Observatoire 3DFovéa:
IMT/TB, CHRU Brest, INSERM U1101, IRBA
Orthoptica, Ophtapointvision.

Objets d'études au sein de 3DFovéa:

- Confort et acceptabilité (PAD).
- Analyse fusion verticale (décompensation d'hétérophorie).
- Compensation des post-effets liés au mouvement.
- Elaboration d'outils de dépistage et de rééducation des troubles de la vision binoculaire.

Motion in depth perception in stereoscopic images

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(Telecom Bretagne, CHRU Brest, INSERM U1101)

RT Santé numérique Brest, 13 septembre 2013

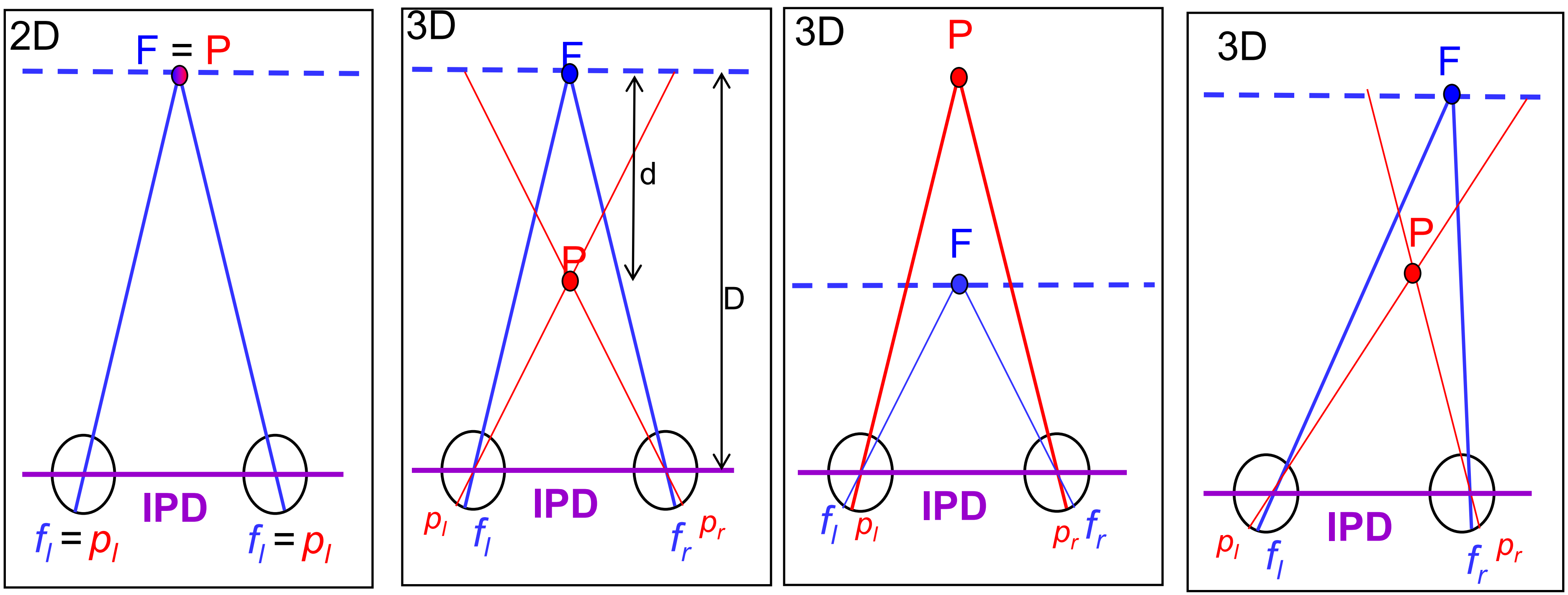
Relief perception using stereoscopic pairs

F = fixation point
P = object
IPD = intra-pupilar distance (A)

No fixation disparity (no relief)

