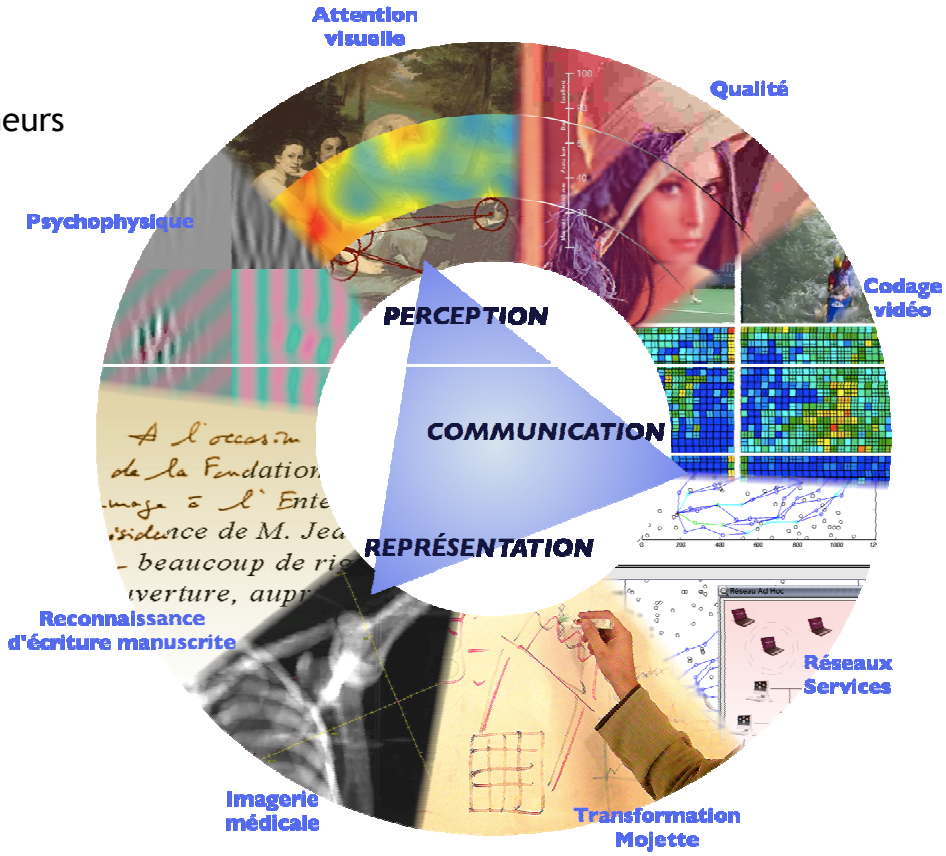
# Vision humaine et applications en traitement d'images


## Patrick LE CALLET

## IRCCyN équipe Images et VideoCommunication

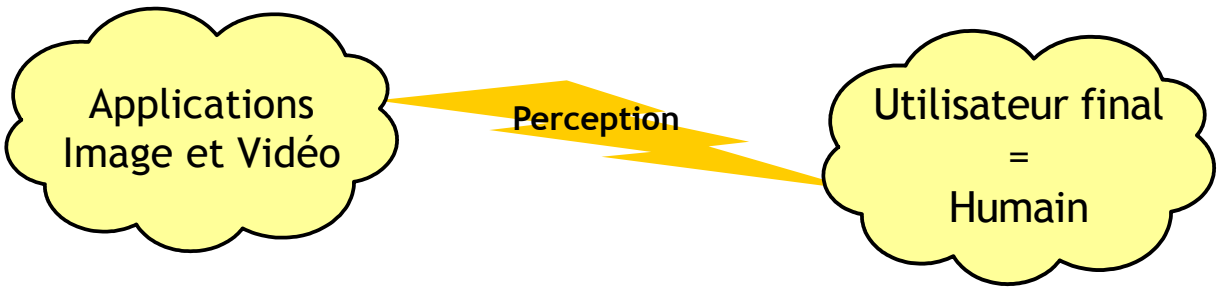

## IRCCyN équipe IVC

35 personnes :
- 10 enseignants-chercheurs
- 15 doctorants
- 5 post-doc
- 5 ingénieurs



# Explosion des services liés à l'image et la vidéo


# Et l'utilisateur final ?




## Recherche fondamentale :

faire progresser les connaissances sur la perception

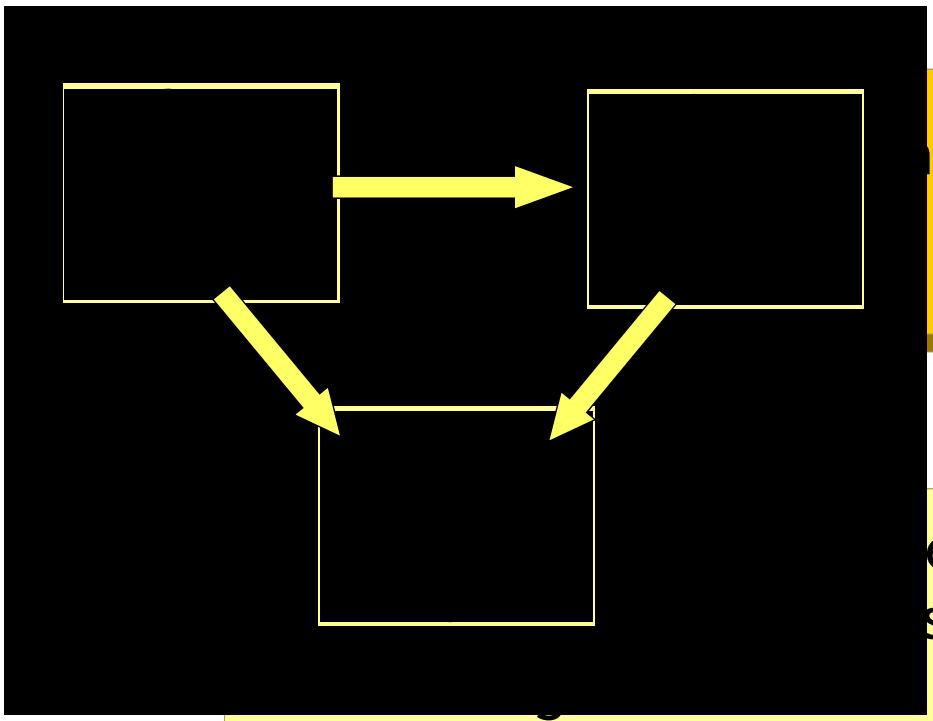
## Recherche appliquée :

Appliquer les connaissances sur le SVH dans les applications et services

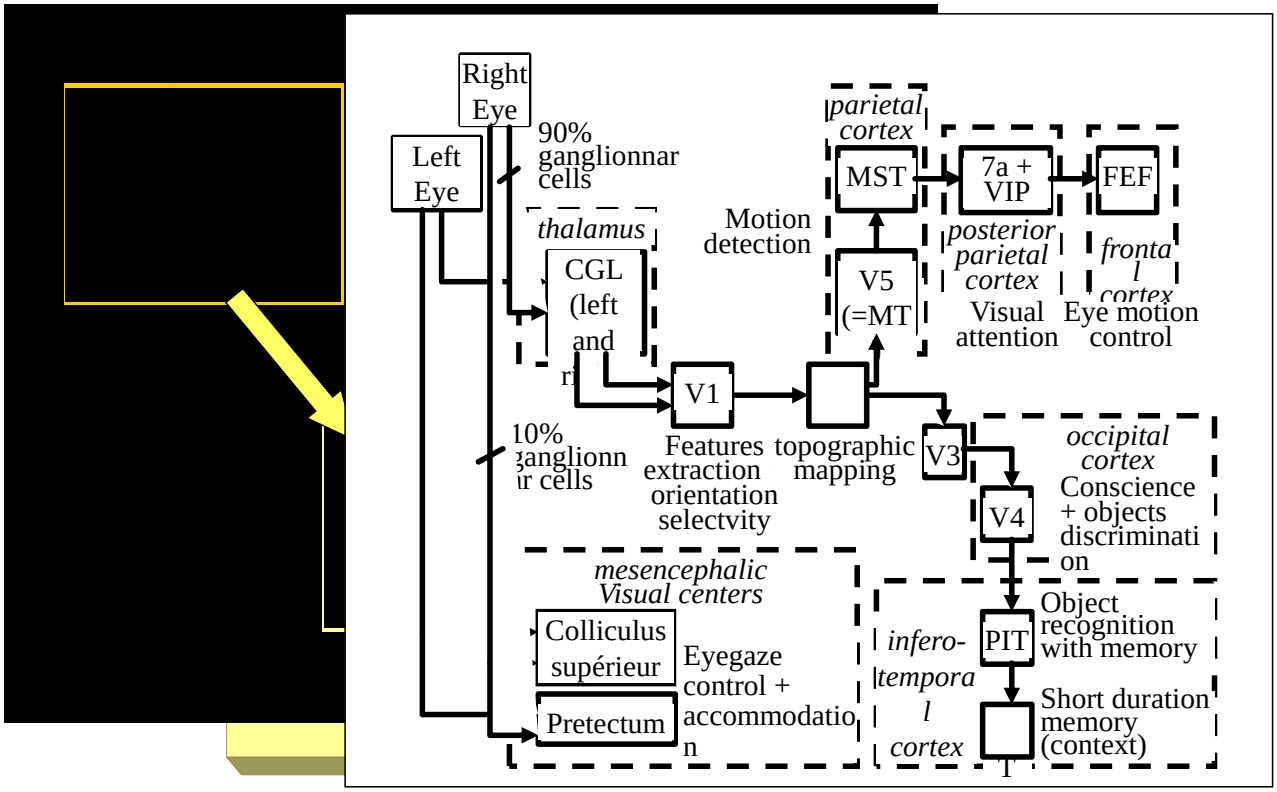
Caractérisation et modélisation du Système Visuel Humain

Utilisation des modèles dans des applications de traitements d'images ou de vidéo

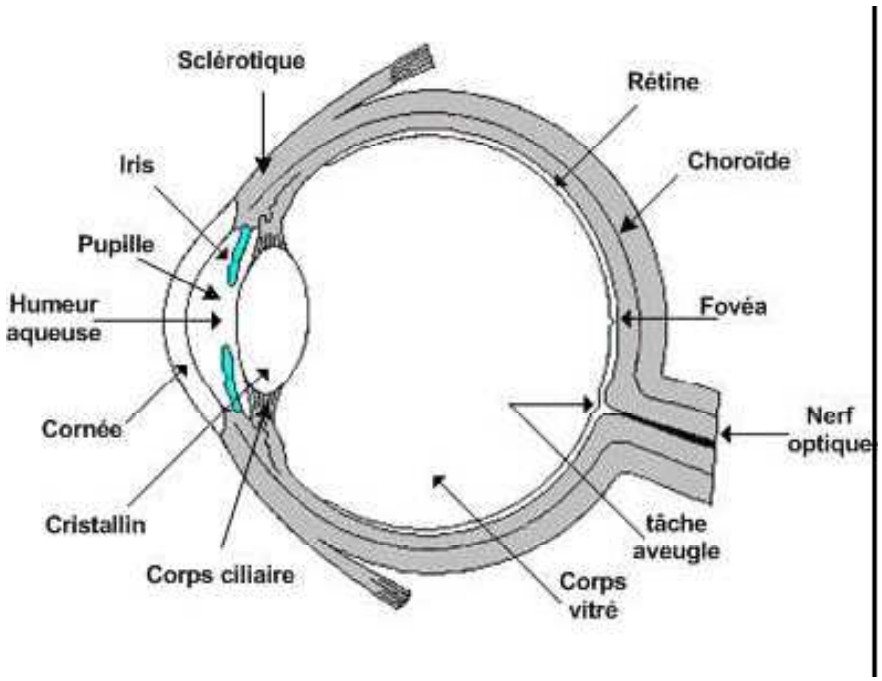
Cercle vertueux



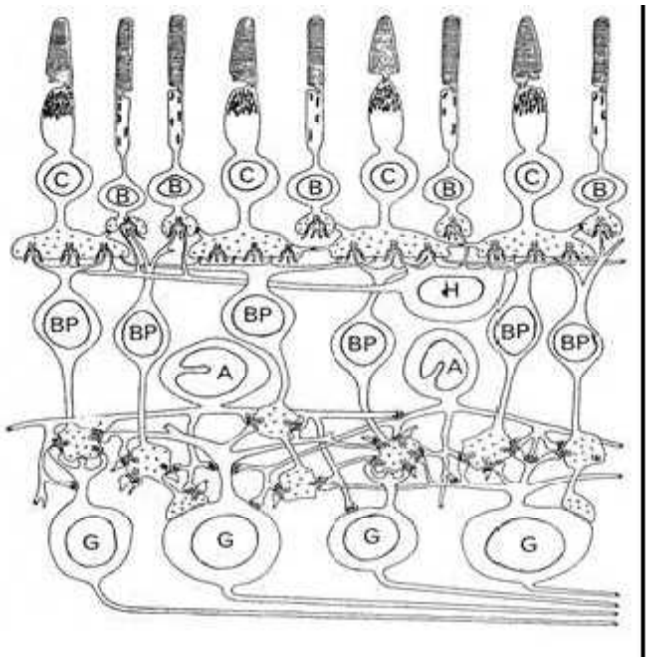
# SVH : Anatomie




# Anatomie de l'œil



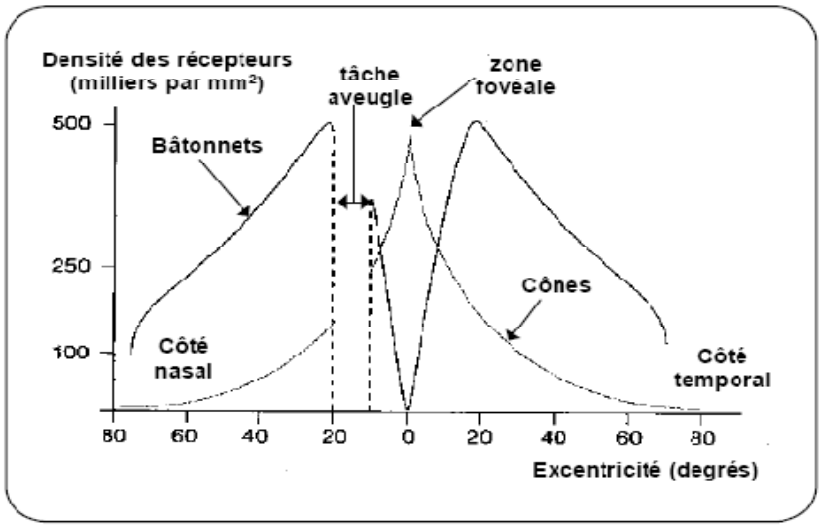
# la rétine : un système multicapteurs




photorécepteurs

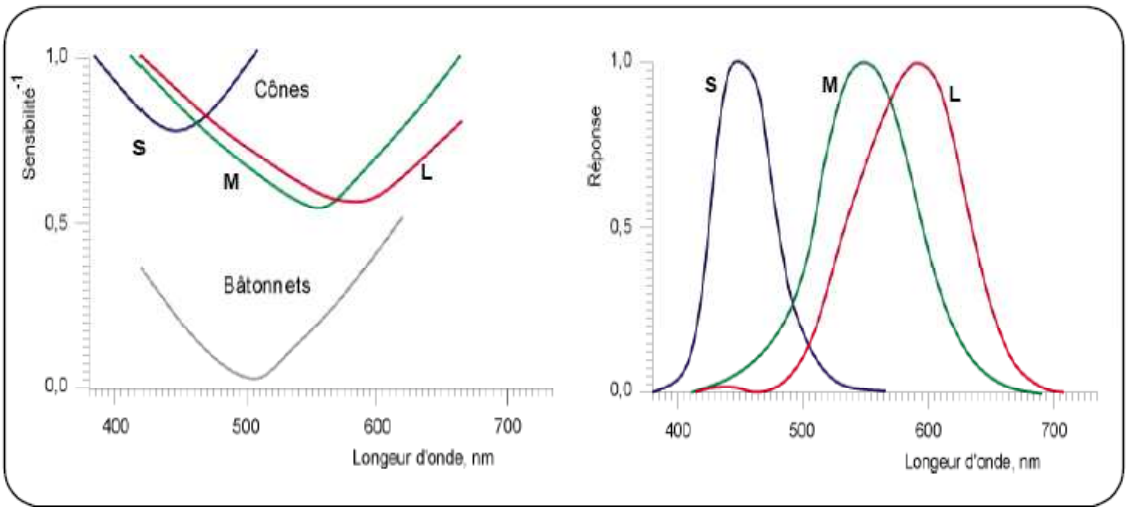
Couches de cellule

# photorécepteurs : les cônes et les bâtonnets



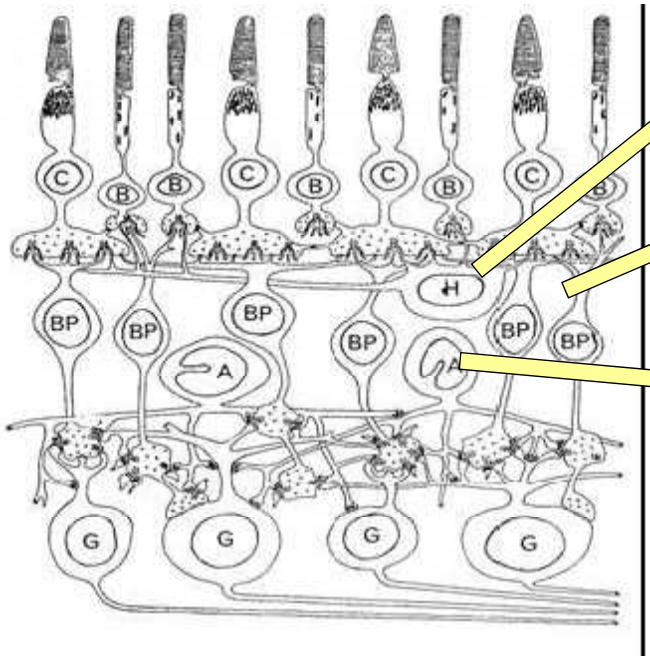

| | Bâtonnets | Cônes |
|---|---|---|
| Répartition spatiale | périphérie rétinienne | fovéa |
| Population | 100 millions | 5 millions |
| Gamme de fonctionnement | scotopique | photopique |
| Résolution spatiale | faible | élevée |
| Résolution temporelle | faible | élevée |
| Capacité de détection en vision périphérique | élevée | faible |
| Information couleur | non | oui (cônes S,M,L) |
| Maillage | convergent | non-convergent |

