.

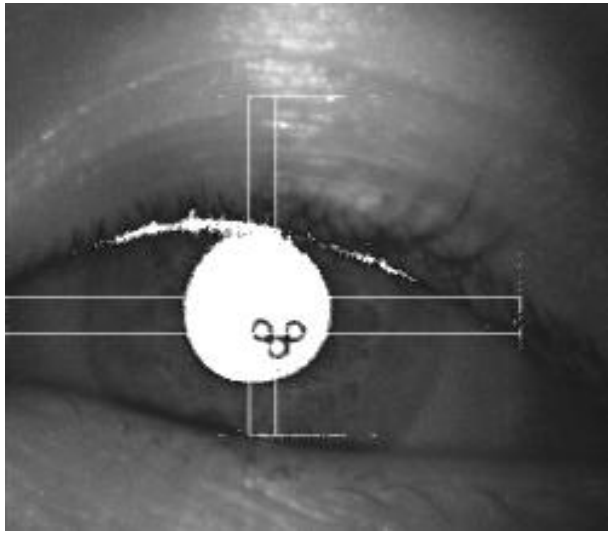




Computer Vision

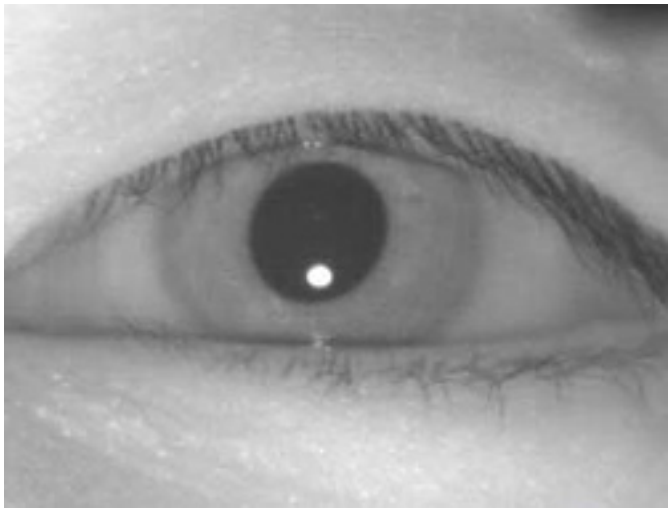
- Capture eye image.
- By image processing (pattern matching), eye center is calculated.
- Reflesh rate = video rate.