Crossed disparity $p_l f_l = p_r f_r$

Uncrossed disparity $p_l f_l = p_r f_r$



Negative Parallax

Positive Parallax

No side view

$$\eta = \pm \frac{Ad}{D^2 \mp Dd}.$$

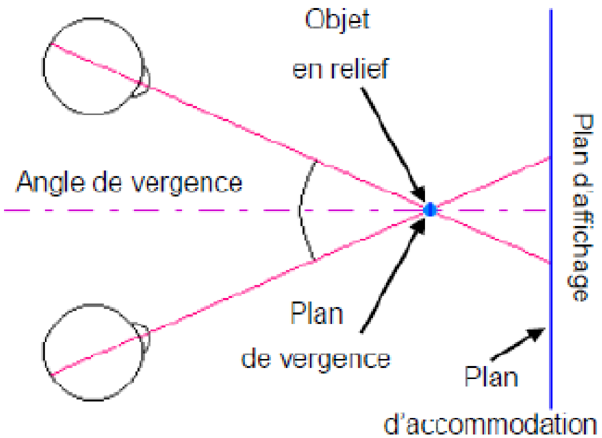
η is a function of the distance and IPD

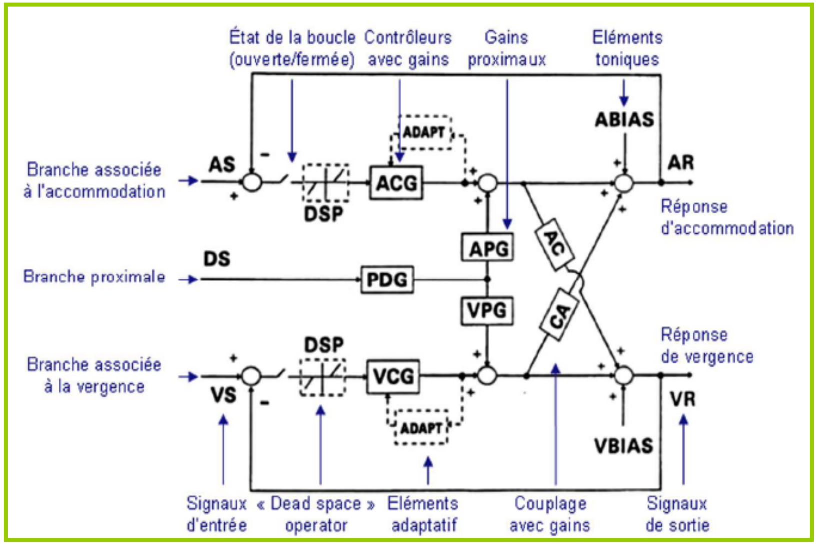
Accommodation-Vergence (A&V)

-Natural vision, A&V demand co-varies (interactive dual-feedback exists).

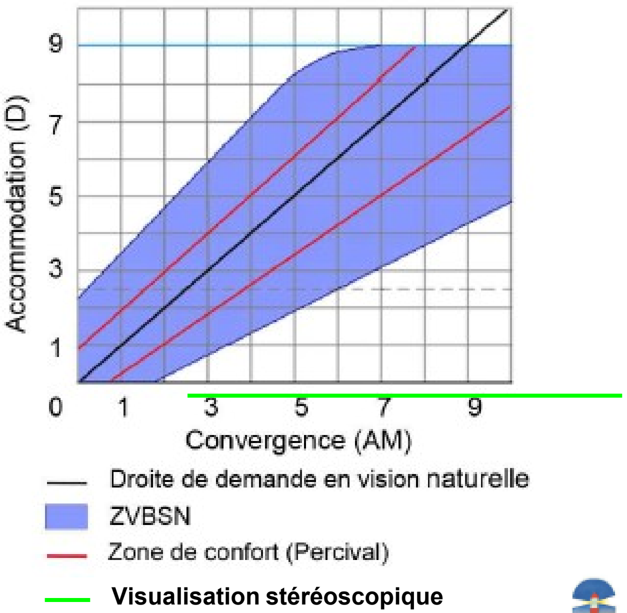
-3D vision, A&V does not operate in a synkinetic way, resulting in oculomotor conflicts.

Both A&V exhibit adaptation after extended near viewing. When the stimulus is removed, the A&V system returns towards its tonic position. If stimulus is removed after an extended focusing effort, the relaxation is much slower.

