Normandie Université

Sensory Substitution :

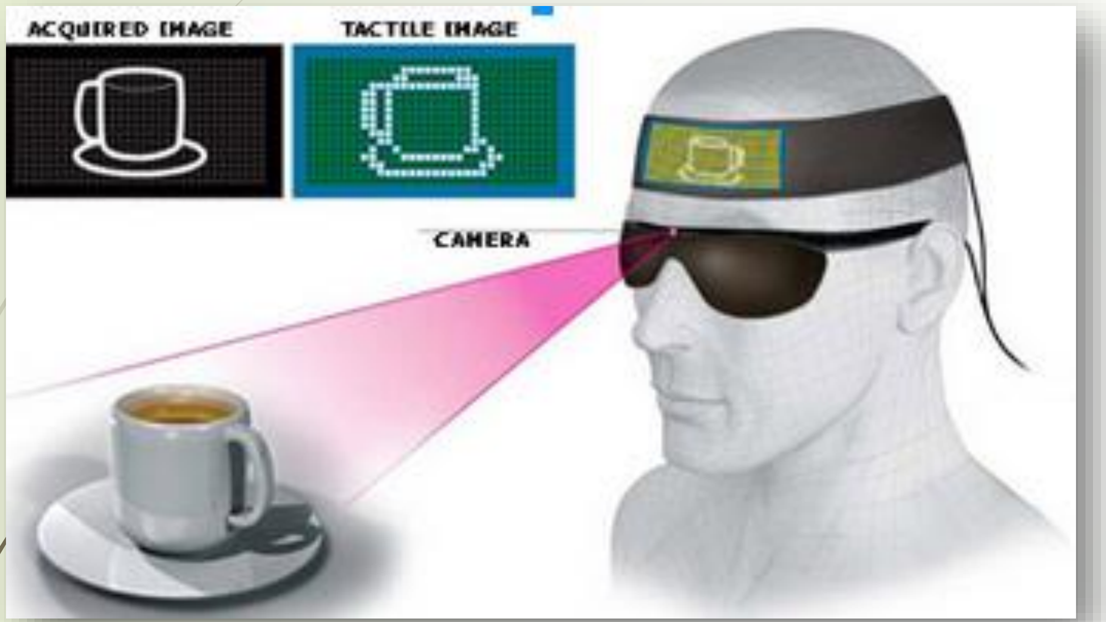
From neuroscience to computer vision

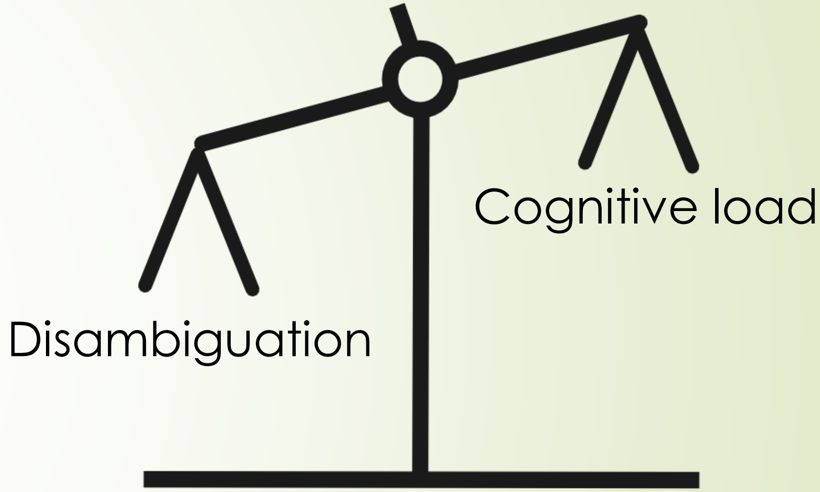
RIVIERE Marc-Aurèle

3rd year PhD in Cognitive Sciences

LITIS – University of Rouen