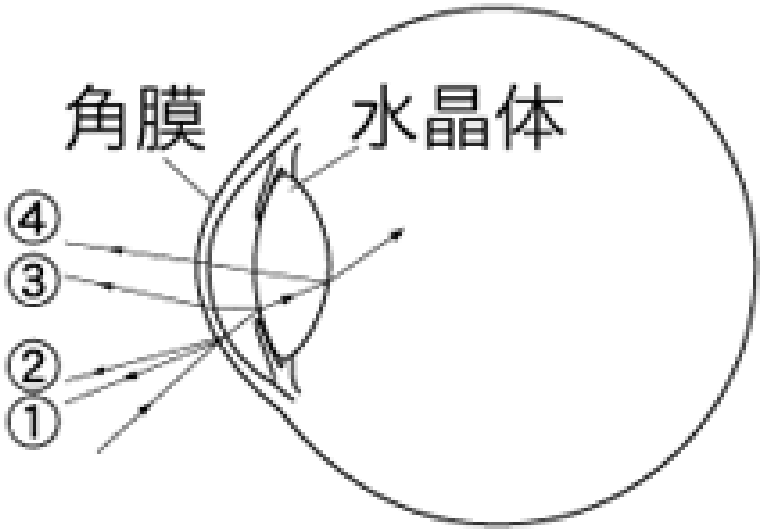


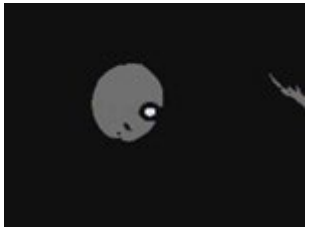
角膜反射／Reflection at Horny Coat

- 点光源の角膜照射時に現れる角膜反射像（プルキニエ像）から眼球運動を計測

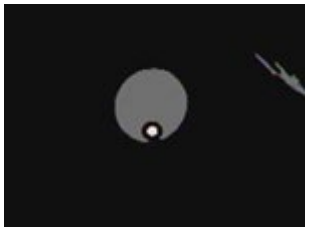


- ビデオカメラで撮影⇒画像処理
- 瞳孔中心との相対位置を使う

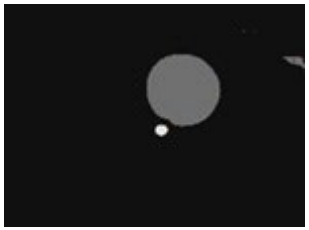




右向き



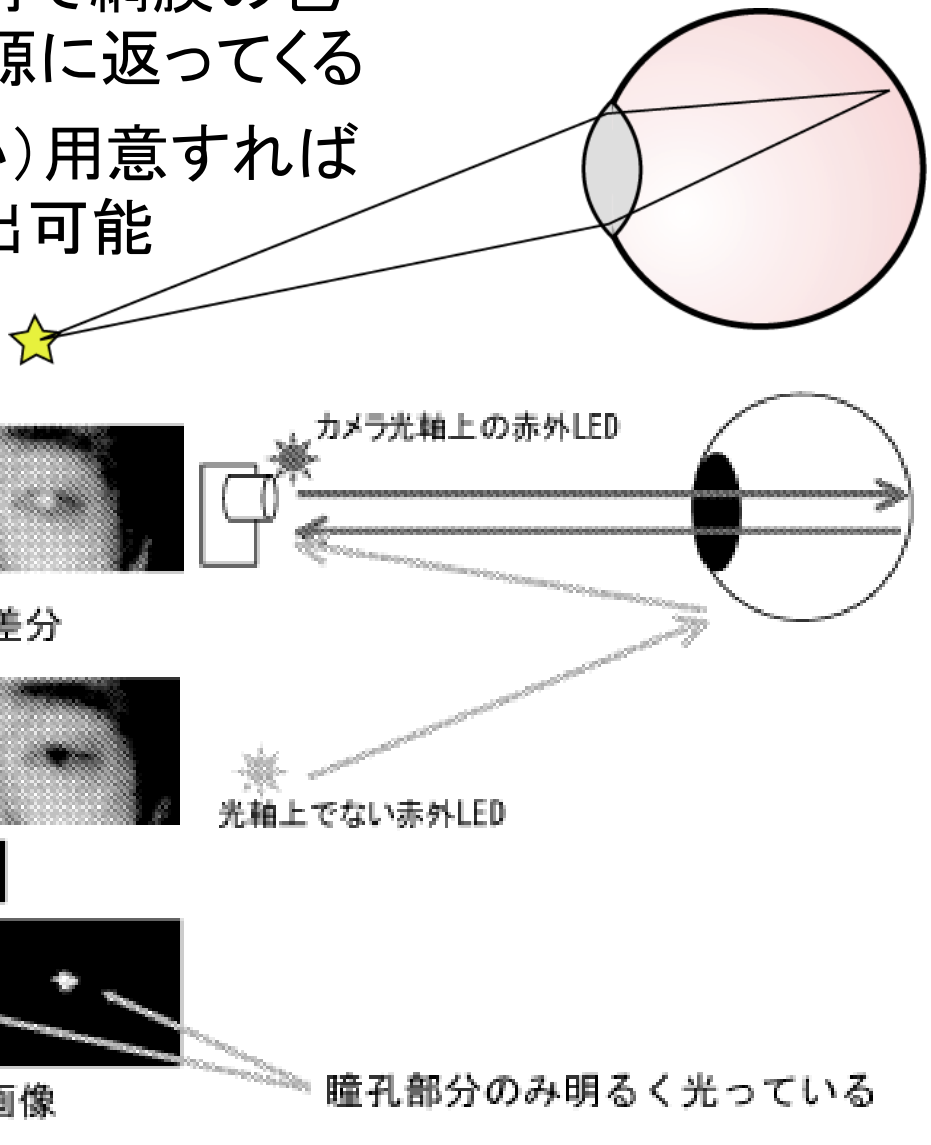
前向き



左向き

赤目現象の利用／Red-eye Effect

- 目のレンズによる再帰性反射で網膜の色（血管）が反射する現象．光源に返ってくる
- 光源を2種類（同軸上か否か）用意すれば差分画像として瞳孔だけ検出可能

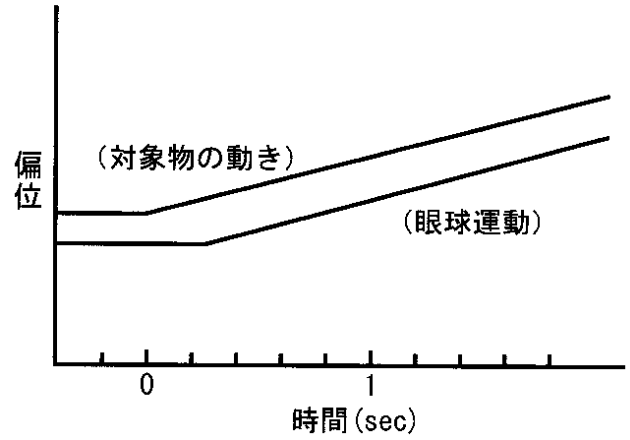


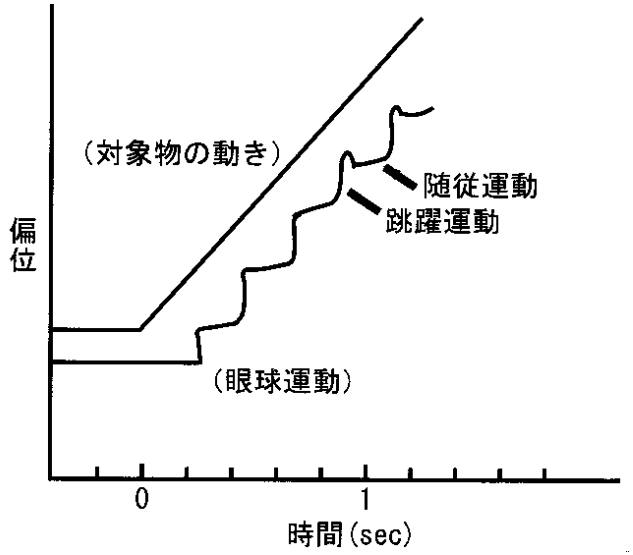