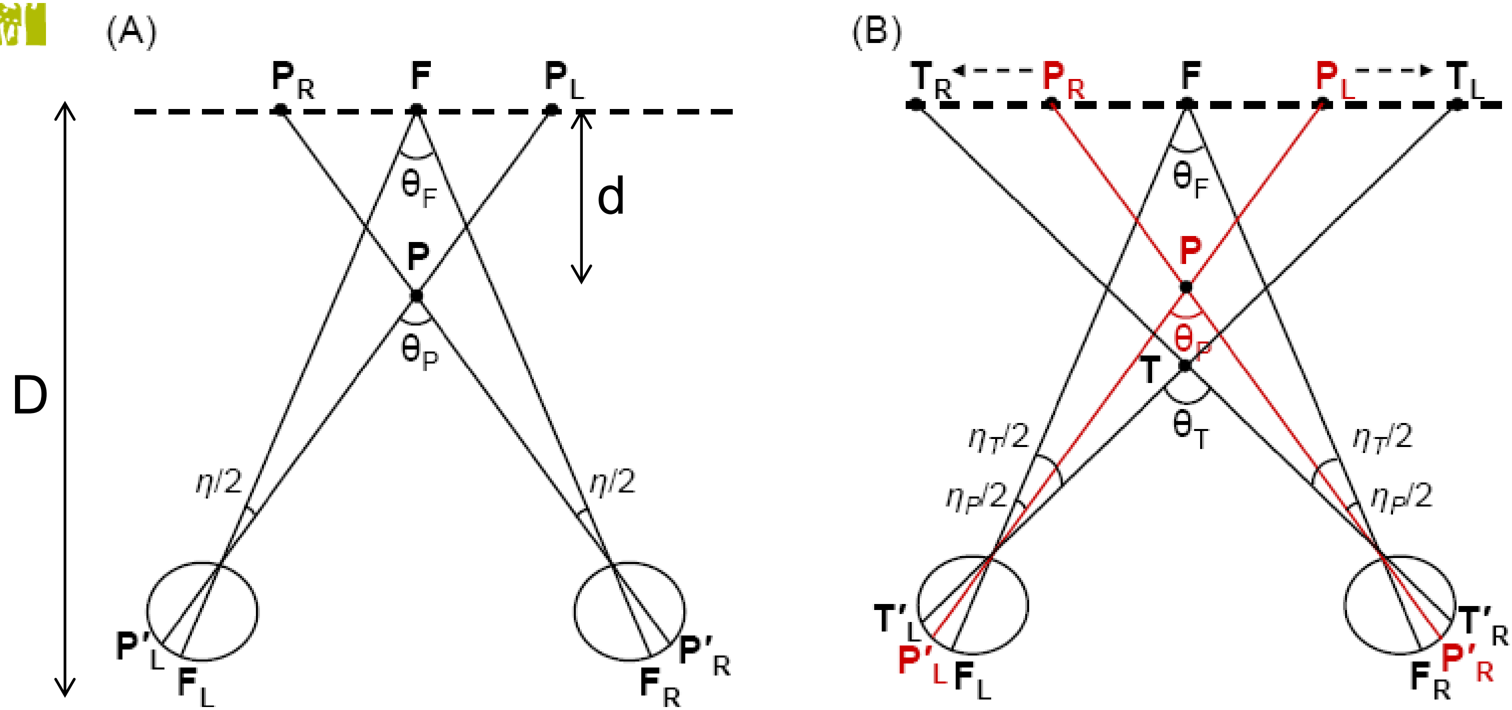




Static model of accommodation and vergence systems of Hung (1996)



Stereo-motion process



$$\eta = \pm \frac{IPD \cdot d}{D^2 \mp Dd}$$

$$\frac{\eta_P}{dt} - \frac{\eta_T}{dt} = \frac{\vartheta_P}{dt} - \frac{\vartheta_T}{dt} = \frac{\Delta \eta}{\Delta t} = \pm 2sf$$

ηis a function of the distance and IPD

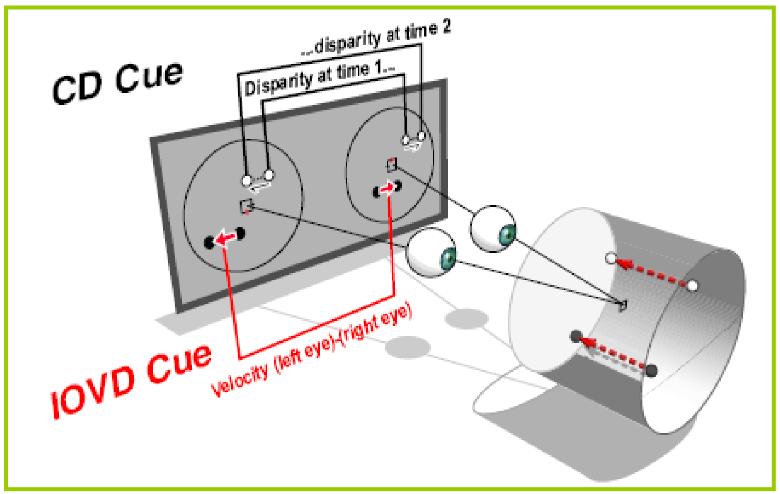
Stereomotion process. (A) The object **P** moves toward to the position of **T** relatively to fixation point **F**. The changes of binocular disparity (**η**), ocular vergence (**θ**), and position of image on the both retinae are changed over time in that way. The image of the fixation point is always projected on the left and right eyes fovea, F_L and F_R, respectively.

Accommodation/Vergence conflicts and Motion in Depth Perception cues.

Analyse the link (and conflict) between cortical mechanisms (mono- & binocular perception) and accommodation vergence (reflex) mechanism.