# photorécepteurs : les cônes et les bâtonnets




# la rétine : un système multicapteurs

photorécepteurs




**Cellules horizontales : interaction antagoniste du centre sur le pourtour**

Cellules bipolaires :

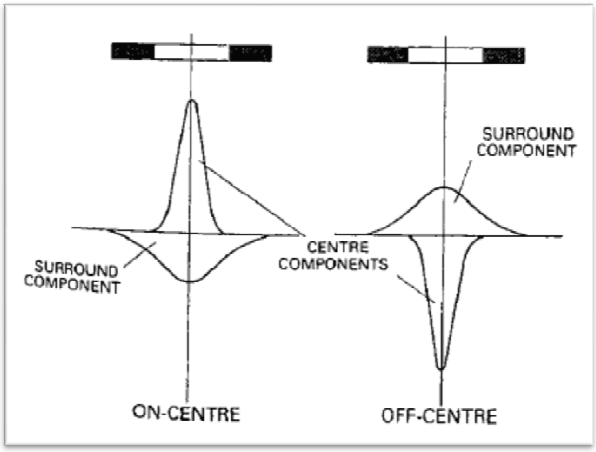
**=> mécanisme d'inhibition latérale.**

Cellules amacrines :

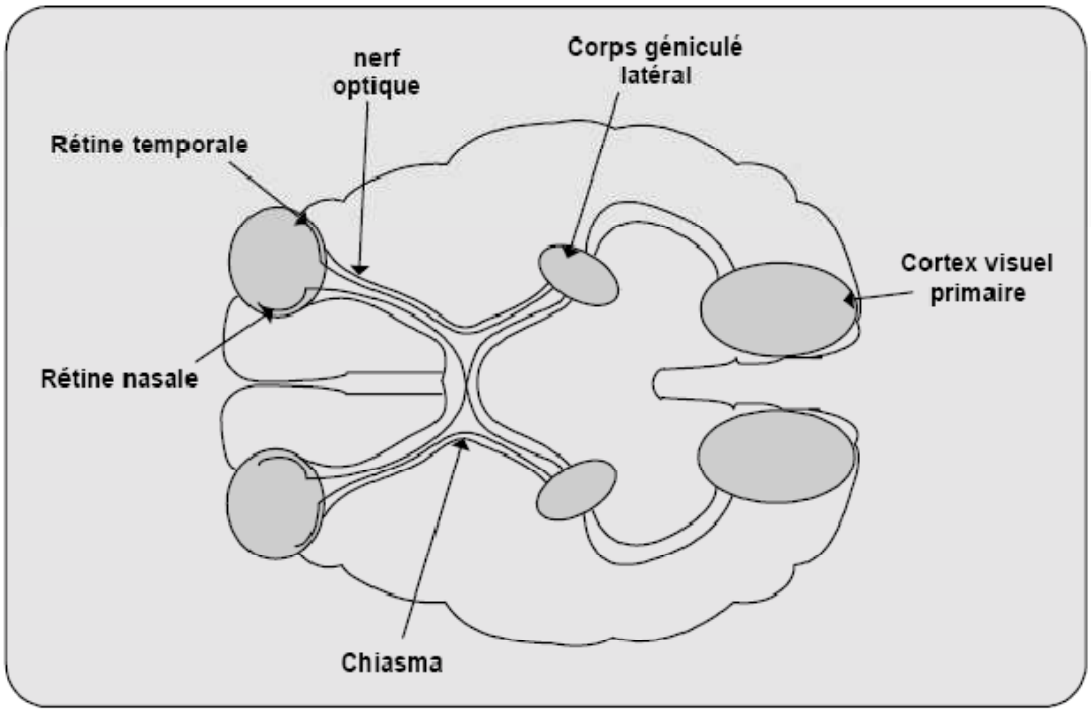
propagation latérale de l'information

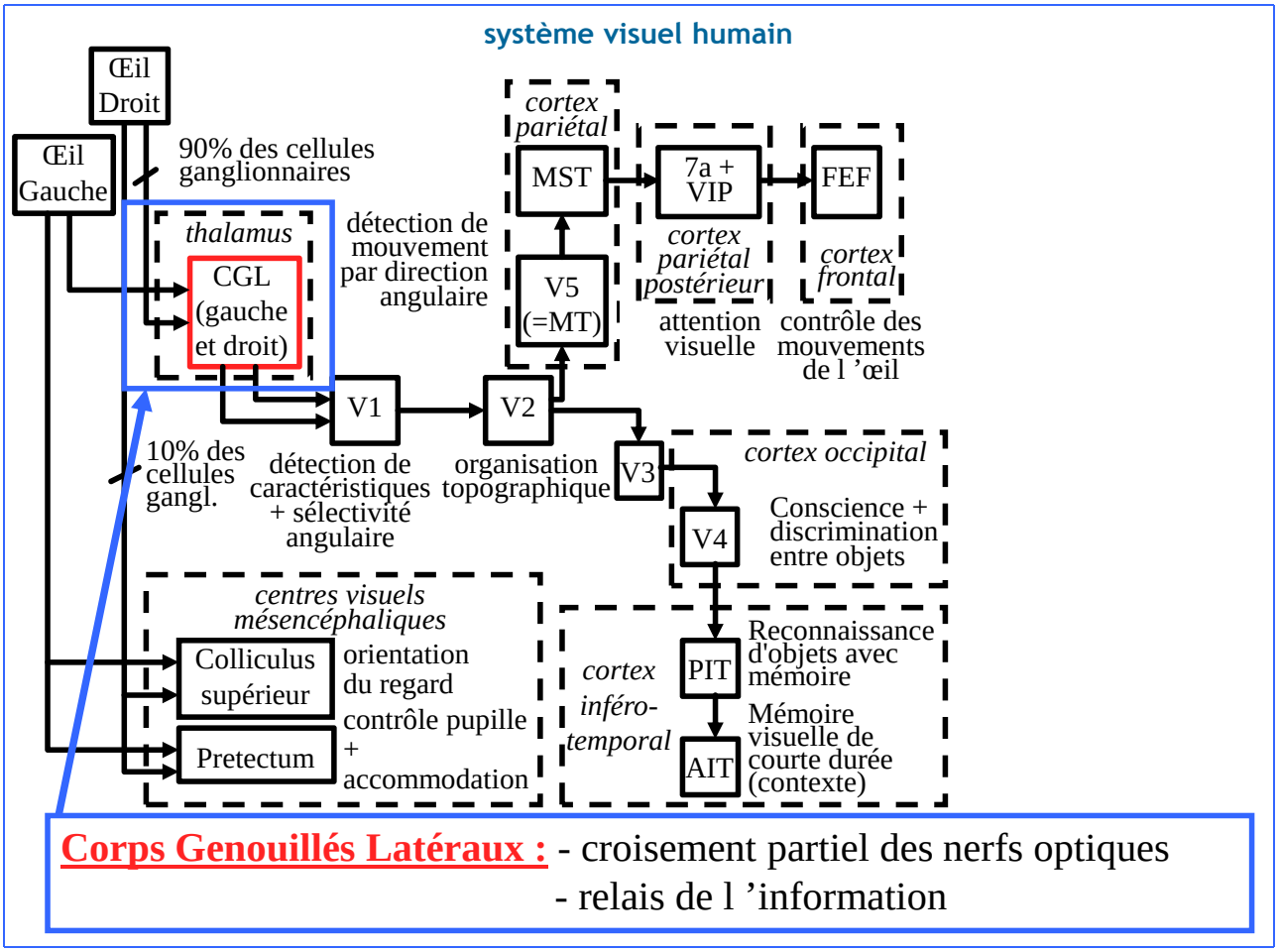
# Cellules rétiniennes: interaction antagoniste centre-pourtour

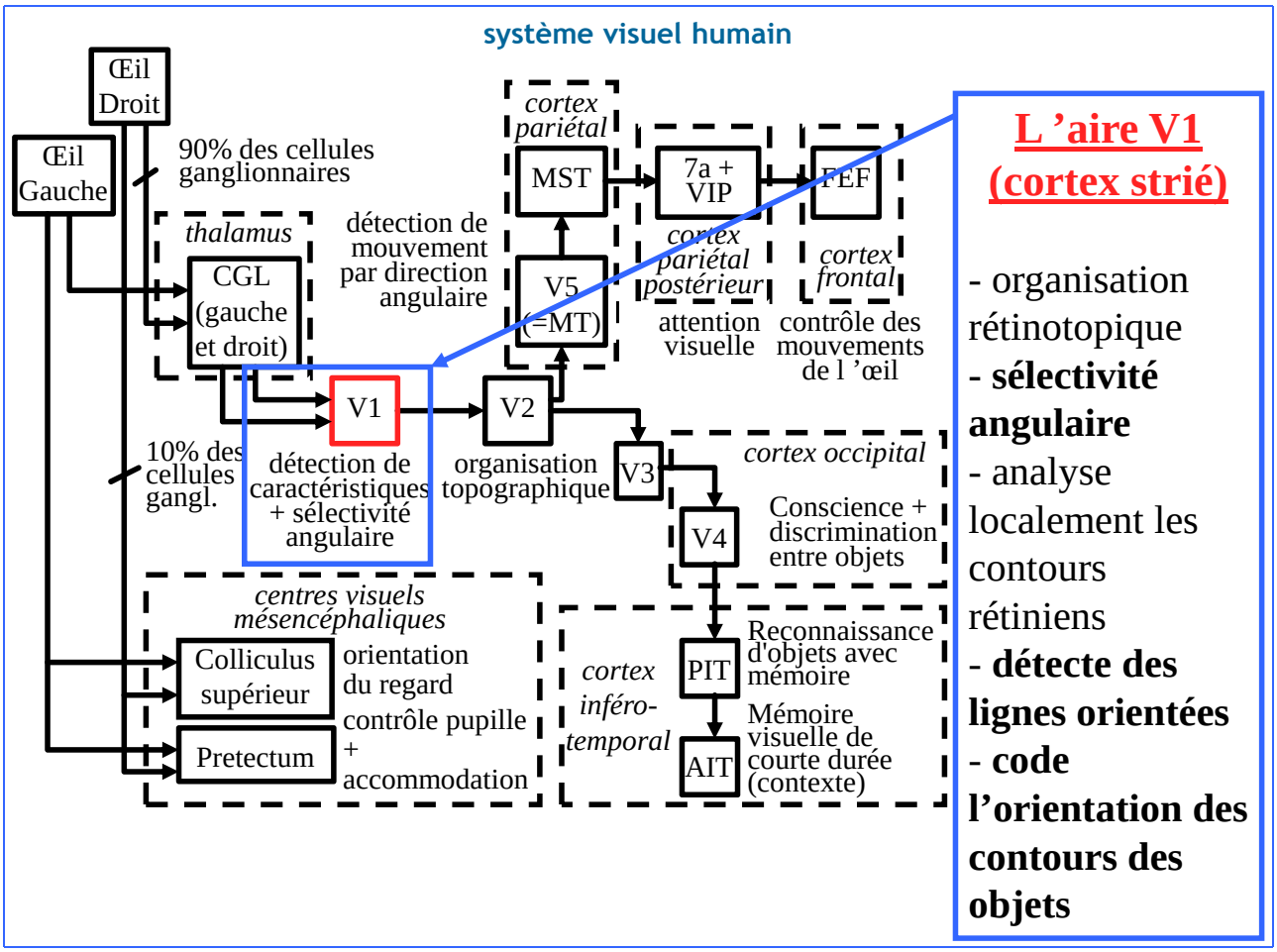
**Une zone excitatrice + une zone inhibitrice**