眼球運動の種類／Eye movements

- スムーズパースート（滑動性眼球運動）／Smooth Persuit
  - Follow slow movement of small dots. Voluntary (conscious)

- サッケード（跳躍性眼球運動）／Saccade
  - Stepwise movement
  - Motion start is voluntary and involuntary.
  - During motion,
    - You cannot stop (involuntary)
    - Visual acuity drops.

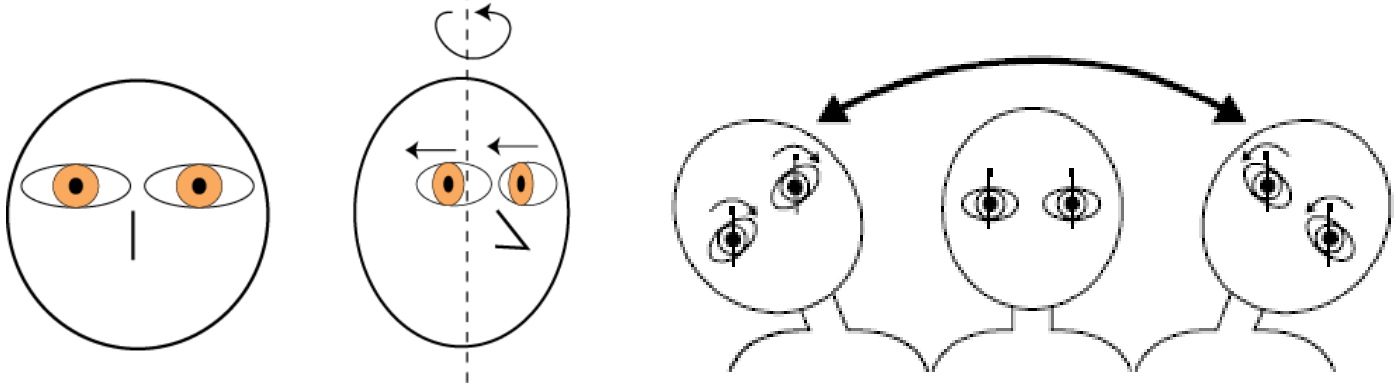
- 固視微動／Miniature eye movement
  - Very small vibration. 30～100Hz.
  - Reflesh the image on the retina.
    - Anesthetisation of muscles⇒No visual image.