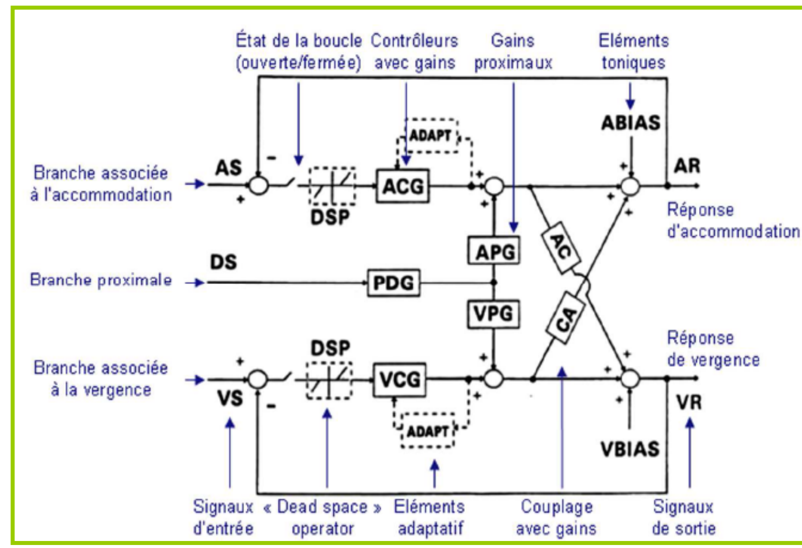
How do these models co-operate? Are they responsible for after-effects?

What kind of link exists with psychological reaction mechanisms (blinking eyelids, saccades etc.)



Link

conflicts



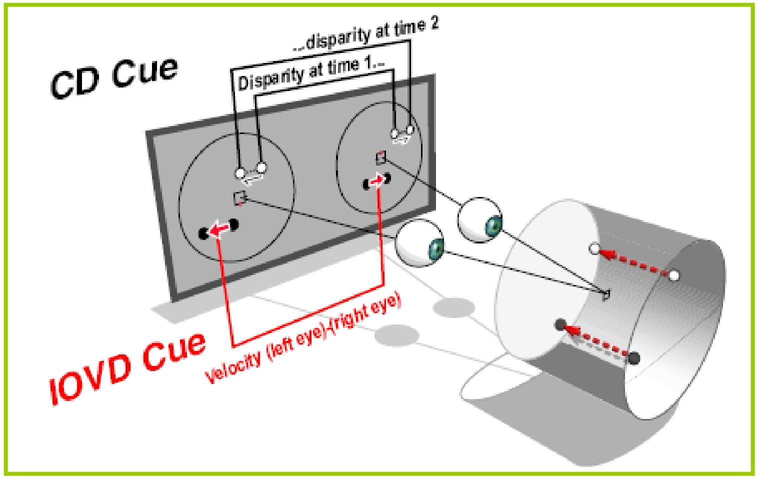
Model of monocular and binocular perception

Static model of accommodation and vergence systems of Hung (1996)

IOVD = InterOcular Velocity Difference

CD = Changing Disparity

MID perception (cortex level)

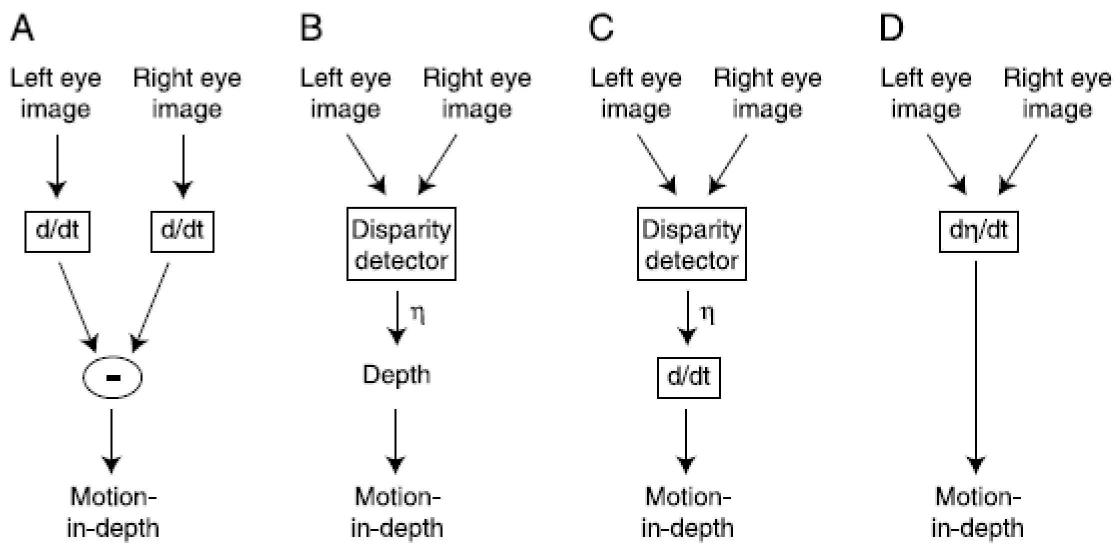


IOVD - interocular velocity difference

Each monocular image moves at a different velocity, providing a second potential source of information - IOVD cue. To use this signal, two separate and independent monocular velocity signals must first be derived, and subsequently combined vectorially across the two eyes (Figure A)