# Traitements post rétiniens




système visuel humain
Œil Droit
Œil Gauche
90% des cellules ganglionnaires
thalamus
CGL (gauche et droit)
détection de mouvement par direction angulaire
cortex pariétal
MST
7a + VIP
FEF
V5 (=MT)
cortex pariétal postérieur
cortex frontal
attention visuelle
contrôle des mouvements de l 'œil
V1
V2
V3
cortex occipital
10% des cellules gangl.
détection de caractéristiques + sélectivité angulaire
organisation topographique
V4
Conscience + discrimination entre objets
centres visuels mésencéphaliques
Colliculus supérieur
orientation du regard
Pretectum
contrôle pupille + accommodation
cortex inféro-temporal
PIT
Reconnaissance d'objets avec mémoire
AIT
Mémoire visuelle de courte durée (contexte)
Corps Genouillés Latéraux : - croisement partiel des nerfs optiques
- relais de l 'information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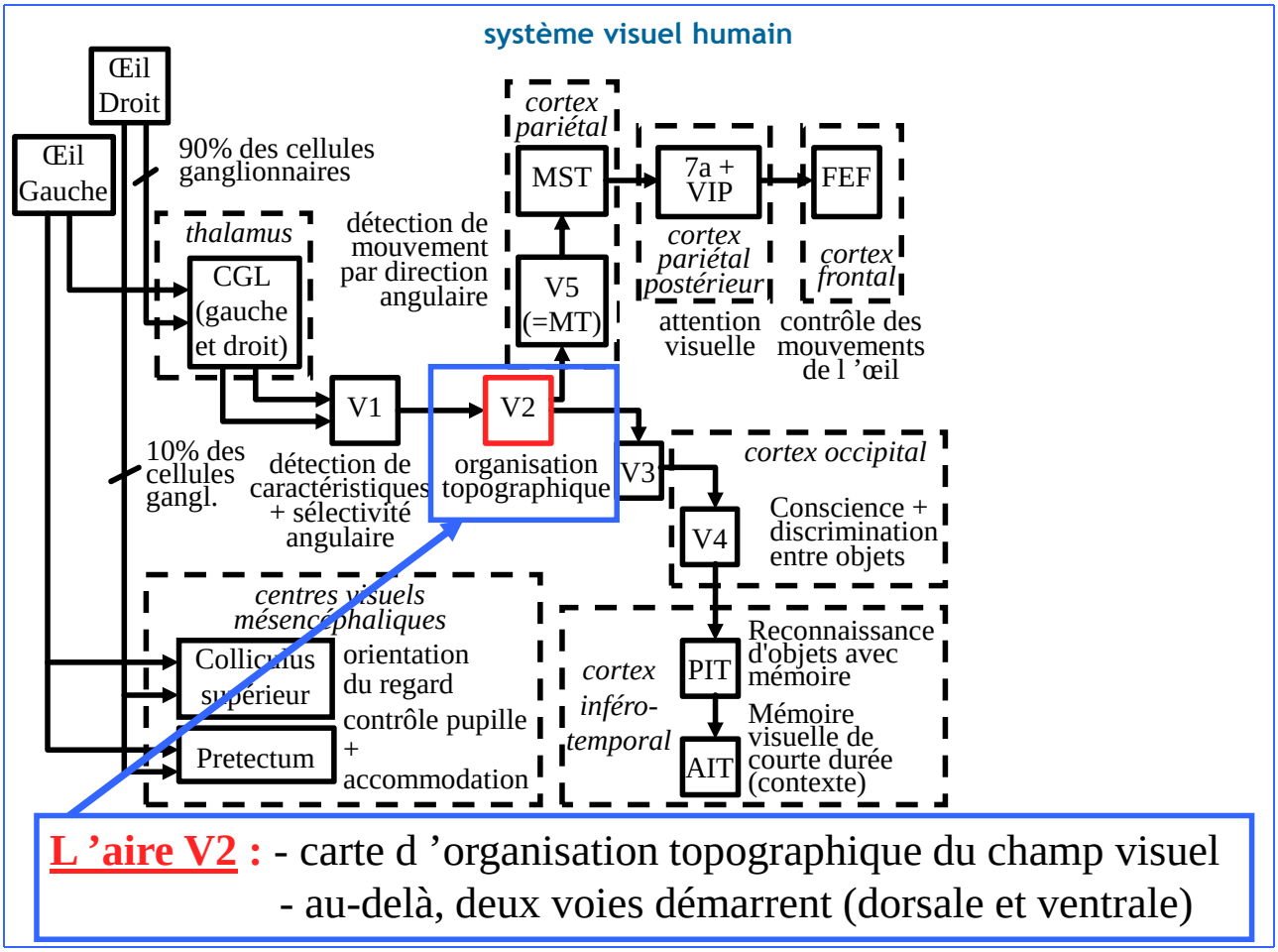
Reconnaissance d'objets avec mémoire
AIT
Mémoire visuelle de courte durée (contexte)
L 'aire V1 (cortex strié)
- organisation rétinotopique
- sélectivité angulaire
- analyse localement les contours rétiniens
- détecte des lignes orientées
- code l'orientation des contours des objets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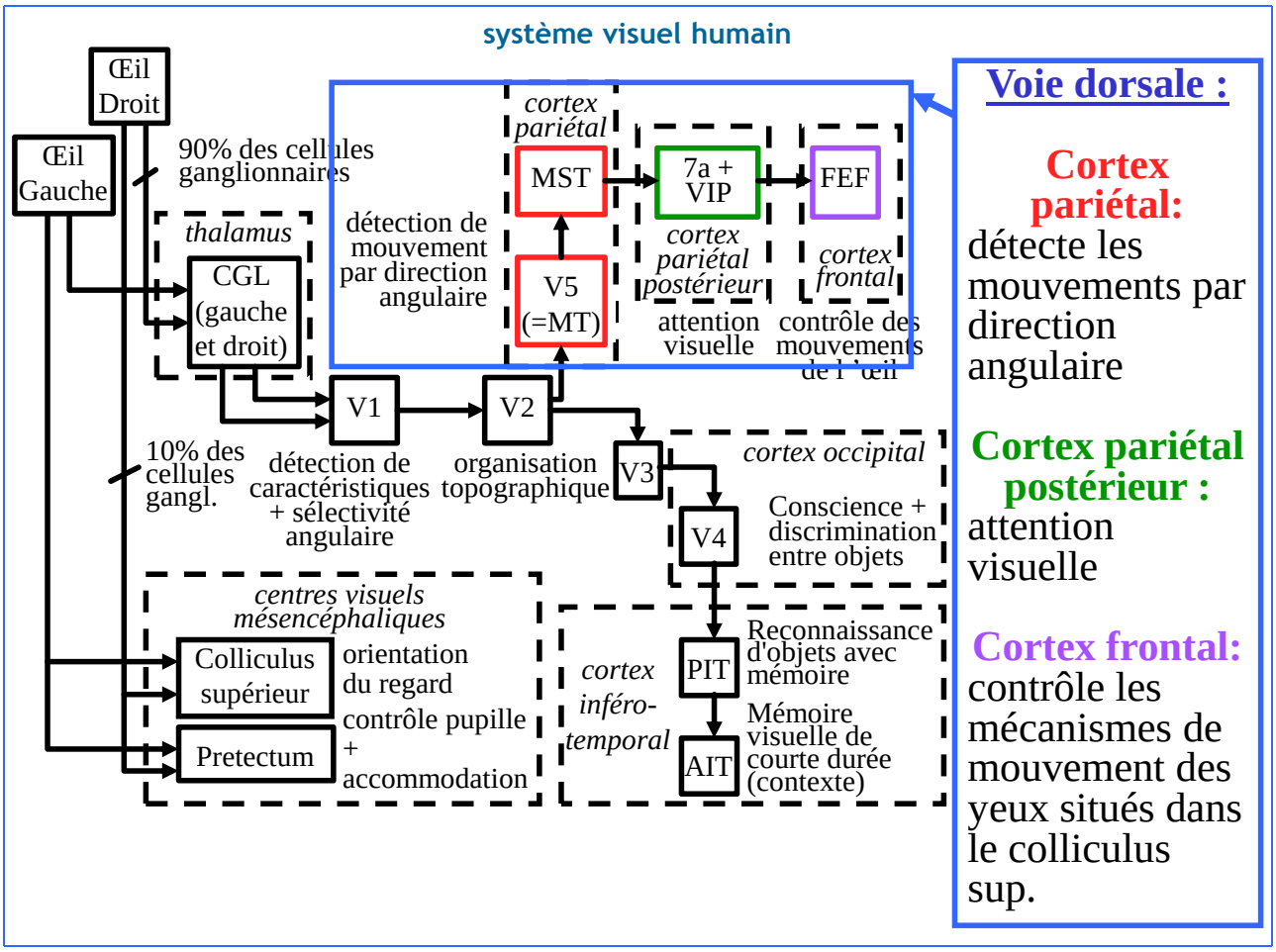
Mémoire visuelle de courte durée (contexte)
L 'aire V2 : - carte d 'organisation topographique du champ visuel
- au-delà, deux voies démarrent (dorsale et ventrale)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Reconnaissance d'objets avec mémoire
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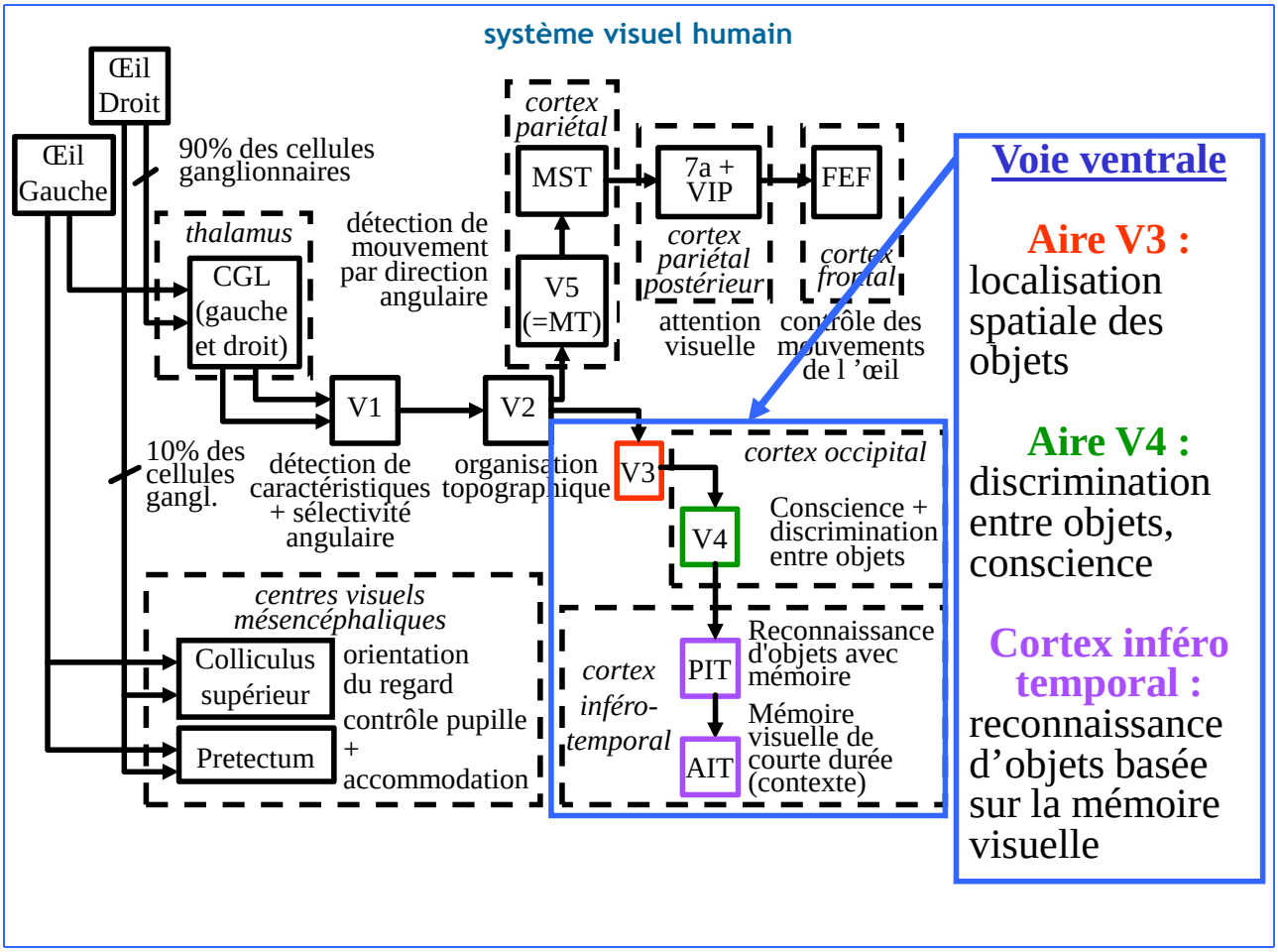
Mémoire visuelle de courte durée (contexte)
Voie dorsale :
Cortex pariétal:
détecte les mouvements par direction angulaire
Cortex pariétal postérieur :
attention visuelle
Cortex frontal:
contrôle les mécanismes de mouvement des yeux situés dans le colliculus sup.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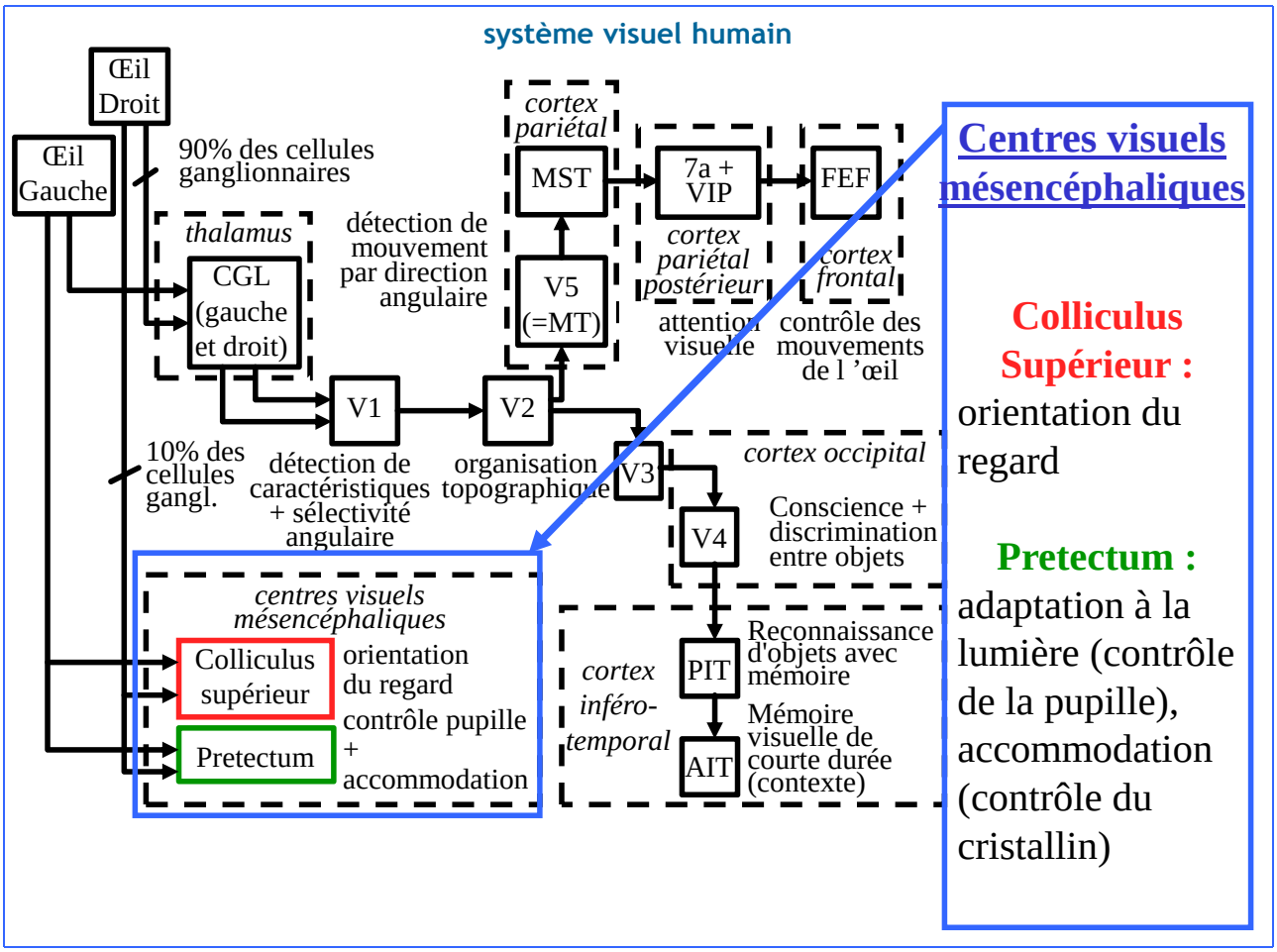
Mémoire visuelle de courte durée (contexte)
Voie ventrale
Aire V3 :
localisation spatiale des objets
Aire V4 :
discrimination entre objets, conscience
Cortex inféro temporal :
reconnaissance d'objets basée sur la mémoire visuelle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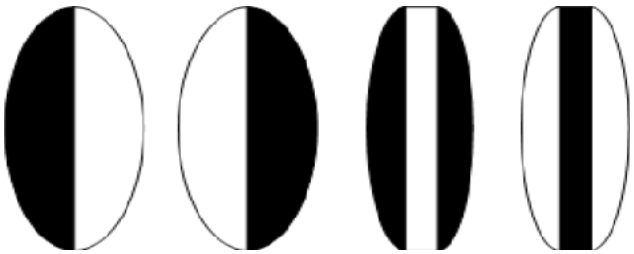
Centres visuels mésencéphaliques
Colliculus Supérieur :
orientation du regard
Pretectum :
adaptation à la lumière (contrôle de la pupille), accommodation (contrôle du cristallin)

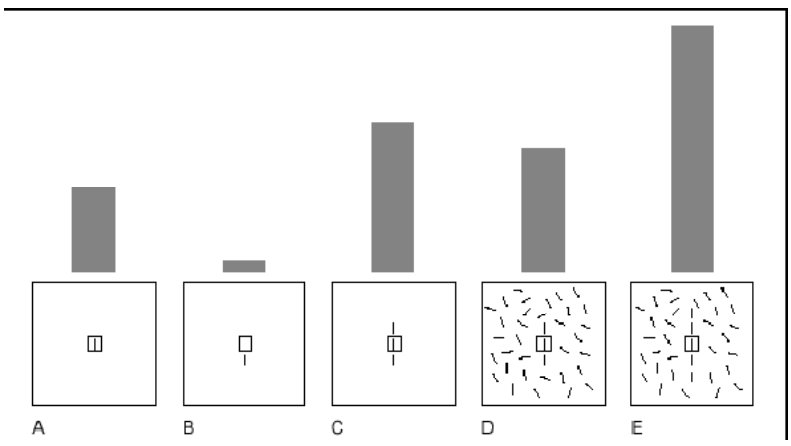
# Aire V1

- neurones de type champ récepteur
- Champ récepteur classique CRF :
  - centre/pourtour ayant des comportements antagonistes (orientation, fréquence, contraste)

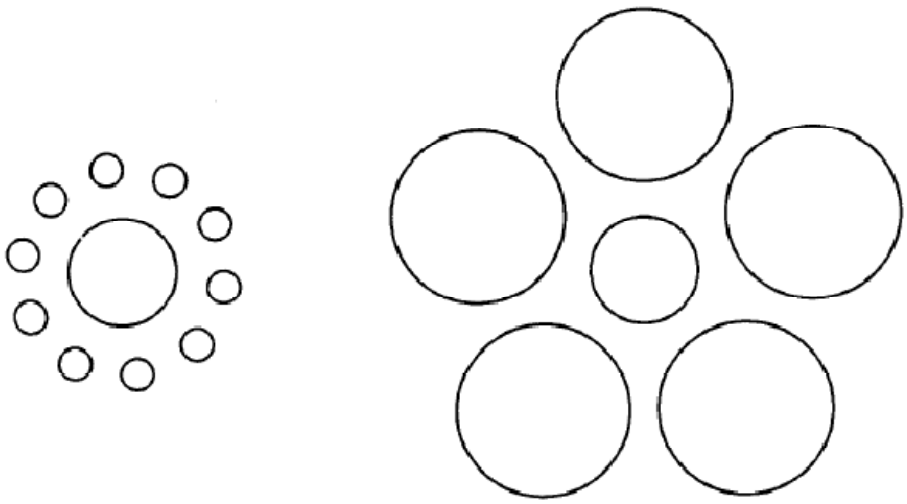


# Interactions facilitatrices

- Champ récepteur non classique NCRF :
  - modulations facilitatrices lorsque le stimuli central et périphérique sont iso-orientés et alignés