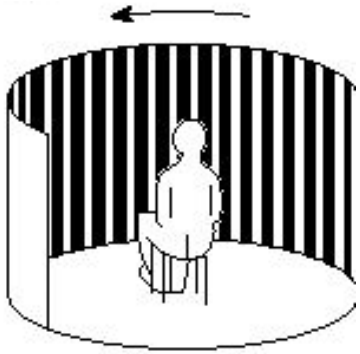


安定化のための反射としての眼球運動
Eye movement for stabilization

- 前庭動眼反射／Vestibulo-ocular reflex(VOR)
  - Cancel head rotation.



- 視運動性眼球運動／Optokinetic Response(OKR)
  - When the whole visual field moves, the eye follows.



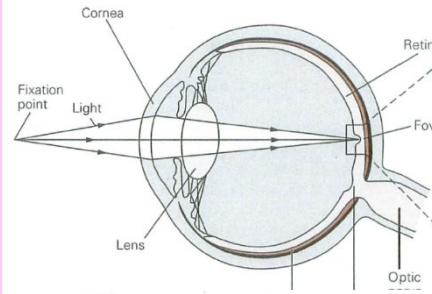
Railroad ties

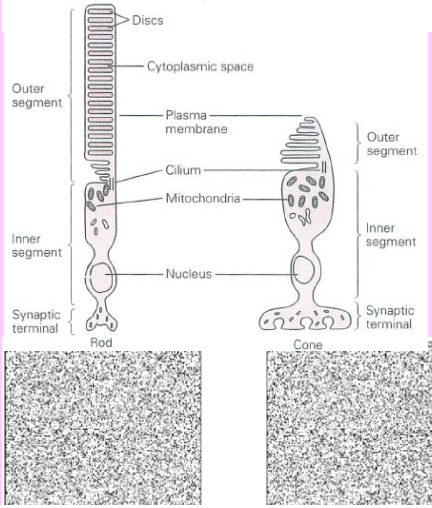
参考：Chicken Head Tracking - Smarter Every Day

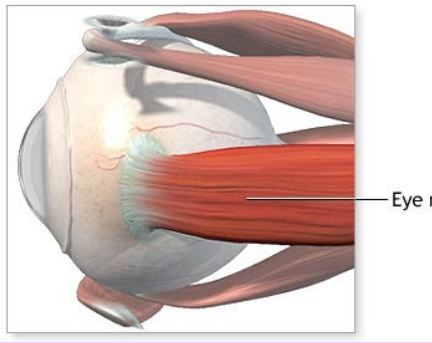
http://www.youtube.com/watch?v=_dPlkFPowCc

TODAY's SUMMARY

- 眼の構造／Eye structure
  - conea, retina, fovia, blind spot
- 眼のセンサ／Eye sensors
  - rod cell, cone cell, color vision
  - peripheral & central vision
  - image processing
- 奥行き知覚／Depth perception
  - accommodation, vergence
  - binocular disparity
- 眼球運動／Eye movement
  - smooth persuit, saccade,
  - VOR, OKR







小テスト／Mini Test 次回開始までに提出

https://goo.gl/forms/85xfExX2mLheNncR2

以下の全てに100字以内程度で解答せよ／Answer all questions within 50 words

1. ウエバー・フェヒナーの法則について説明せよ Explain Weber-Fechner's law
2. 調整法について説明せよ Explain the method of adjustment.
3. 極限法について説明せよ Explain the method of limit.
4. 恒常法について説明せよ Explain the method of constant.
5. 錐体細胞と桿体細胞の分布の違いについて述べよ Describe difference of distribution of cone cell and rod cell.
6. 錐体細胞と桿体細胞の明暗および色感受性の違いについて述べよ Describe difference of color and brightness perception of cone cell and rod cell.
7. 焦点調節について説明せよ Explain Accommodation
8. 運動視差について説明せよExplain Motion Parallax
9. 輻輳について説明せよ Explain Vergence Eye Movement
10. 輻輳調節矛盾について説明せよ Explain Vergence-Accommodation Conflict
11. 両眼視差について説明せよ Explain Binocular Disparity
12. 前庭動眼反射について説明せよ Explain Vestibulo-ocular reflex(VOR)
13. 視運動性眼球運動について説明せよExplain Optokinetic Response(OKR)
    眼底電位計測について説明せよ Explain Electroculography (EOG)
14. 強膜反射法について説明せよ Explain Limbus Tracking Method
15. 角膜反射法について説明せよ Explain Eye Capture System Using Reflection at Horny Coat