CD - changing disparity over time

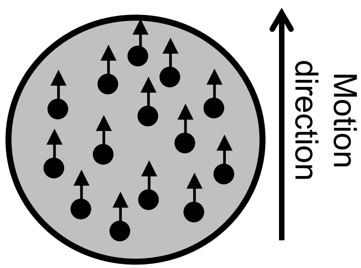
Positional information must first be combined from both monocular images to establish a disparity signal, which can then be differentiated over time to yield the speed of the object in depth (Figure B – D)



Sakano, Allison, & Howard, Journal of Vision (2012) 12(1):11, 1–15

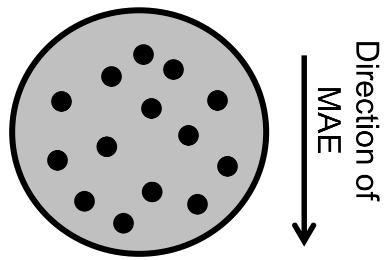
MID impacts measured by MAE magnitudes

Step 1: MID perception

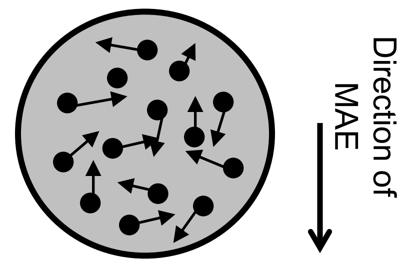


100% coherent motion

Step 2: Reaction - observing MAE



Case (a): stable image

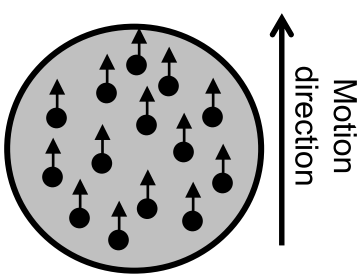


Case (b): 0% coherent motion

Exemple of MAE:
Waterfall illusion

Scheme of one trial for creation and measuring strength of MAE using RDS

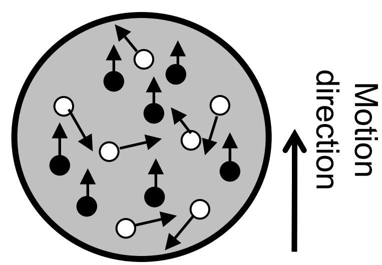
MID adaptation



100% coherent motion

MAE

Nullify MAE



50% of coherent motion

Correctly matched quantity of signal dots compensate MAE. **The larger the percentage of signal dots needed to null the DMAE, the stronger the after-effect** (Blake, 1993).

↑ Shows magnitude of motion

MID perception mechanisms

3D motion in complex scenes

Oculomotor system

RD
(relative disparity : CD & IOVD)

AD
(absolute disparity)

A/V conflict
(accommodation/vergence)

MID adaptation is revealed by MAE
(motion aftereffect)

exposure time

?

A/V conflict adaptation is revealed by oculomotor changes

Measuring MAE
(nulling paradigm)

?

Measuring oculomotor changes
(pre/post exposure paradigm)

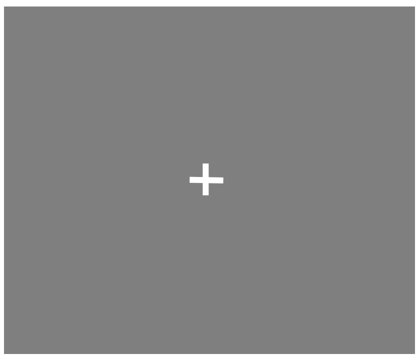
Study the link between RD and AD in MID perception :

conflict, co-operation, relative contribution of each process of MID perception?

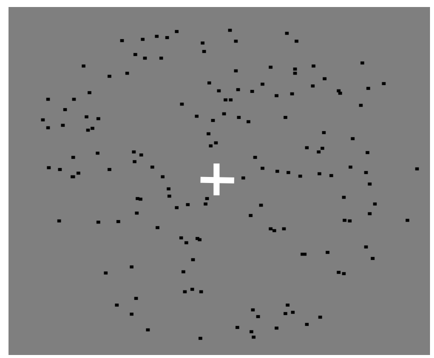
A&V versus CD&IOVD

Investigation of different channels for 3D motion perception (MID).