I. Introduction: sensory substitution

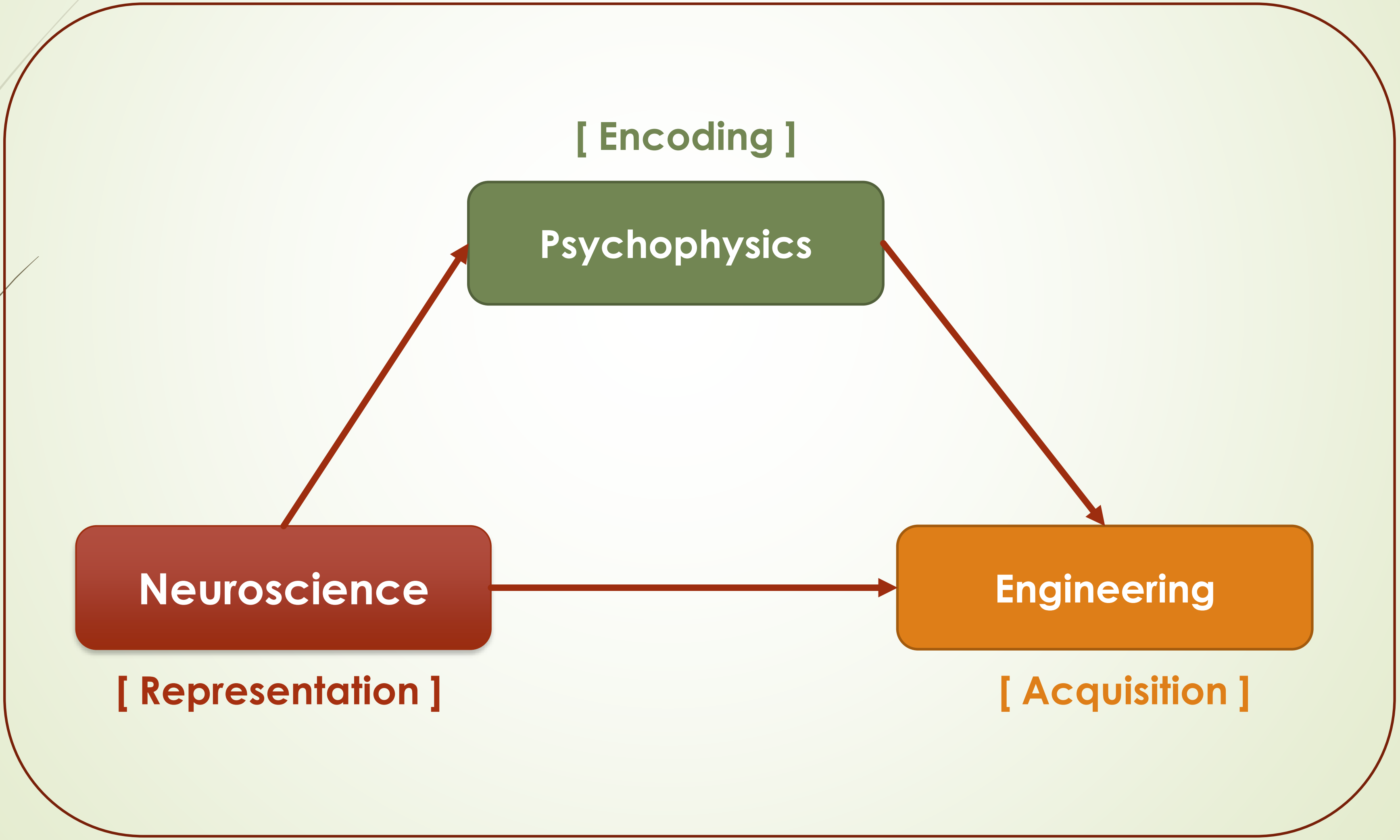




Low-level signals → (Adaptation / Plasticity) → Automatization: Cognitive → Perceptive

Low-level signals → (Adaptation / Plasticity) → Externalization: Sensation → Object