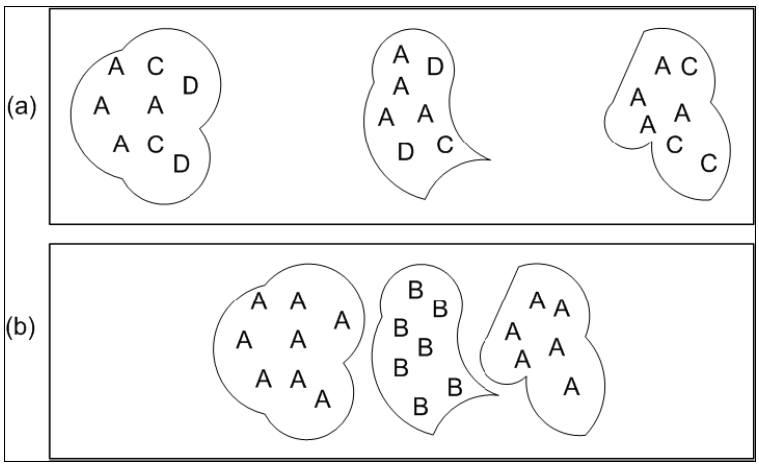


# codage de contexte

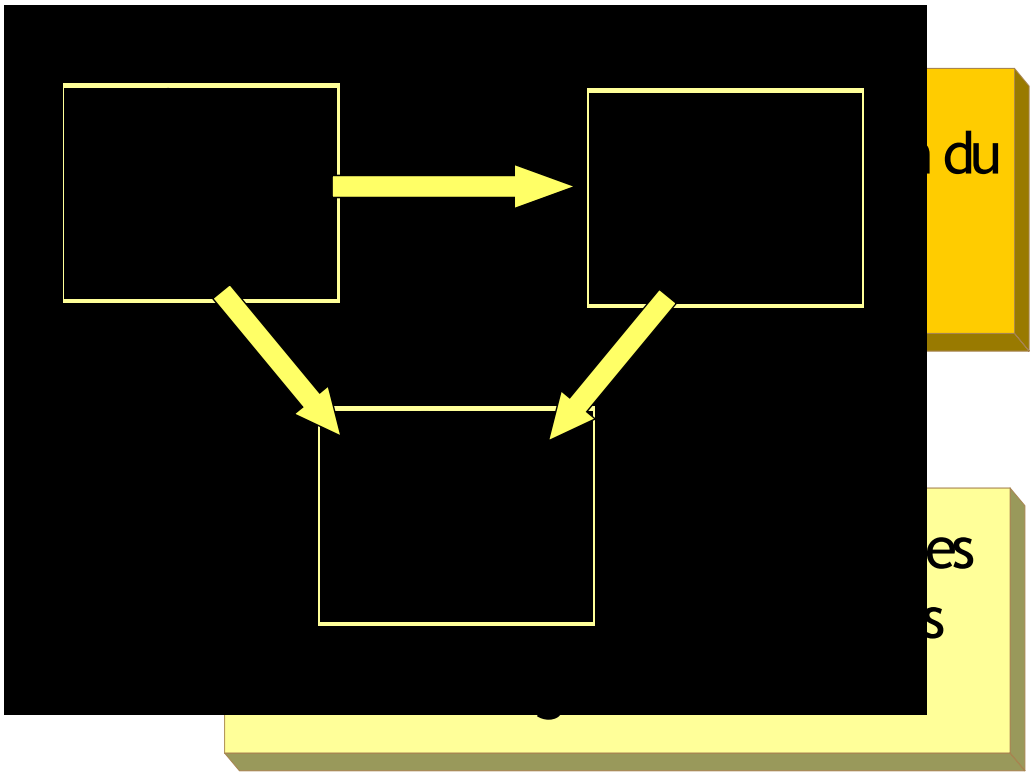


# SVH : haut niveau

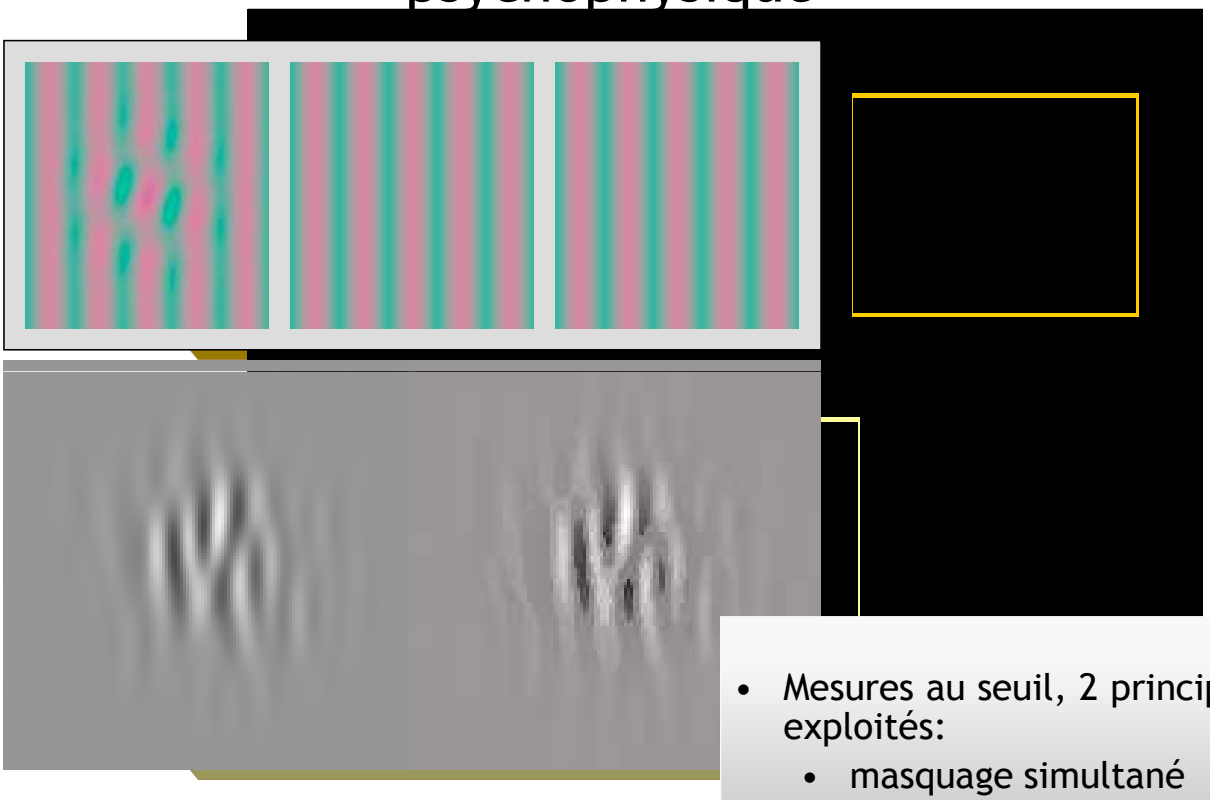
- Ecole Gestaltiste
  - the whole is different from the sum of its parts
  - Perception de forme :
    - groupement par proximité
    - groupement par similarité