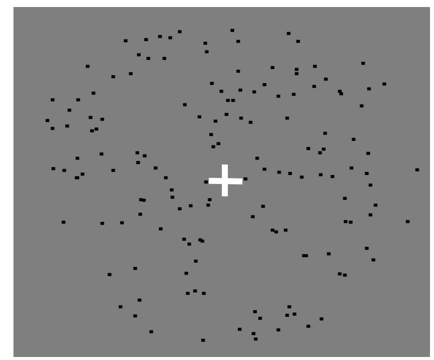
A/V reflex stimulus	**CD/IOVD cortical stimulus**	**co/contra A/V CD/IOVD stimuli**
Experiment 1	Experiment 2	Experiment 3 :



Sine or pendulum motion of a central cross



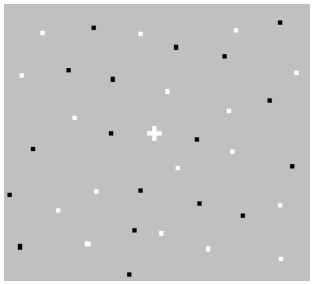
Dynamic Random Dot Stereograms (DRDS). Central steady cross



Sine motion of central cross and DRDS

Physiological and perceptive Motion After-Effect?

Typical used protocol



Impact of RD on MAE and oculomotor system?

- **Motion of the dots relative to the cross = RD.**
- **IOVD chosen because:**

➔ direction discrimination for 3D motion is primary supported by velocity based cue (monocular cues).

➔ more relevant for faster speed and peripheral zone (T. B. Czuba et al., 2010)

➔ **generating** strong MAE ➔ better for adaptation as well as perception of 3D motion.

RDS = only RDS containing disparity information for every dots depth perception is studied in its purest form. For RDS, local and global information can be independently manipulated.
Number of dots: 80 viewed by each eye. **Dots color:** depending of the stimulus presented.

- **MID perception: 150 trials,** 100s initial adaptation (IOVD : dot pairs binocularly anti-correlated, each black dot on one eye paired with corresponding white dot on other eye. Dots moved in opposite directions on the left and right eye with constant monocular velocity resulting in temporally correlated motion.

1 trial:

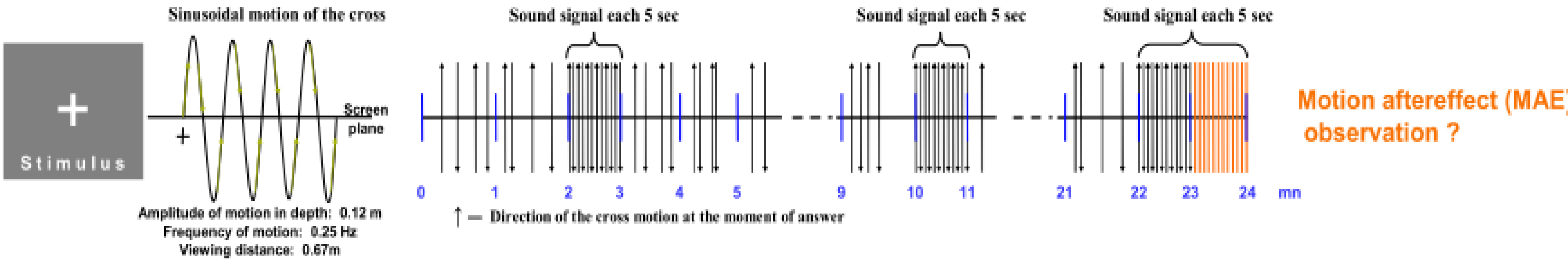
- adaptation period 4s (IOVD: toward or backward),
- inter-stimulus interval 1.25 s (noise),
- 1 s of test stimulus (full stimulus (IOVD + CD) = signal dots (toward/backward) + noise dots),
- inter-stimulus interval 1.25s = subject determine the target motion of when signal sound appears.

- Signal dots % tested (coherence levels): ± 5, 20, 50, 80, 95% (15 trials per level).

First results: A/V reflex stimulus

(Presented at ECVP conference Bremen 2013)

9 subjects exposed to a 23 min moving cross followed by 1 min steady cross fixation. Subjects are instructed to discriminate cross motion direction in depth during the 24 min exposure. Oculomotor system is assessed before and after exposure using an haploscope-optometer. A questionnaire about occurrence, duration of diplopia is proposed to all subjects at the end of experiment.