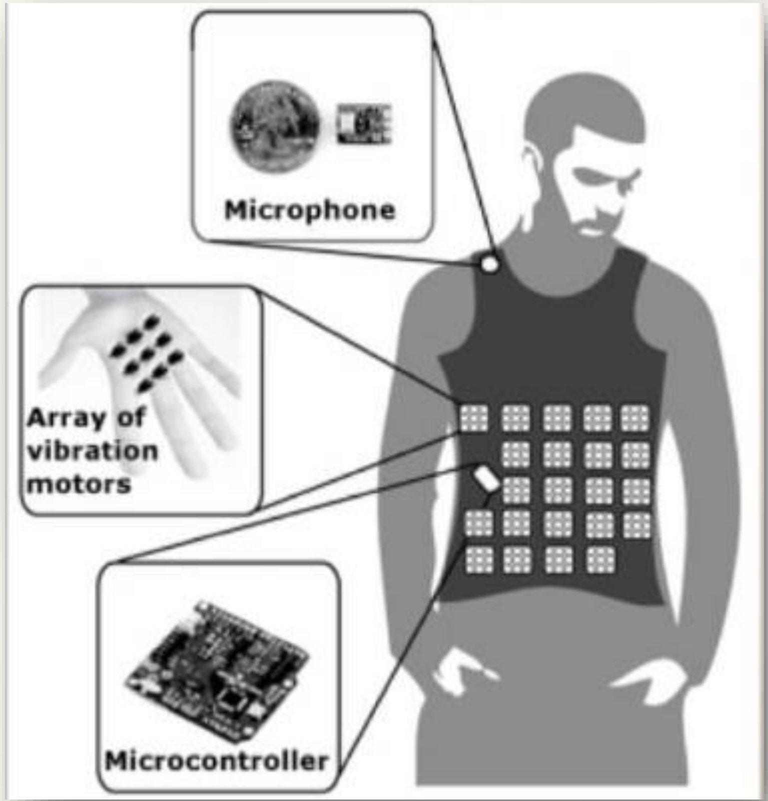
I. Introduction: sensory substitution



I. Introduction: examples

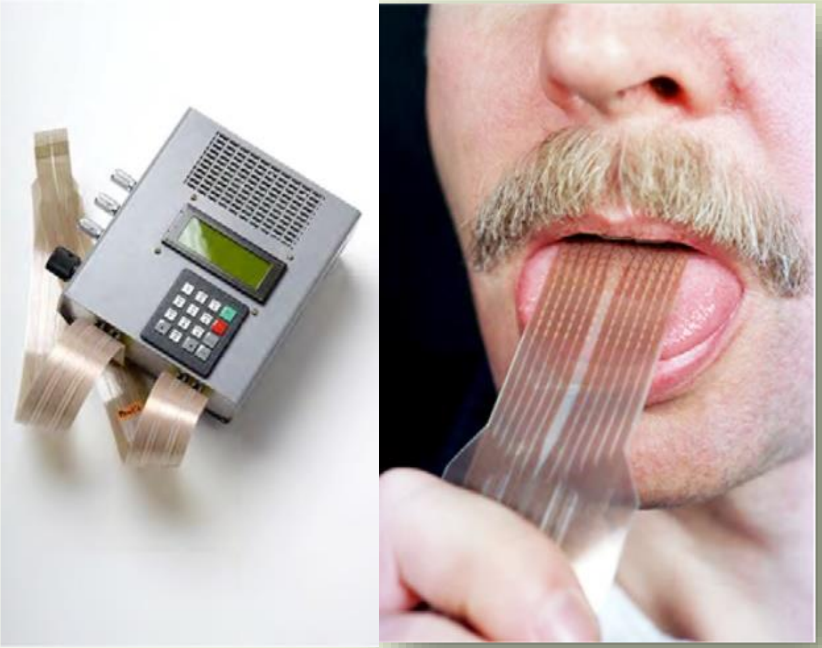
The vOICe

(Meijer, 1992)



(NeoSensory) VEST

(Novich, 2015)



Tongue Display Unit

(Bach-y-rita et al., 1998)

I. Introduction: examples (navigation)

NAVIG

(Katz et al., 2012)

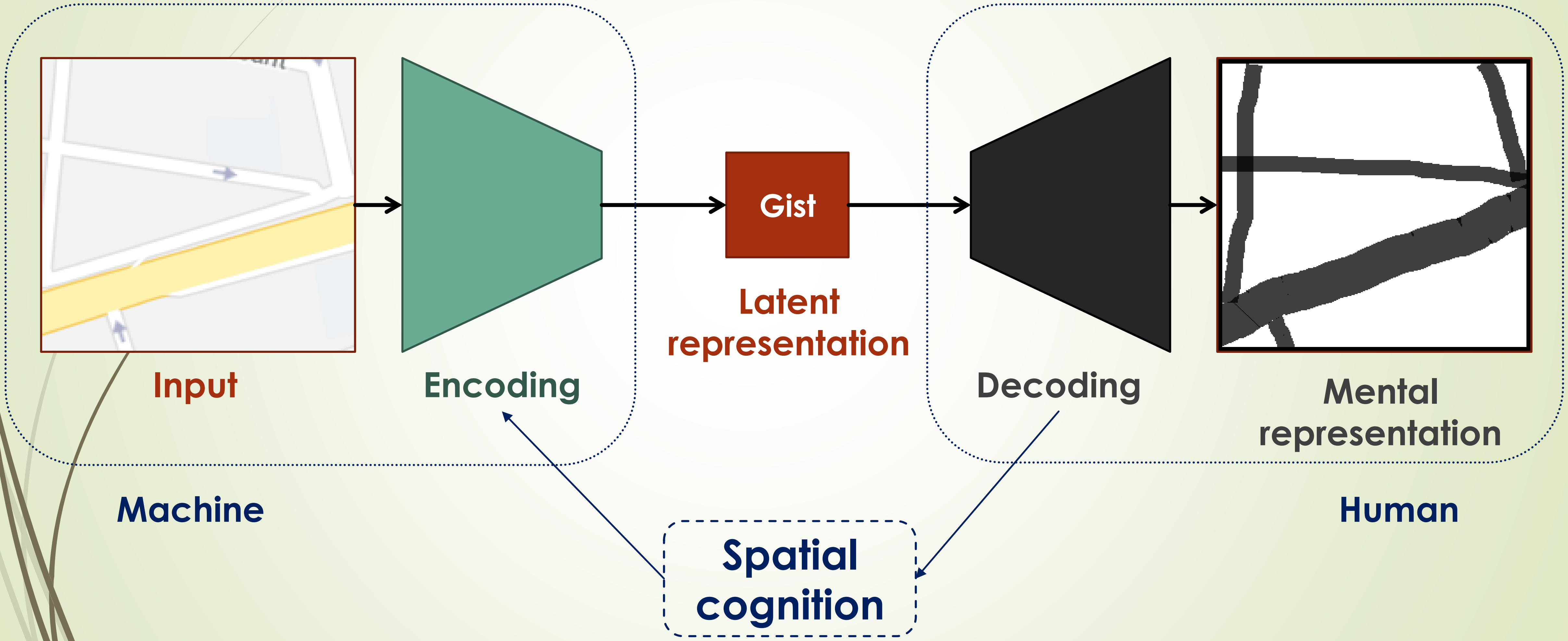
ALVU (MIT)