# Cercle vertueux

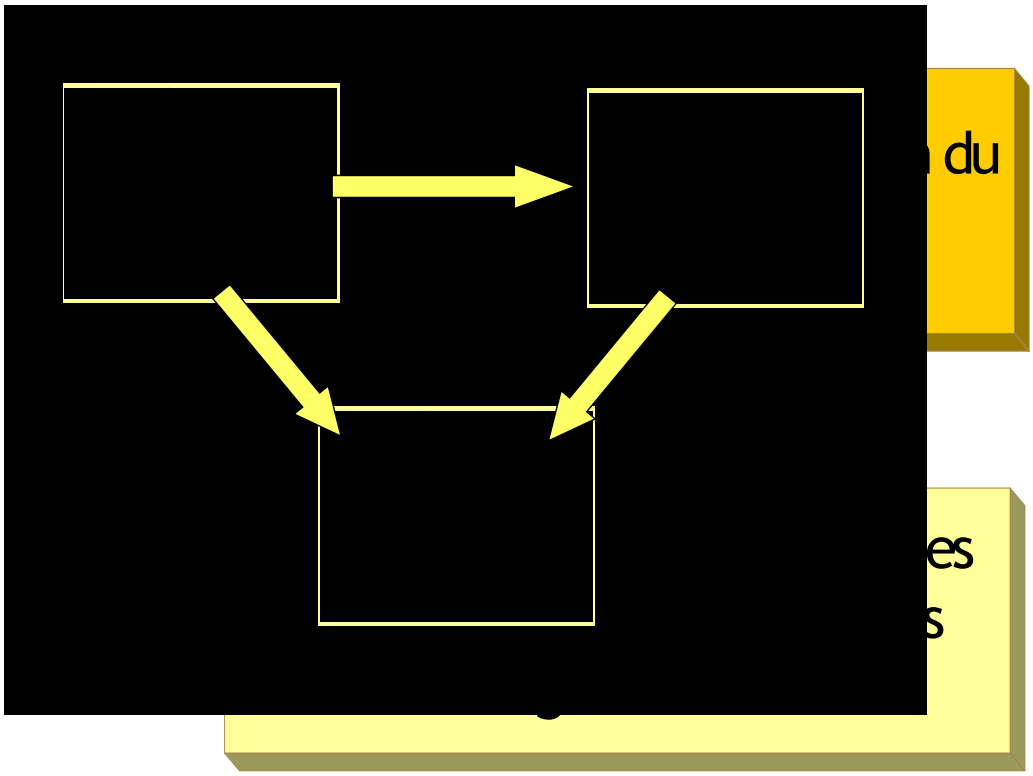



# psychophysique



- Mesures au seuil, 2 principes exploités:
  - masquage simultané
  - adaptation

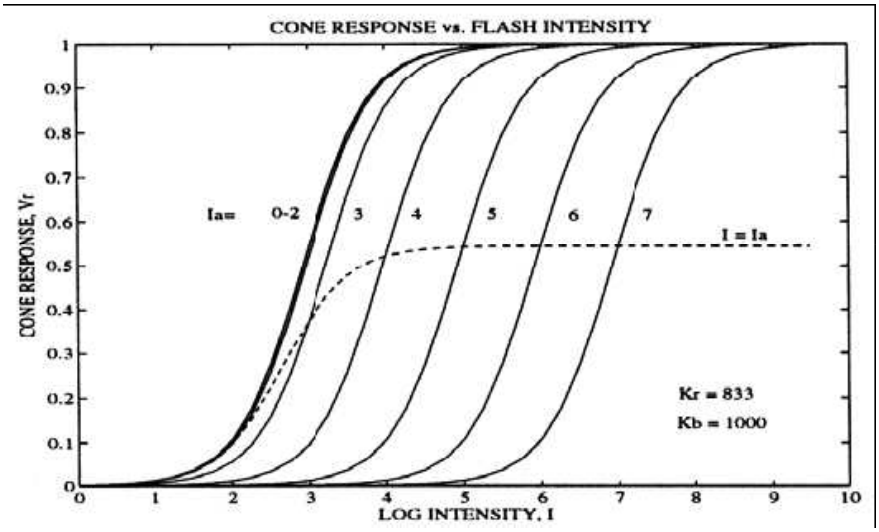
# Modélisations du SVH



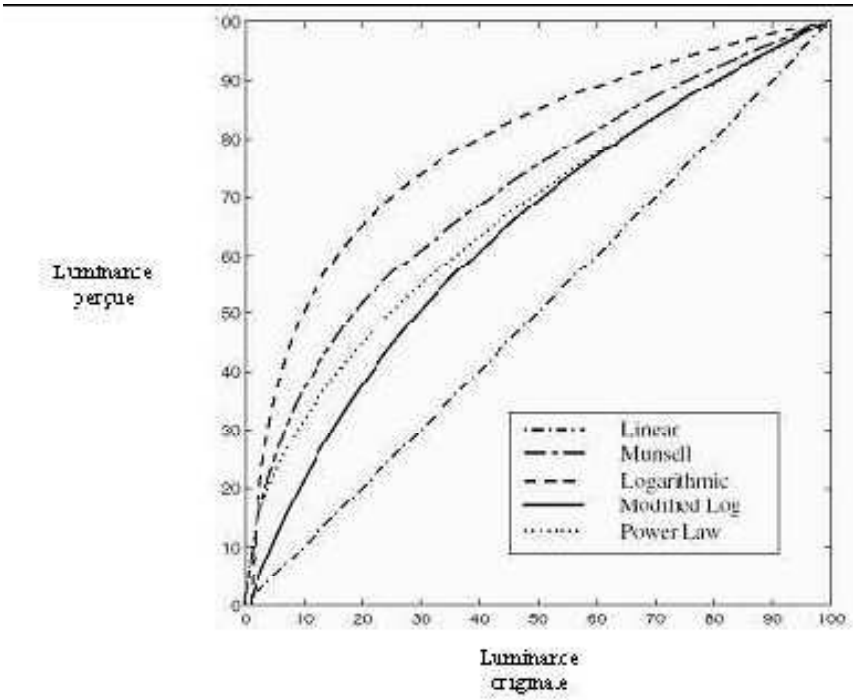
**Modélisation bas niveau ….JND**

**(jusqu’à l’aire V1)**

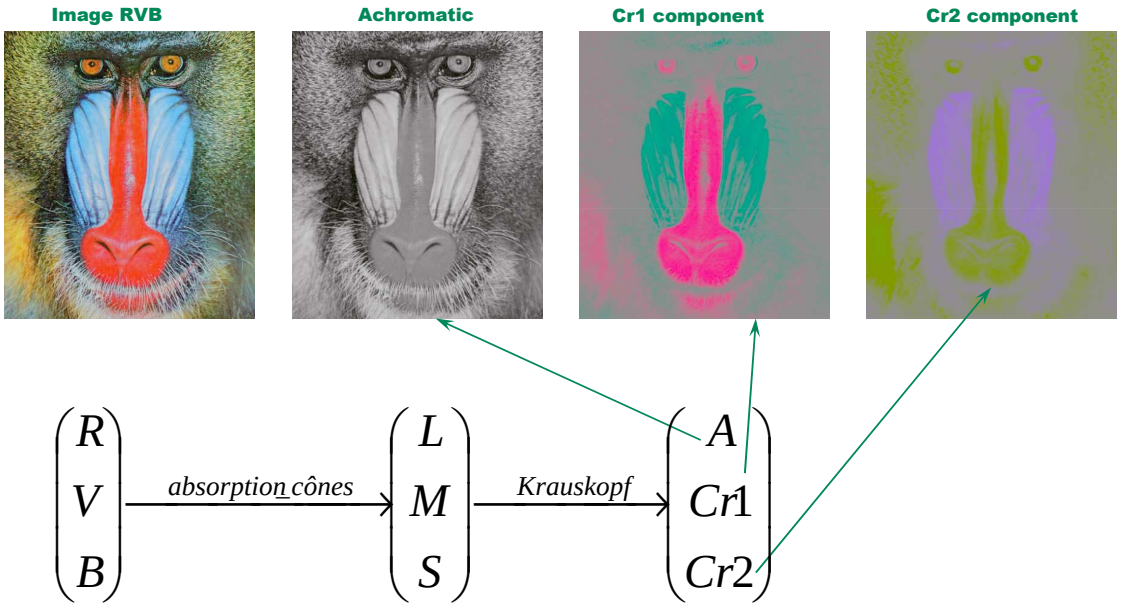
# Adaptation à l'intensité lumineuse



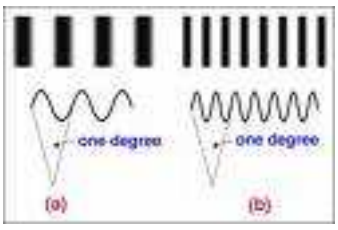

# Luminance perçue

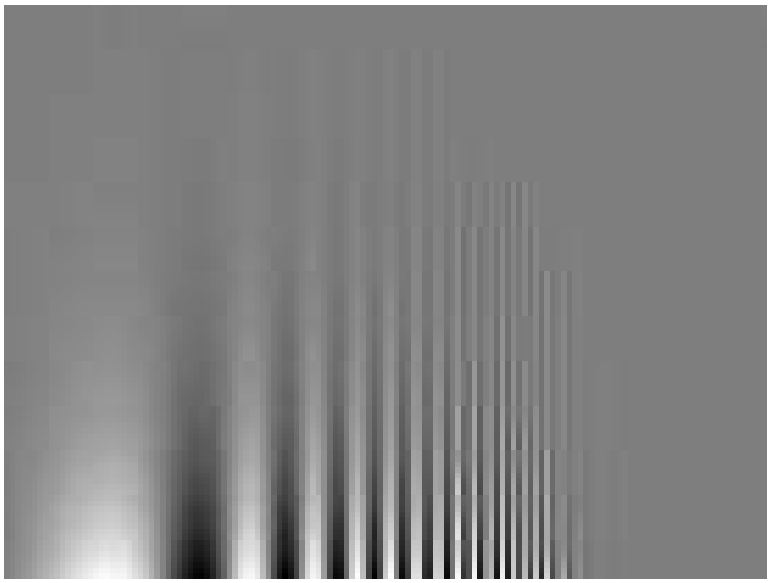


# Représentation des couleurs




# Sensibilité aux contrastes



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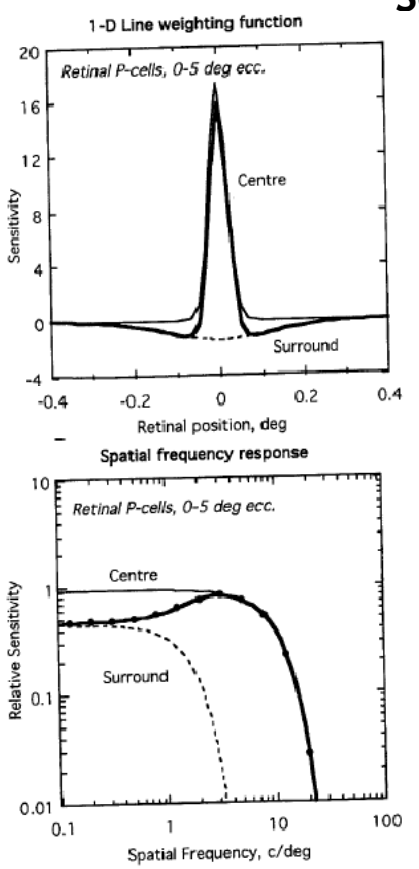
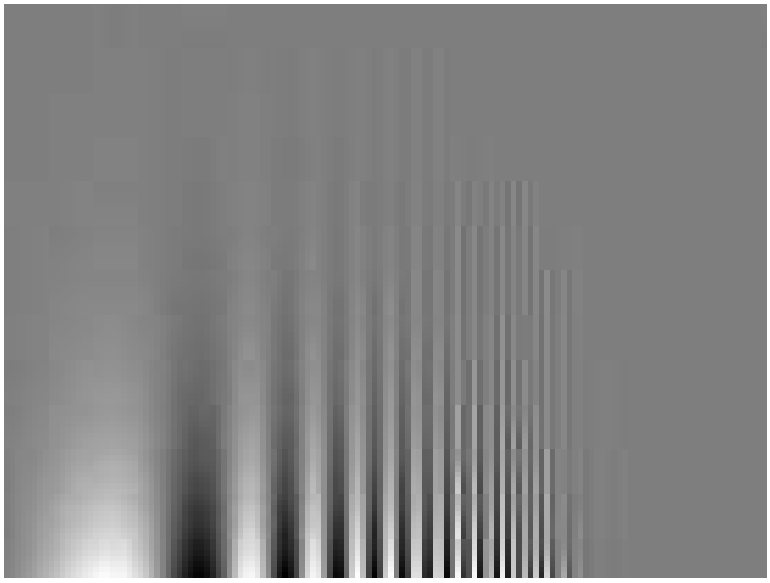
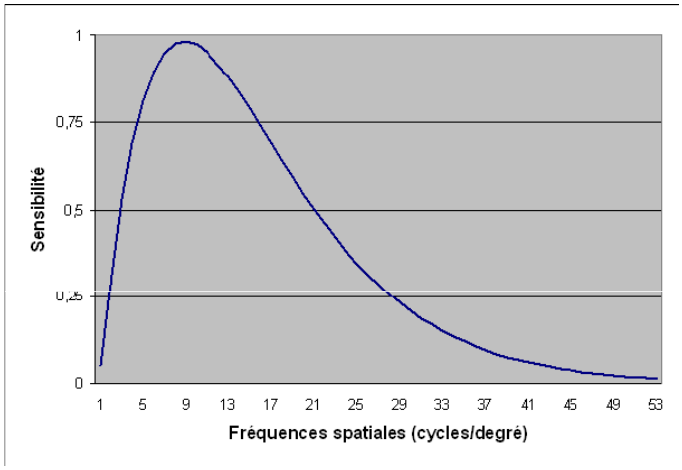
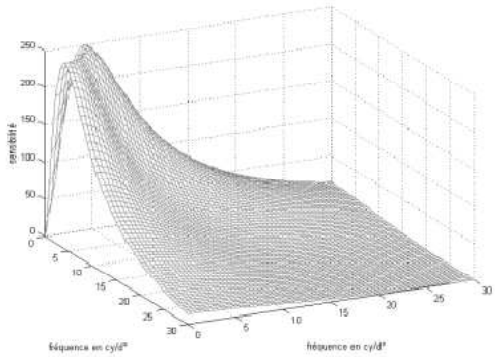


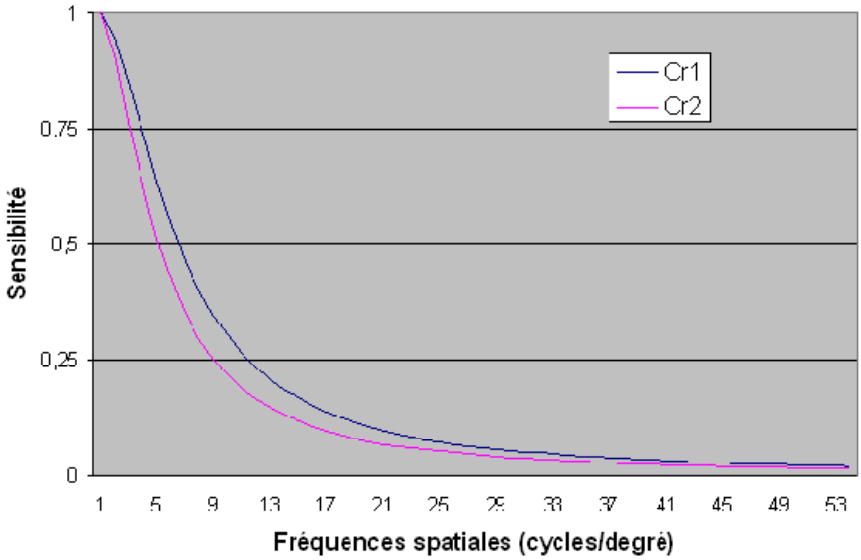



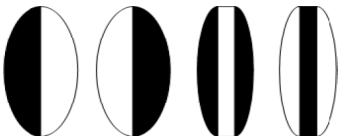
# CSF modèles: Barten, Kelly, Daly ….



# CSF Cr1 Cr2

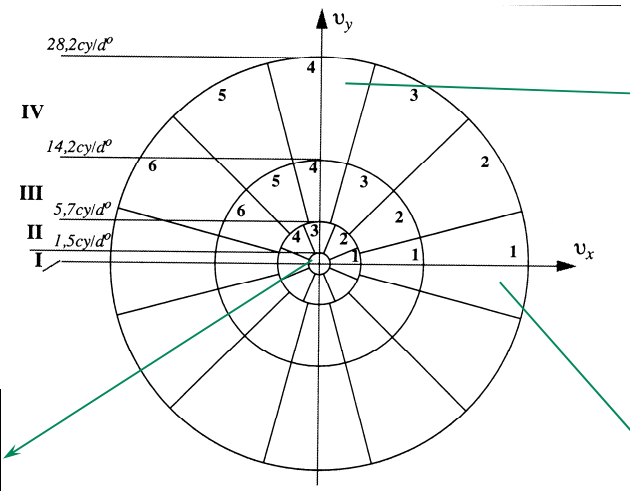


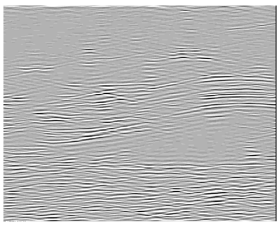



# Canaux perceptuels

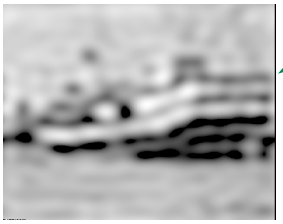
**Perceptual channels decomposition**

Original image

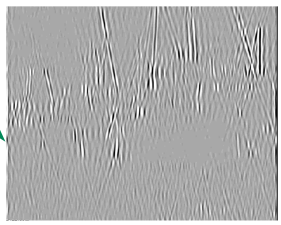


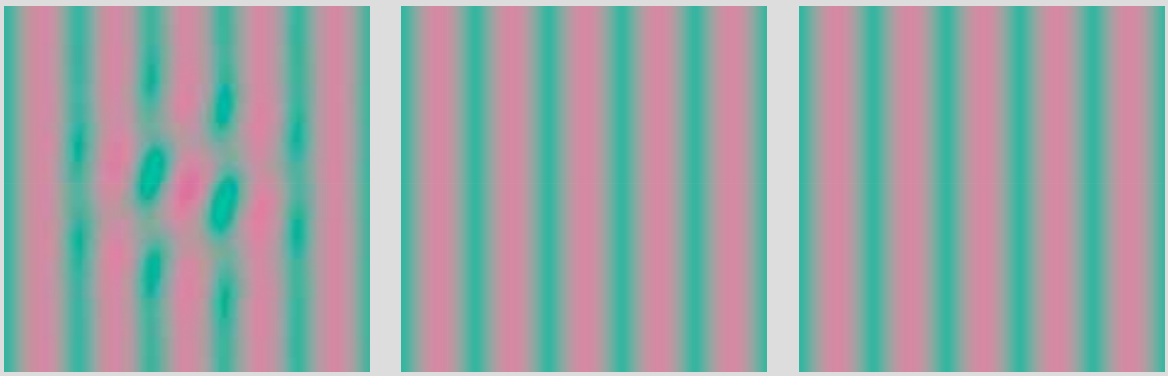
Vertical
high frequencies



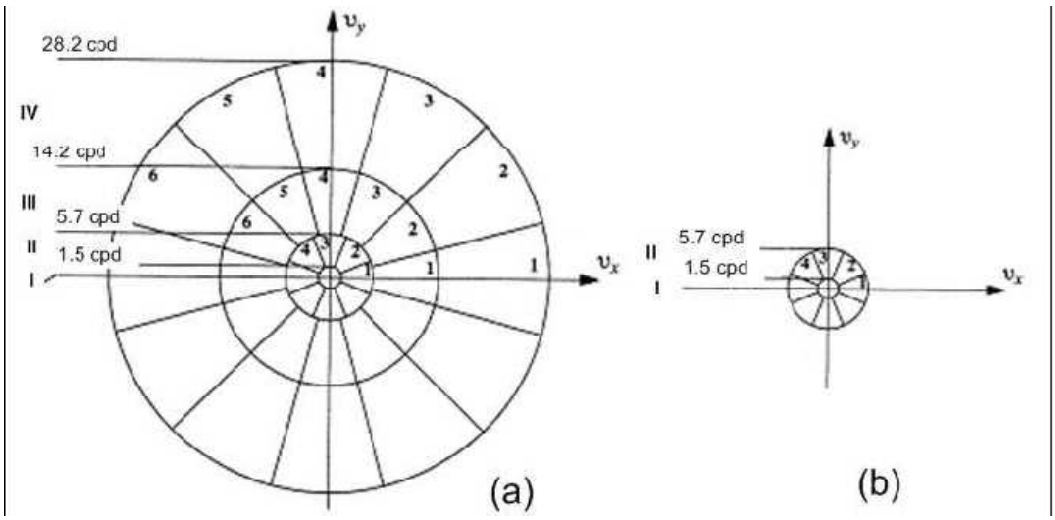
Low frequencies



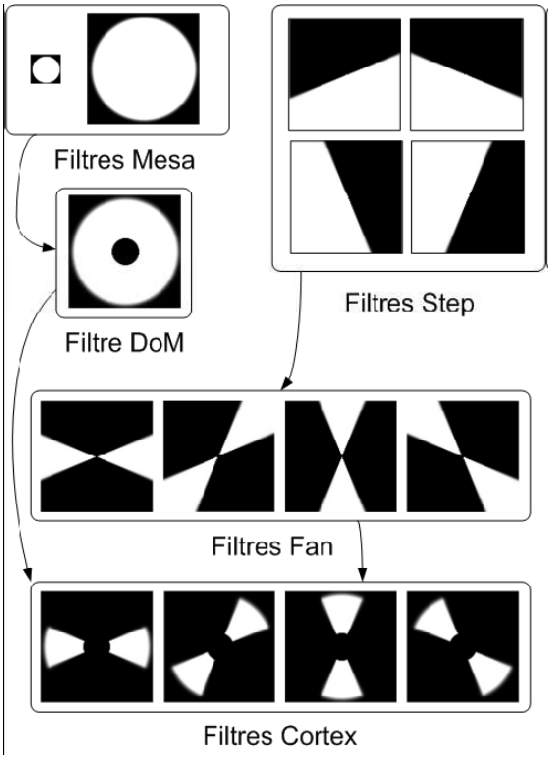
Horizontal
high frequencies



## Canaux perceptuels



## Transformée Cortex




$$mesa(\omega) = \begin{cases} 1 & \text{pour } \omega < \omega_c - \frac{t_w}{2} \\ \frac{1}{2}.(1+\cos(\frac{\pi.(\omega-\omega_c+\frac{t_w}{2})}{t_w})) & \text{pour } \omega_c - \frac{t_w}{2} < \omega < \omega_c + \frac{t_w}{2} \\ 0 & \text{pour } \omega > \omega_c + \frac{t_w}{2} \end{cases}$$

$$fan_i(\theta) = \begin{cases} 1 & \text{pour } |\theta - \theta_i| < \theta_c - \frac{\theta_w}{2} \\ \frac{1}{2}.(1+\cos(\frac{\pi.(\theta-\theta_c+\frac{\theta_w}{2})}{\theta_w})) & \text{pour } \theta_c - \frac{\theta_w}{2} < |\theta - \theta_i| < \theta_c + \frac{\theta_w}{2} \\ 0 & \text{pour } |\theta - \theta_i| > \theta_c + \frac{\theta_w}{2} \end{cases}$$

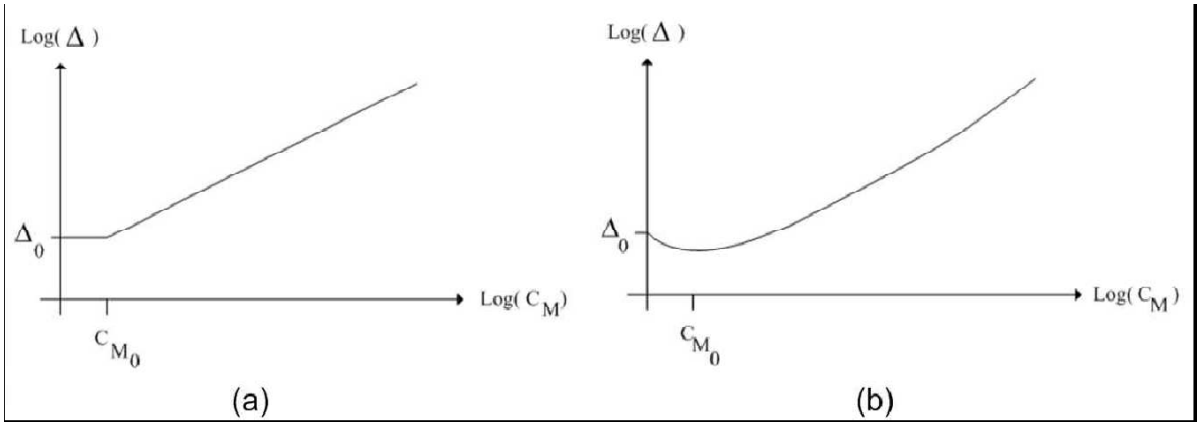
# Masquage Visuel

Modification of the visibility of a signal due to the presence of background (masking signal)

Two visual masking effects :

- Contrast masking :
  - Modification of the visibility threshold due to the contrast value
- Semi-local masking :
  - Modification of the visibility threshold due to the neighborhood (semi-locality) characteristics.
  - *Also called : Entropy masking, local texture masking, activity masking*

# Masquage



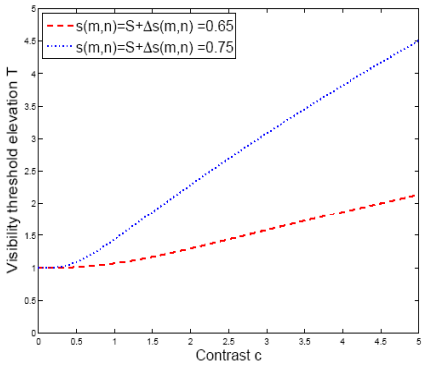

# Modèles de masquage visuel

*Masking functions from Daly's model*

➢Contrast masking *(Daly)*

$$T_{l,o}(m,n) = (1+(k_1 \times (k_2 \times |\tilde{c}_{l,o}(m,n)|)^{s})^{b})^{\frac{1}{b}}$$