From questionnaire results, a majority of subjects had diplopia ($p = 0.02$, $\chi 2 = 5.44$), but during less than 30% time of experiment ($p< 0.01$, $\chi 2 = 15.38$). Diplopia appeared especially for a relative divergence to the screen ($p = 0.03$, $\chi 2 = 9.22$) and independent on the period of the test (beginning/middle/end).

- Presence of fatigue does not affect target motion direction definition as well as AD changes do not produce any motion aftereffects, thereby excluding possibility of illusory motion interfering real motion perception.
- The experimental data shows that crosslink interaction between accommodation and vergence tends to changes by prolonged stimulation of OS in stereoscopic displays.
- Despite the stereo devices are able to create diplopia, i.e. discomfort of MID perception, it seems that OS is capable of adapting to other conditions than ordinary ones and thus reduces generated discomfort.

Test carried out on a new population sample (25 subjects)

Acknowledgments

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- J.B. Curt ingénieur de recherche (3DFovéa).

The students of Télécom Bretagne as volountary subjects

APPENDICES

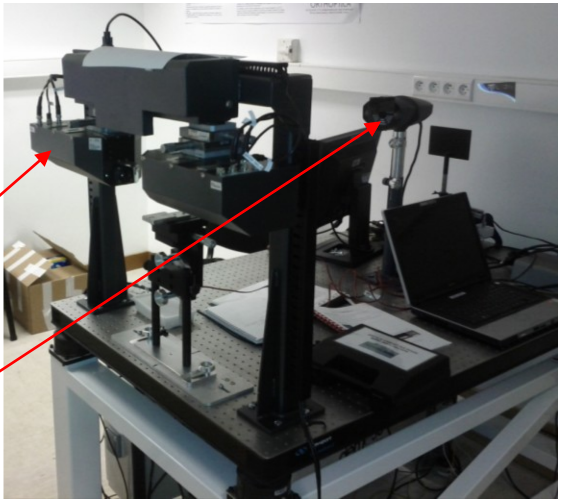
Oculomotor change measurements

- **Device used: haploscope-optometer**

  Ciuffreda 1997, Schor 1986, Kasthurirangan. 2003

2 arms: 1 for accommodative stimulation (on the dominant eye), 1 for vergence stimulation and measurements (nonius technique).

1 optometer: continuous assessment of accommodation**.**



Oculomotor parameters assessed:

- tonic accommodation and vergence = minimal innervations of the oculomotor system (i.e. position of rest)

- accommodative/vergence crosslink = accommodative stimulus simultaneously results in accommodative and vergence responses (accommodative vergence, i.e. AC/A) and inversely for vergence stimulus (vergence accommodation, i.e. CA/C).

Test protocol and target depend of oculomotor parameters assessed

Méthodologie analyse données

Exemple tests de verticalité

(examen sous écran du parallélisme)

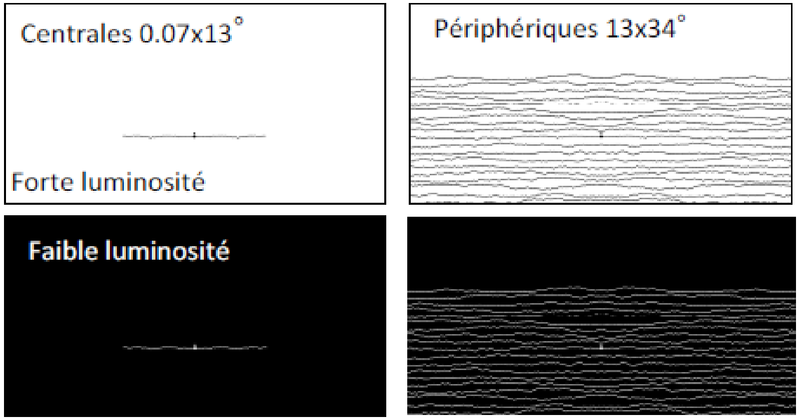
Type de données recueillies :

Distance de visualisation 1,5 - 3 m

Régime luminance : scoto/méso/photopique

Dispositif visualisation : Projecteur DLP/ TVPDP

Méthode d'analyse : ANOVA => Quels sont paramètres ou combinaisons de paramètres qui influencent le résultat.