***s is a constant***




➢Proposed semi-local masking *(Daly sLM)*

$$T_{l,o}(m,n) = (1+(k_1 \times (k_2 \times |\tilde{c}_{l,o}(m,n)|)^{s(m,n)})^{b})^{\frac{1}{b}}$$

*s(m,n) depends on the neighborhood entropy*



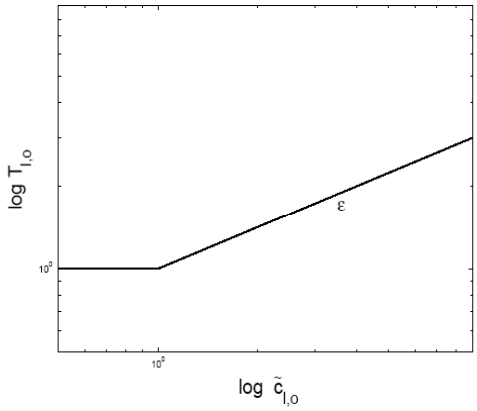
# Masquage Visuel

*Masking functions from Nadenau's model*

➢ Contrast masking *(Nadenau)*

$$T_{l,o}(m,n) = \max(1, \tilde{c}_{l,o}(m,n)^{\varepsilon})$$

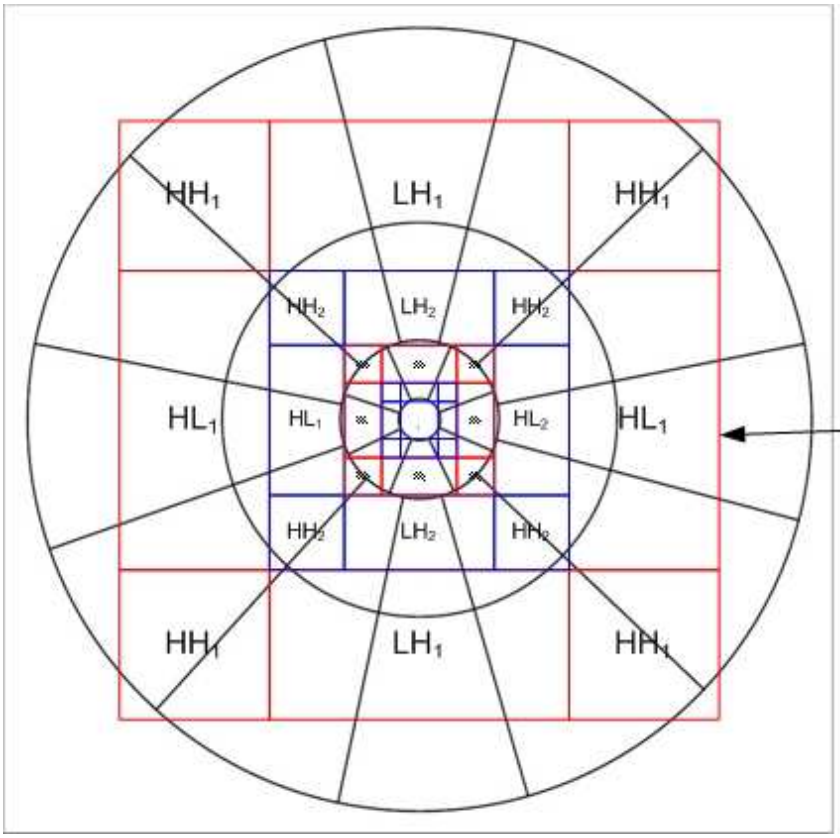
➢ Semi-local masking *(Nadenau sLM)*



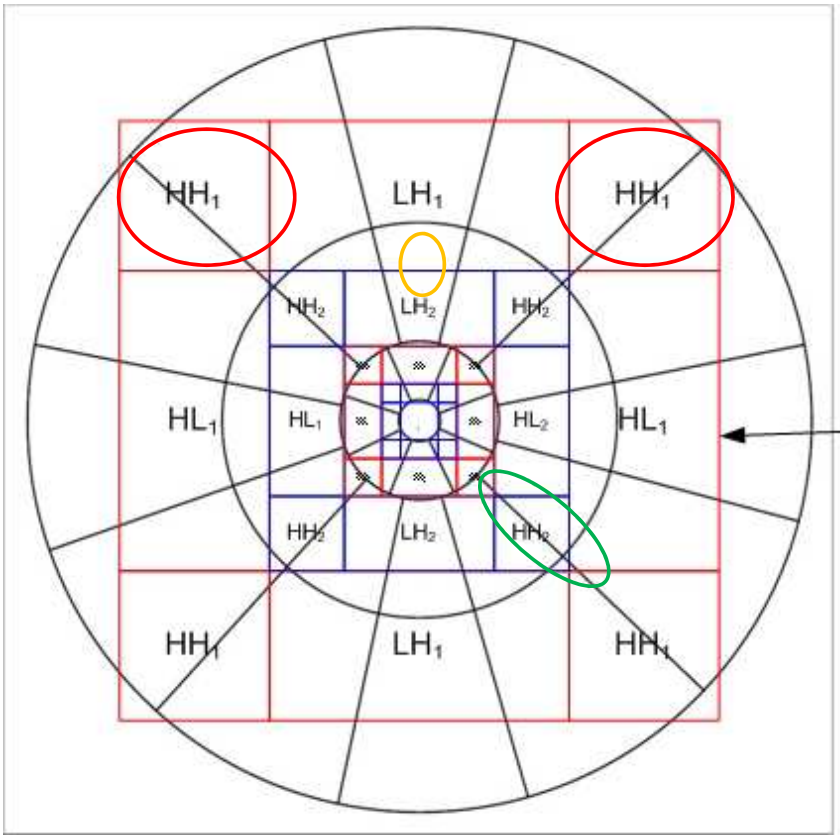

$$T_{l,o}(m,n) = \max(1, \tilde{c}_{l,o}(m,n)^{\varepsilon}).(1+\omega_{\Gamma})$$

*$\omega_\Gamma$ depends on the neighborhood energy*

## Modèles et approximations : DCP et ondelettes

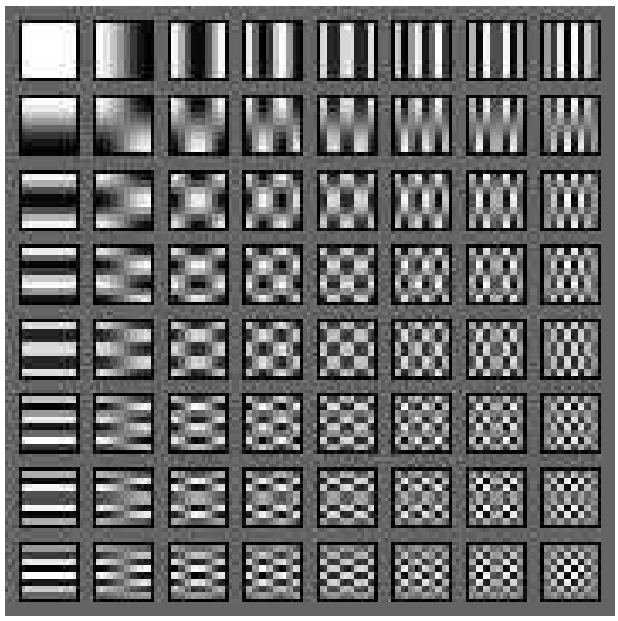



## Modèles et approximations : DCP et ondelettes



## Modèles et approximations : DCP et DCT

$$DCT(i,j)=\frac{1}{\sqrt{2N}}\sum_{x=0}^{N-1}\sum_{y=0}^{N-1}Pix(x,y)C(i)C(j)\cos\left[\frac{(2x+1)i\pi}{2N}\right]\cos\left[\frac{(2y+1)j\pi}{2N}\right]$$



Caractérisation et modélisation du Système Visuel Humain

Modèle JND

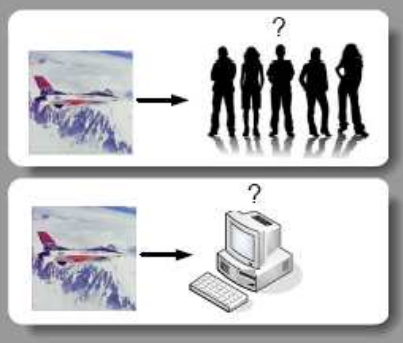
Utilisation des modèles dans des applications de traitements d'images ou de vidéo

Métrique de qualité « Full reference »

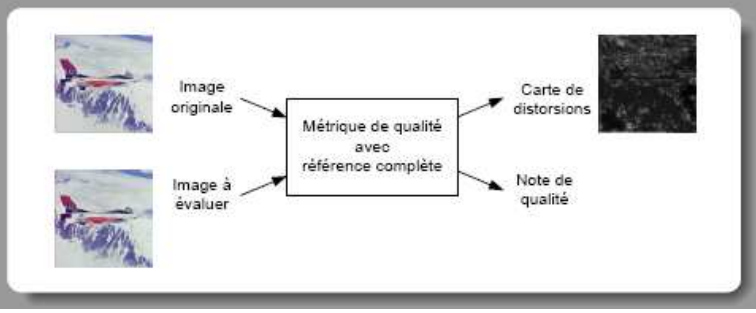
# Application: évaluation de qualité

L'évaluation de la qualité visuelle peut être :

- Subjective
- Objective




Métrique de qualité avec référence complète






# Experimental set up at IRCCyN for human factors studies

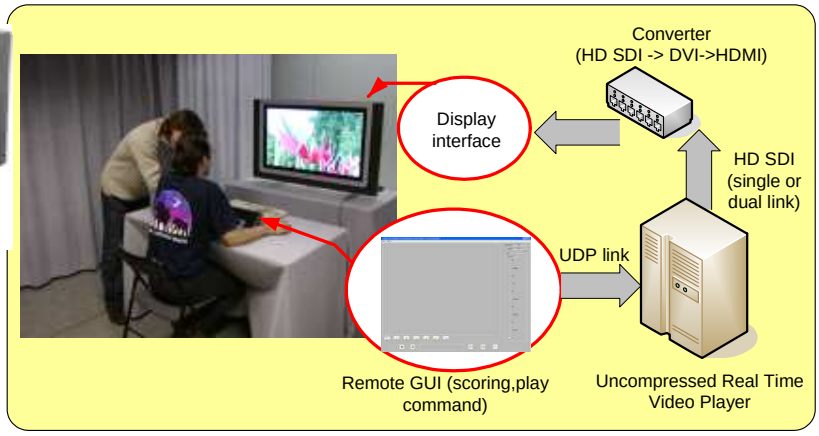
Suitable environment and protocols (and corresponding GUI)

HW players : uncompressed … up to 2K, 3D

Displays :

- CRT, LCD (**without post processing => offline processing**)
- High resolution Medical imaging
- Autostereoscopic displays (multiview, holographic …)

Large panel of observers

# Bases de données qualité

http://www.irccyn.ec-nantes.fr/ => plateformes

**Still images databases**

IRCCyN/IVC Still Image Database

Subjective Quality assessment of LAR coded art images

IRCCyN/IVC-Toyama database (LCD)

**Video database**

IRCCyN/IVC Videos 1080i Database

A 1080i50 videos database. This database is composed by 24 original sequences and 168 distorted videos by h264 coding.

IRCCyN/IVC Eyetracker SD 2009 12 Database

A SD videos database. This database is composed by 20 original sequences and 80 distorted videos by h264 coding with transmission errors. The h264 streams and the eyetracker data are available for this database.

IRCCyN/IVC SD ROI Database

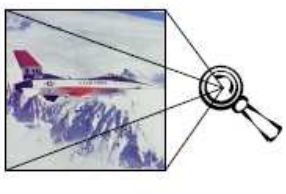
A SD videos database. This database is composed by 6 original sequences and 84 distorted videos by h264 coding with or without transmission errors. The h264 streams are available for this database.



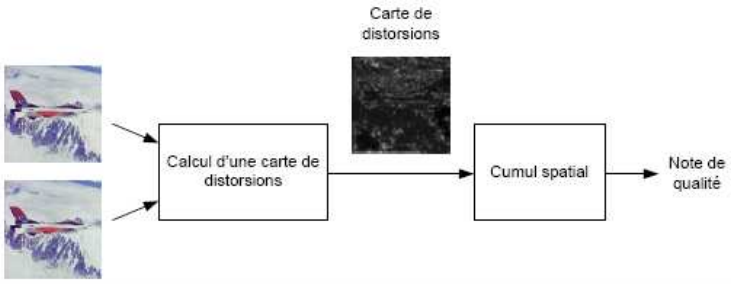
# Problématiques

- Concevoir une méthode objective d'évaluation locale des distorsions visuelles pour les images et les vidéos

- Concevoir une méthode objective d'évaluation globale de la qualité visuelle pour les images et les vidéos

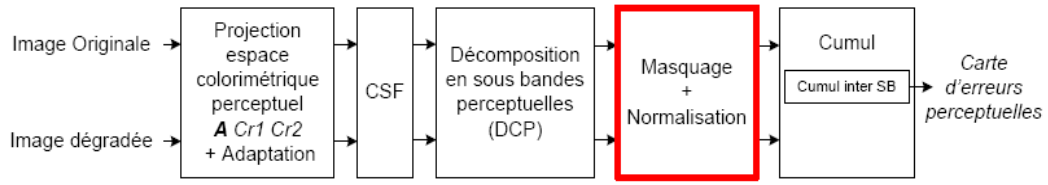


# Approches classiques




| Approches | Images fixes |
|---|---|
| **Purement de type signal** | PSNR |
| **Signal + aspects qualitatifs du système visuel humain** | SSIM[Wang04a]<br>MS-SSIM[Wang03] |
| **Modélisant finement le système visuel humain** | VDP[Daly92,93]<br>Sarnoff JND[Lubin93,95]<br>DCTune[Watson93] |

**Structure générale des modélisations [Daly92,93][Le Callet01]**




# Modèles de masquage

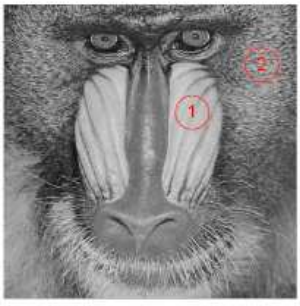
Masquage entropique [Watson97b] (ou de texture [Gaubatz05], ou d'activité [Nadenau00]) $\Rightarrow$ ou masquage semi-local

**Élévation du seuil différentiel de visibilité au site $(m, n)$ dans la sous-bande $\rho, \theta$**

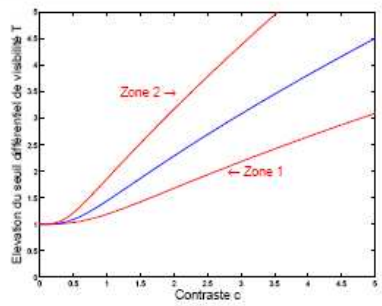
$$T_{\rho,\theta}(m,n) = (1 + (k_1 \cdot (k_2 \cdot |c_{\rho,\theta}(m,n)|)^{s(m,n)})^b)^{\frac{1}{b}} \quad (1)$$

**Version modifiée**

**Zones de complexité semi-locale différente**

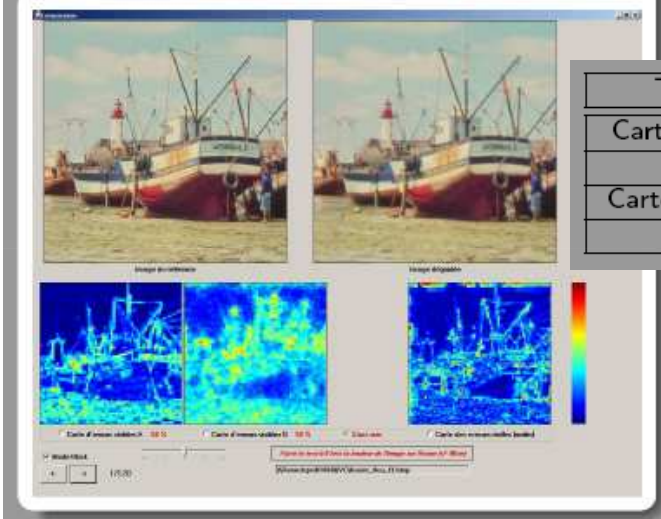



**Fonction de masquage modifiée**



# Première Validation

Tests de préférence d'une carte de distorsions visuelles parmi trois (interface)



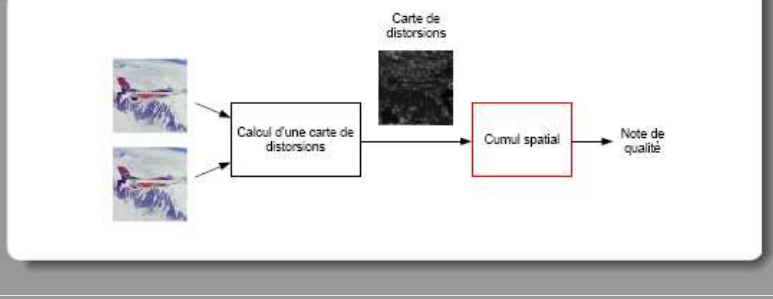
| Types de dégradations | Codage | Flou |
|---|---|---|
| Cartes d'erreurs quadratiques | 2.32% | 1.60% |
| Cartes de SSIM | 17.89% | 31.20% |
| Cartes de l'approche proposée | 65.89% | 37.60% |
| Pas de préférence | 13.89% | 29.60% |

On The Performance of Human Visual System Based Image Quality Assessment Metric Using Wavelet Domain
A. Ninassi, O. Le Meur, P. Le Callet and D. Barba, *SPIE Human Vision and Electronic Imaging XIII, HVEI 2008*



# Seconde Validation: évaluation globale de qualité

Structure générale d'une métrique de qualité visuelle avec référence complète

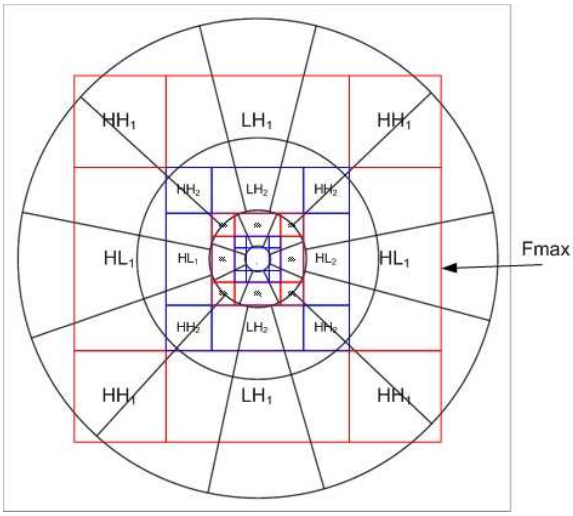



- Cumul spatial des distorsions (sommation de Minkowski)
- Évaluation des performances (tests subjectifs)

Corrélation avec les notes subjectives

| Notes Subjectives | | *IVC* |
|---|---|---|
| *PSNR* | | *0.768* |
| *SSIM* | | *0.832* |
| *MS-SSIM* | | *0.917* |
| Approche proposée | Sans masquage semi-local | 0.897 |
| | Avec masquage semi-local | 0.941 |

# Seconde Validation: impact de la décomposition




| Notes Subjectives | | IVC |
|---|---|---|
| *PSNR* | | *0.768* |
| *SSIM* | | *0.832* |
| *MS-SSIM* | | *0.917* |
| Approche proposée (Fourier) | Sans masquage semi-local | 0.897 |
| | Avec masquage semi-local | 0.941 |
| Approche proposée (Ondelettes) | Sans masquage semi-local | 0.892 |
| | Avec masquage semi-local | 0.923 |

Which semi-local visual masking model for wavelet based image quality metric ?
A. Ninassi, O. Le Meur, P. Le Callet and D. Barba, IEEE *ICIP2008*

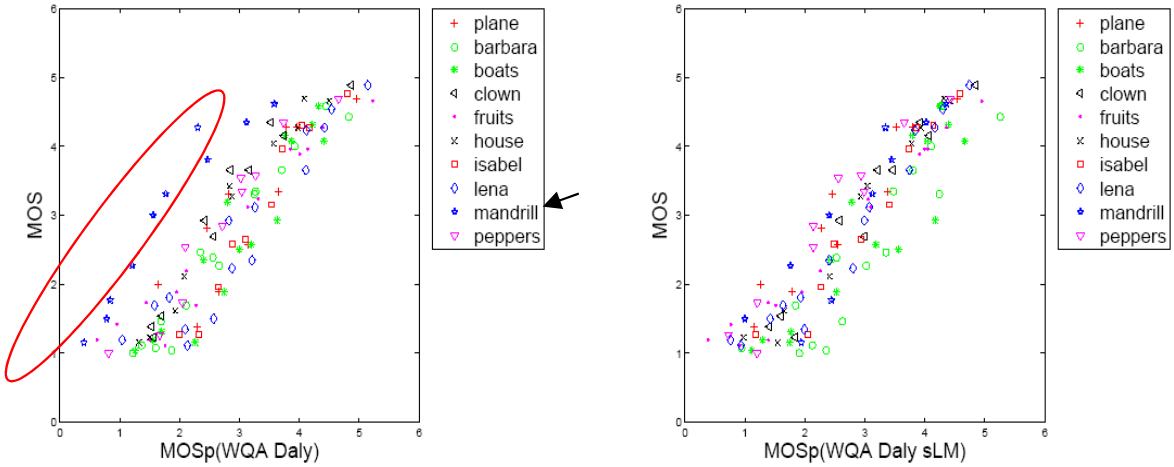


# Analyse qualitative

**MOS according to MOSp by reference image :**

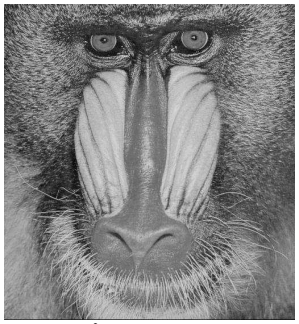
**A. WQA Daly without semi-local masking**
**B. WQA Daly with semi-local masking**

***One outlier image in (A) : Mandrill (picture with a lot active areas)***
***Is the masking effect underestimated in A. ?***

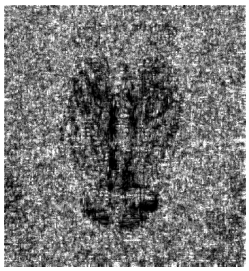


# Analyse qualitative

***Perceptual error maps***

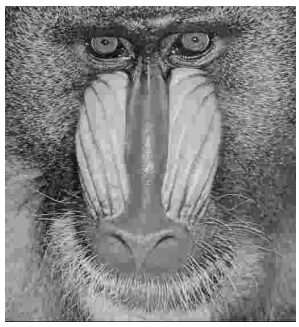


*Mandrill*



*WQA Daly without sLM :*

*Underestimation of the masking effect on the most active areas*



*Mandrill with JPEG compression*

*WQA Daly with sLM :*

*Better estimation of the masking effect on the active areas*

*(black = no perceptual error*
*white = strong perceptual error)*



Caractérisation et modélisation du Système Visuel Humain

Modèle JND

Utilisation des modèles dans des applications de traitements d'images ou de vidéo

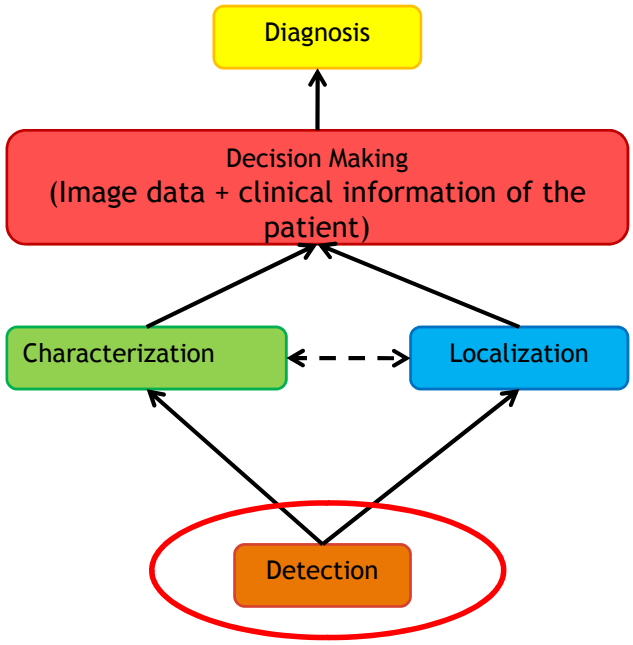
Qualité des images médicales

EQUIMOSE

Région PAYS DE LA LOIRE

# Task-based assessment

- Task-based assessment method has been widely used in the medical image quality assessment domain.
- The diagnostic task mainly comprises of three sub-tasks: detection task, localization task, and characterization task. Since the detection task is the first task, it becomes an essential task of study nowadays.



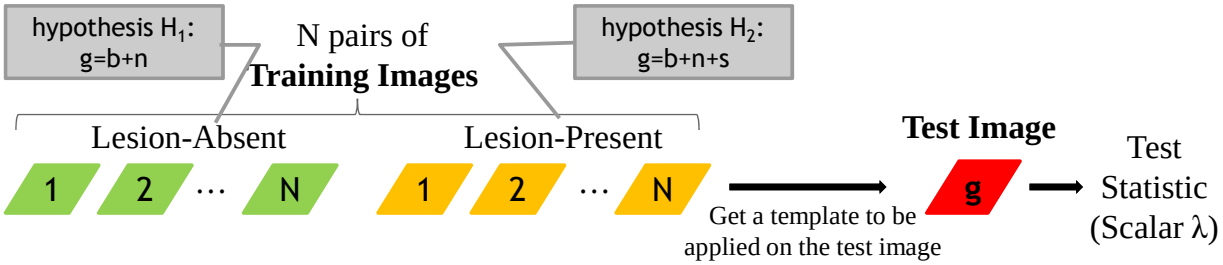



# Methodology

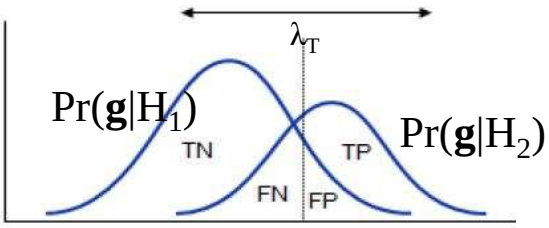
- Subjective task-based assessment
  - by a group of radiologists
  - costly and time-consuming
- Objective task-based assessment : mathematical models which perform a diagnostic task
  - optimal model observer which tries to maximize the task performance
  - perceptual model observer that approach the human observer performance

Our objective: not to replace the radiologists to process diagnosis, but to compare image processing algorithms or display systems from their perspective, to help them easily and quickly select an efficient algorithm or system to gain a high diagnostic accuracy.

# Approche optimale




$$\lambda = T(\mathbf{g}) \begin{cases} < \lambda_T & \text{lesion-absent (hypothesis } H_1) \\ \geq \lambda_T & \text{lesion-présent (hypothesis } H_2) \end{cases}$$




# Model observer

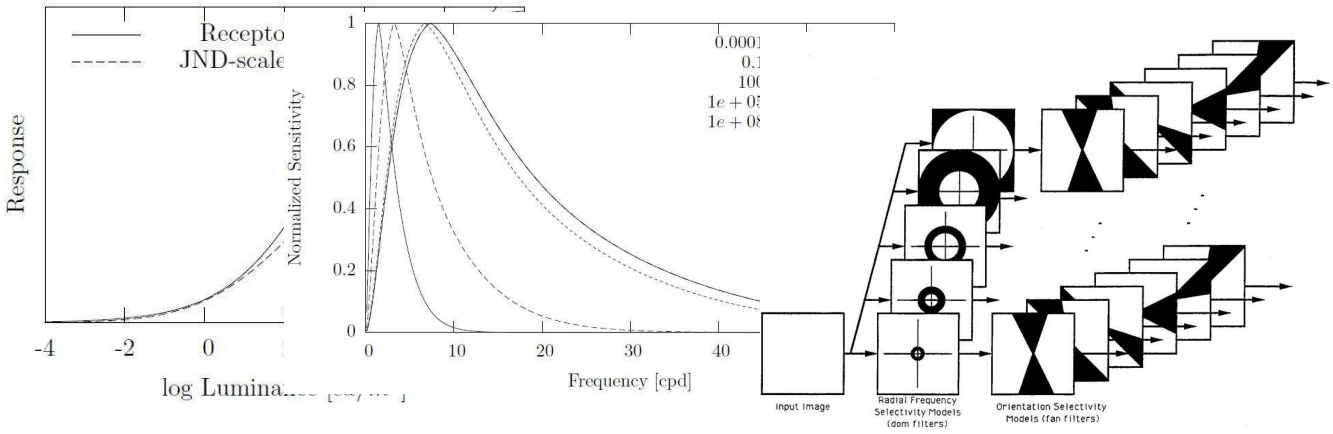
| | Ideal Observer (IO) | Hotelling Observer (HO) | Channelized Hotelling Observer (CHO) |
|---|---|---|---|
| **Necessary data to get the template** | Requires full knowledge of the probability density functions (PDFs) of the image for each hypothesis: $Pr(\mathbf{g}\|H_1)$ and $Pr(\mathbf{g}\|H_2)$. | Required only the first- and second- order statistics of the image data under each hypothesis. | Required only the first- and second- order statistics of the channelized image data. |
| **Calculability** | In general, these PDFs are high-dimentional functions and difficult to compute except for a few cases (e.g. signal-known-exactly; Gaussian background). | High-dimensionality : the ensemble covariance matrix of the image needs to be inverted, if the image dimensions are 256×256, its covariance matrix would be 65536×65536, which is practically not feasible. | Dimentionality reduction & less calculation Amount: normally the value of *P* is really small (much smaller than the value of M) |
| | optimal | optimal | optimal / perceptual |

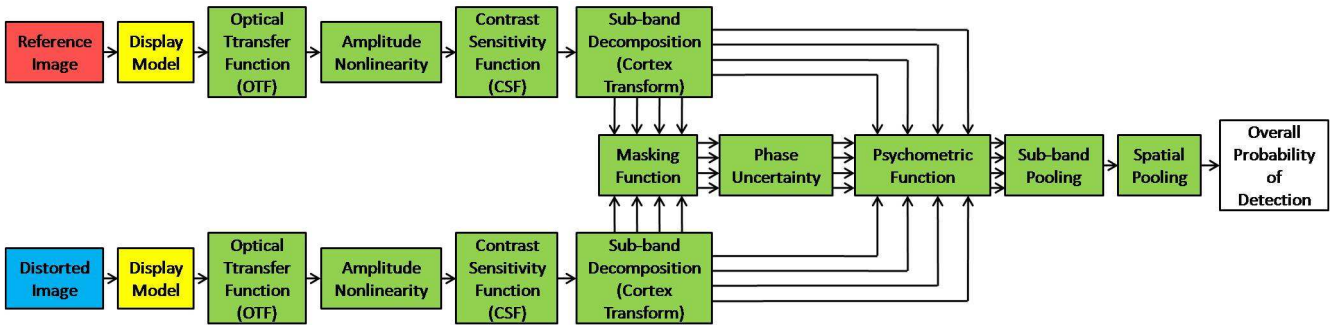
-> CHO normally outperforms humans in detection performance because of the human "inefficiency" which can be attributed in the first place to intrinsic uncertainty of the human observer about signal characteristics, such as the contrast, shape, size and orientation, as well as about background characteristics.

# approche perceptuelle

- Perceptual difference / HVS models (perceptual model observer)
- It's important to note that in psychology, human vision processing is conventionally regarded as two stages: sensation and perception. The existing HVS models are actually only sensation modeling.
  - Sensation: the function of low-level biochemical and neurological events that begin with the impinging of a stimulus upon the photoreceptors.
  - Perception: a dynamic cognitive process of interpreting information. Perception modeling is extremely complicated, since it depends on a lot of factors (e.g. medical image interpretation depends on radiologists' expertise, image modality, studied pathology, etc.).






HDR-VDP

## Differences of Perceptual Difference Models

| Function Parts | VDP | HDR-VDP | VCGC | SSO |
|---|---|---|---|---|
| **Amplitude Nonlinearity** | a photoreceptor model gives arbitrary units of response | a function converts luminance values to a non-linear space that is scaled in JND units | — | — |
| **Contrast Sensitivity Function (CSF)** | one CSF filter changing as a function of radial spatial frequency, orientation, adaptation luminance, images size in visual degrees, viewing distance, and eccentricity | a set of CSF filters for different adaptation luminance (0.0001, 0.01, …, 1000 cd/m$^2$) in place of only one CSF filter, since CSF changes significantly with adaptation luminance and remains constant above 1000 cd/m$^2$ | a band-pass filter with three parameters (note that the *CSF* is not explicitly indicated in the two papers [12], we have used the filter described in [14]) | a band-pass filter with three parameters (note that the *CSF* is not explicitly indicated in the two papers [13], we have used the HPmH filter defined in [15]) |
| **Sub-band Decomposition** | cortex transform filters | cortex transform filters | Gabor array | — |
| **Sub-band Pooling** | probability summation with product series | probability summation with product series | Minkowski summation | — |
| **Spatial Pooling** | probability summation with product series | probability summation with product series | Minkowski summation | Minkowski summation |
| **Masking Function** | a type of intra-channel (intra sub-band) masking: quantify the effect that the visibility of a signal decreases due to the presence of a supra-threshold background by a threshold elevation function of the background contrast | a type of intra-channel (intra sub-band) masking: a threshold elevation function of the background contrast which quantify the effect that the visibility of a signal decreases due to the presence of a supra-threshold background | a type of inter-channel (inter sub-band): a division of the excitatory signal from each neuron by an inhibitory signal that is a linear combination of responses of neurons within a neighborhood in space, frequency, orientation, and phase. | — |



# Perceptual Difference Models

- radiologists' behaviors vary in terms of sensation and in terms of perception; radiologists' behaviors and naïve observers' behaviors are unlike.
- Several different perceptual difference models exist.
- Subjective experiments with radiologists have to be done for several questions:

(1) Could the HVS models based on subjective experiments with naïve observers be used as the radiologists' sensation modeling? The performance of which model is the most approximate to that of radiologists?