Sujet	Dispositif	Distance (m)	Condition lumineuse	Fond	Dimension	Aléatoire	Résultat (D)
1	DLP	1,5	Scotopique	Blanc	Périph	Oui	1,93
1	DLP	1,5	Scotopique	Blanc	Centrale	Oui	0,75

La fusion est influencée par ? :

- la taille de la cible
- la distance de la cible
- les conditions lumineuses
- le contenu de l'image
- le dispositif de visualisation

Le paramètre de distance influence significativement le résultat

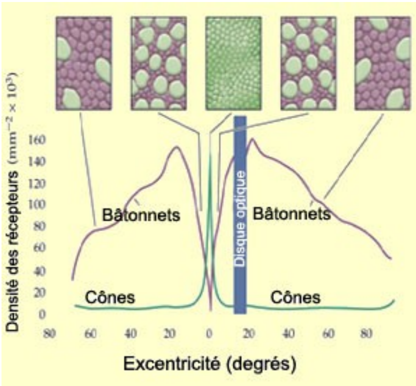
Tableau ANOVA

	Valeur de p	Puissance
Distance	<,0001	1,000
Condition lumineuse	,0730	,420
Fond	,0030	,881
Sujet * Dispositif	,0030	,905

La taille du groupe étudié est suffisante pour ce paramètre

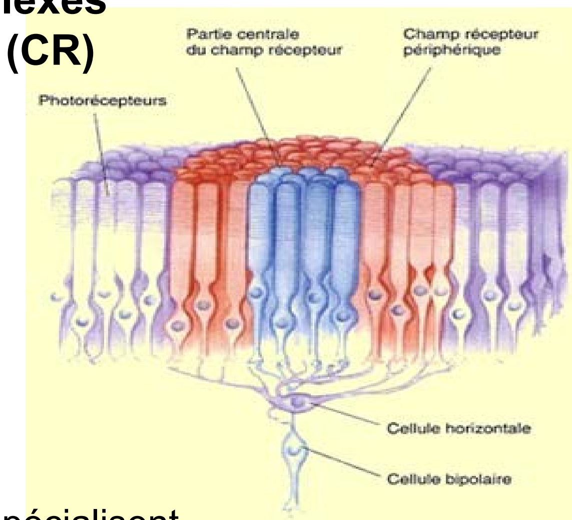
Ces paramètres n'influencent pas les résultats mais la puissance du test est mauvaise donc il faut augmenter la taille de l'échantillon.

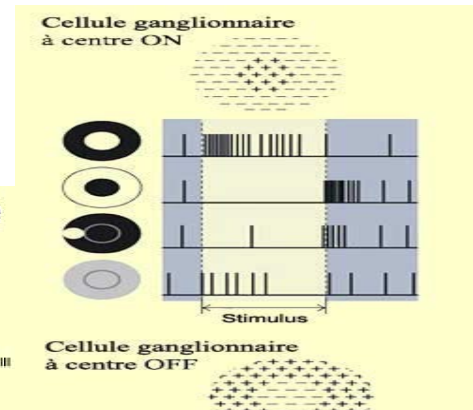
3D et mouvements (physio):



La perception de stimuli visuels complexes s'effectue par des champs récepteurs (CR)

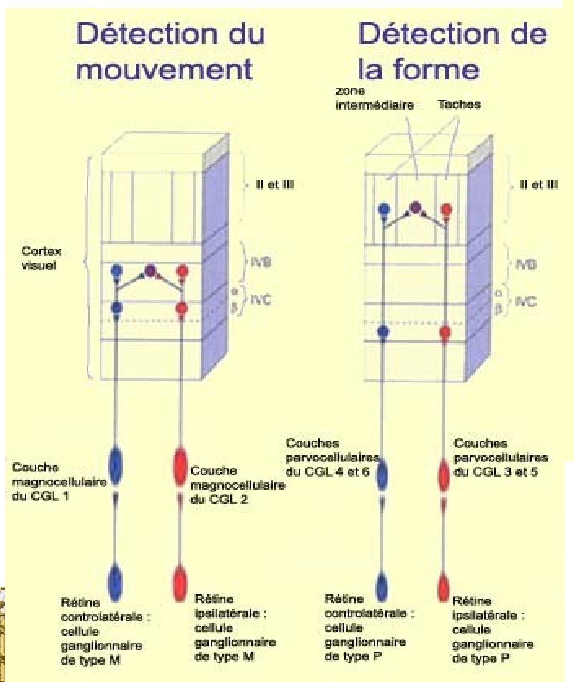
Outre les liens directs avec les photorécep -teurs, les cellules bipolaires reçoivent des afférences de cellules horizontales.





Informations radiales et horizontales spécialisent l'analyse de l'information visuelle couplée à sommation temporelle liée au temps de dépolarisation des récepteurs.

D. Hubel & T. Wiesel (Nobel 81)



Les cellules de type M ont les plus grands champs récepteurs, propageant les potentiels d'action plus rapidement dans le nerf optique (impliquées dans la détection du mouvement).

Disparition scintillement 50Hz en vision centrale, 85Hz en périphérique

Effet β: 2 images légèrement décalées présentées rapidement sont perçues en mouvement du fait de l'intégration des champs récepteurs et des aires corticales visuelles impliquées dans la détection-orientation du mouvement.