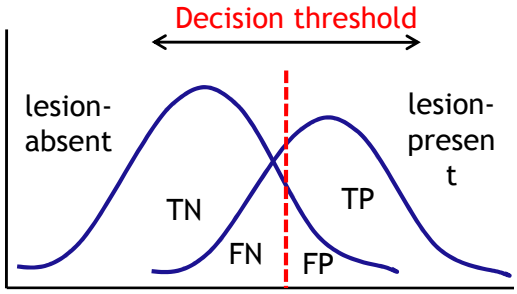
(2) How much HVS models could approach radiologists' perception stage performance? Which model is better in this sense?

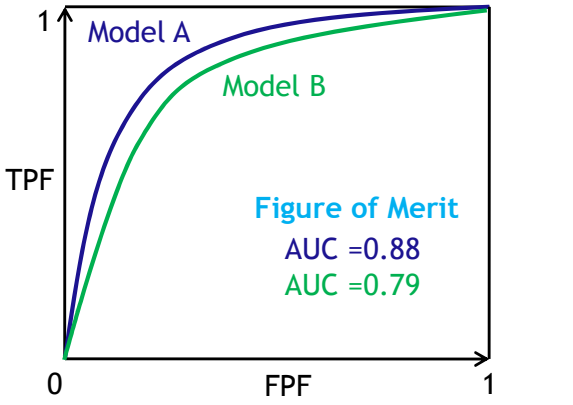
L. Zhang, C. Cavaro-Ménard, P. Le Callet et al., "The effects of anatomical information and observer expertise on abnormality detection task," *Proc. SPIE Medical Imaging*, vol. 7966, 2011.

# Comparison of Perceptual Difference Models

**Use radiologists' consensus as gold standard so that the estimated AUC measures the distance between the HVS model and the radiologist perception**

| 4 scenarios | | Gold Standard | |
|---|---|---|---|
| | | lesion-present | lesion-absent |
| Decision | positive | TP | FP |
| | negative | FN | TN |



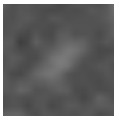




ROC (Receiver Operating Characteristics)

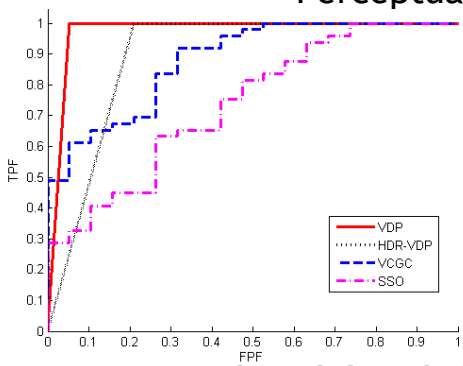


## Subjective experiments for the consensus

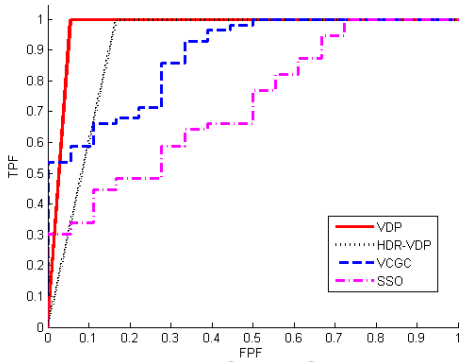
- **Case 1 (sensation task on whole cerebral slice):** A healthy cerebral MR slice of T2 FLAIR sequence with one superimposed simulated lesion is shown to the radiologist. We asked radiologist if he can detect a hyper-signal on the slice.
- **Case 2 (sensation task on white matter region):** A homogeneous white matter region selected from the same slice used in the experiment 1 (to ensure its characteristics remain the same, e.g. Fig. 5) with one superimposed simulated lesion is shown to the radiologist. We asked radiologist if he can detect a hyper-signal on the region.
- **Case 3 (perception task on whole cerebral slice):** The same whole cerebral slice as in experiment 1 is shown to the radiologist in each trial. This time, we asked radiologist if a clinical sign exists on the slice.
- **Case 4 (perception task on white matter region) :** The same homogeneous white matter region as in experiment 2 is shown to the radiologist. We asked radiologist if a clinical sign exists on the region.



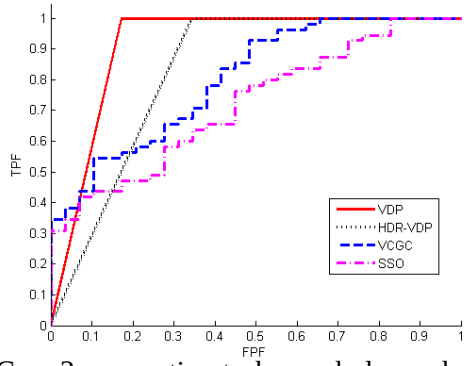
## Comparison of Perceptual Difference Models



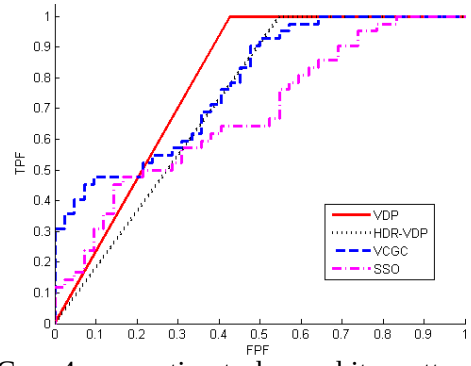

Case 1: sensation task on whole cerebral slice




Case 2: sensation task on white matter region




Case 3: perception task on whole cerebral slice




Case 4: perception task on white matter region



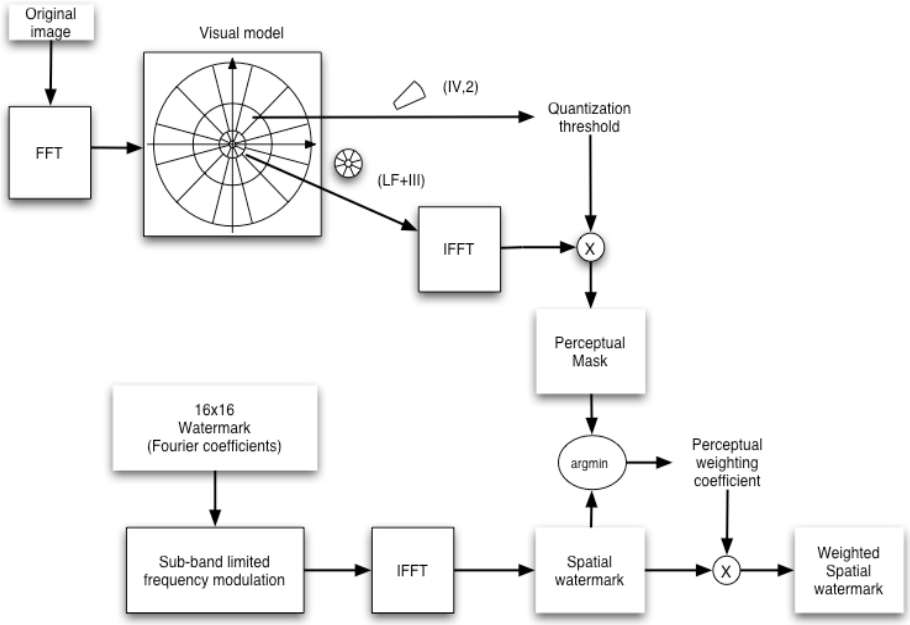
Caractérisation et modélisation du Système Visuel Humain

Modèle JND

Utilisation des modèles dans des applications de traitements d'images ou de vidéo

tatouage

# perceptual watermarking




*F. Autrusseau et P. Le Callet*
*A robust image watermarking technique based on quantization noise visibility thresholds*
*Signal Processing, Elsevier, june 2007, Vol. 87 , Issue 6, Pages 1363-1383*



Caractérisation et modélisation du Système Visuel Humain

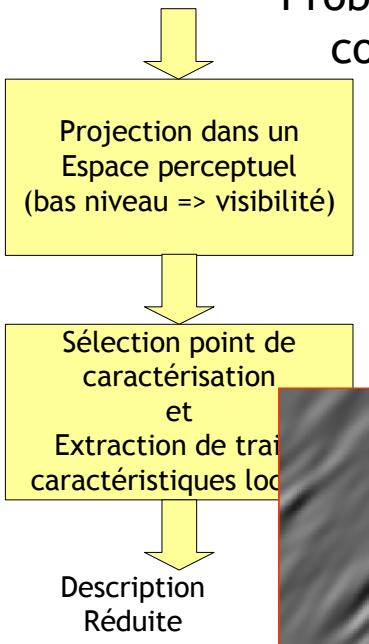
[redacted]

Utilisation des modèles dans des applications de traitements d'images ou de vidéo

[redacted]

# Représentation perceptuelle réduite

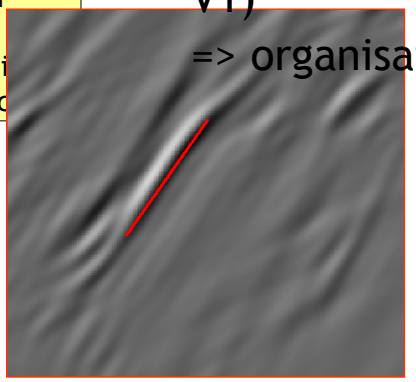
Problème : extraction de traits caractéristiques comparables à ceux utilisés par le SVH




Extraction d'informations liées à la reconnaissance

=> information structurelle locale (aire V1)

=> organisation topologique (aire V2)



**Structures linéiques** décrites par des paramètres géométriques

**+ Valeurs moyennes locales** (luminance+couleur)



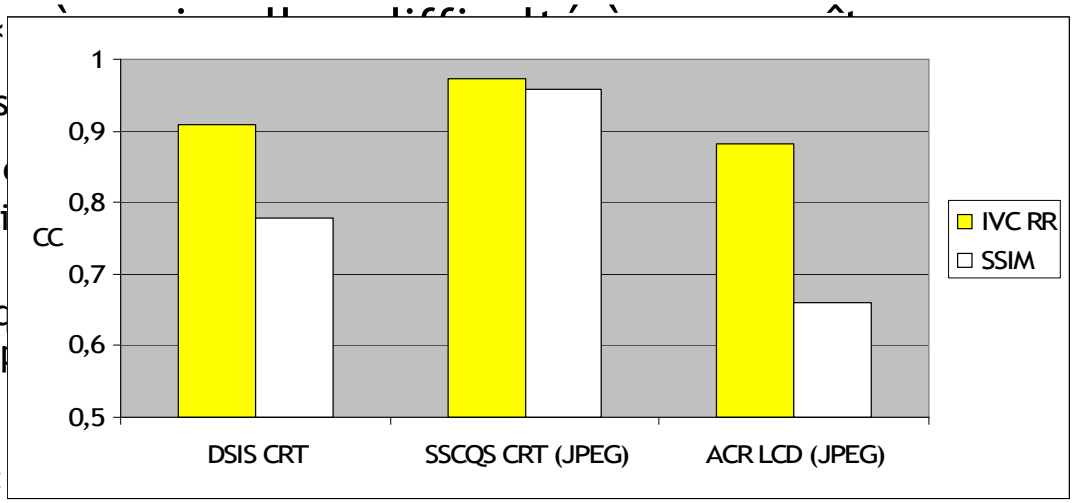
# Application métriques de qualité RR (image fixe)

«

Hypothès

Relation
(relati

=> Métric
percep




Validation :

Protocoles : DSIS *(Double Stimulus Impairment Scale)*, ACR *(Absolute Category Rating)*, SSCQS *(Single Stimulus Continuous Quality scale)*

Écrans CRT et LCD

Distorsions

Objective quality assessment of color images based on a generic perceptual reduced reference , M Carnec, P Le Callet and D Barba, *Signal Processing: Image Communication, Volume 23 , Issue 4, Pages 239-256, April 2008.*

Caractérisation et modélisation du Système Visuel Humain

[redacted]

Utilisation des modèles dans des applications de traitements d'images ou de vidéo

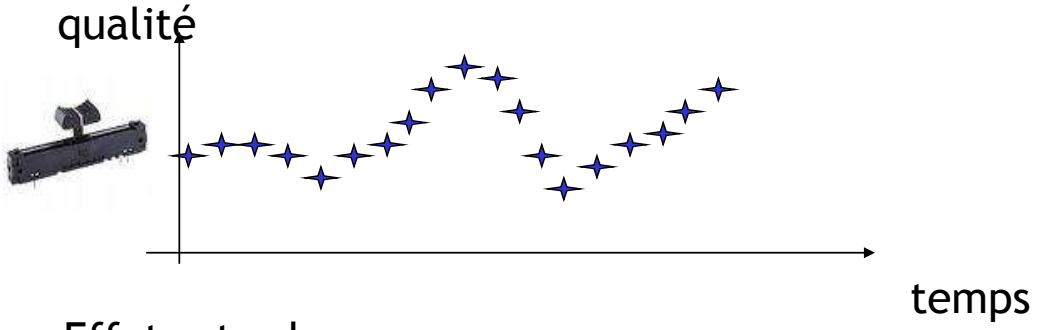
[redacted]



# Mécanisme haut niveau

Problème : intégration temporelle dans la construction du jugement de qualité

Cas particulier : évaluation continue (protocole SSCQE)

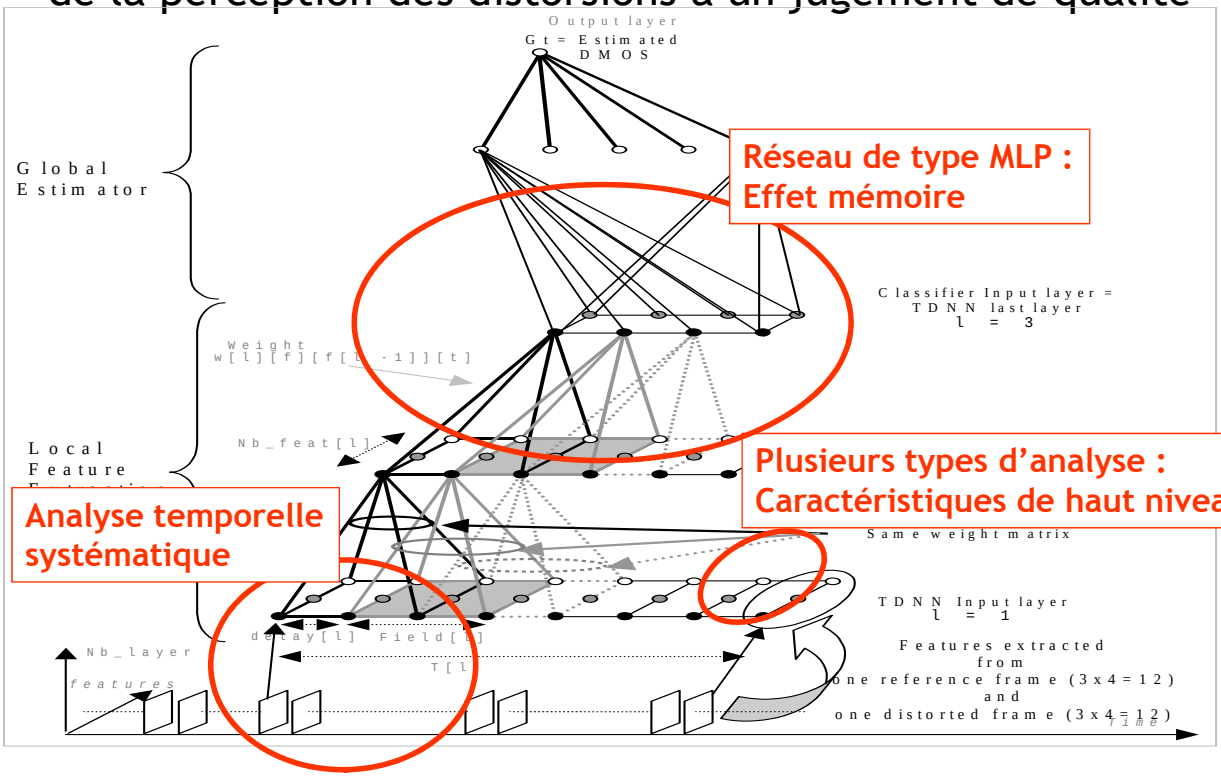



Effet retard

Stephen Wolf : «Humans are quick to criticize, slow to forgive» => effet mémoire

# Mécanisme haut niveau

## de la perception des distorsions à un jugement de qualité




A convolutional neural network approach for objective video quality assessment , P Le Callet, C Viard-Gaudin and D Barba, *IEEE Transactions on Neural Networks, Vol. 17, Issue 5, 2006.*