(Katzschmann, Araki, & Rus, 2018)

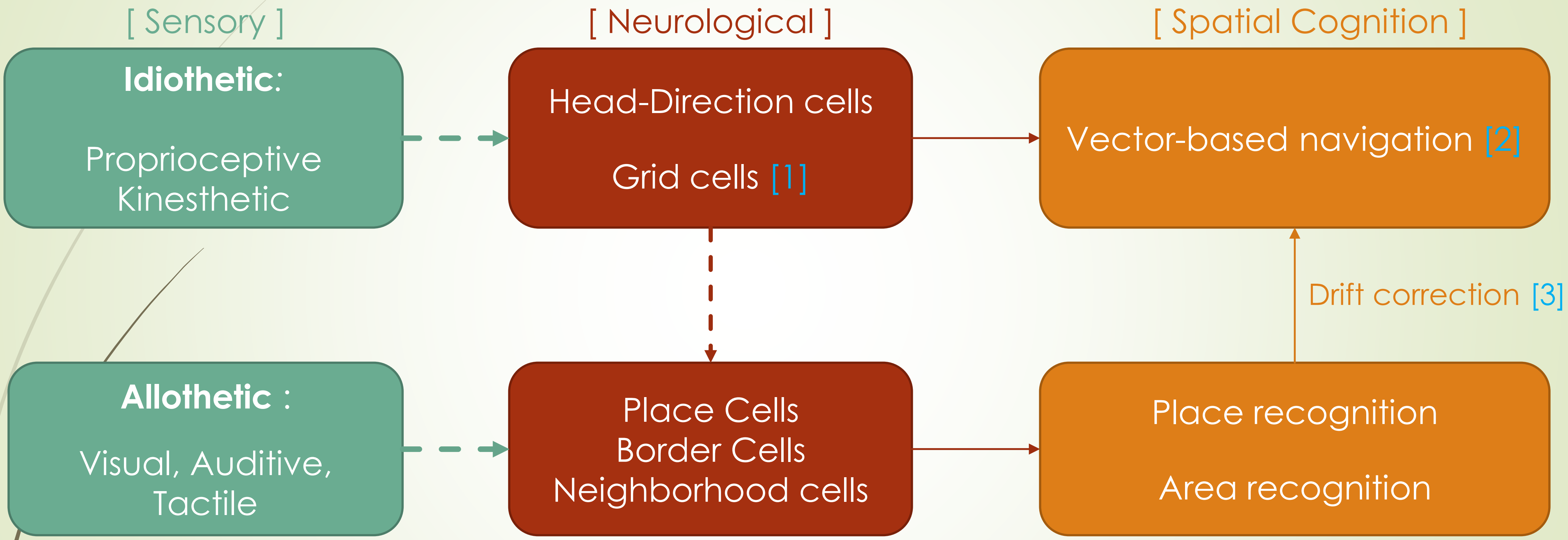
Project 1:

Autonomous navigation

II. Autonomous navigation



II. Autonomous navigation



[1] Hafting, T., Fyhn, M., Molden, S., Moser, M.-B., & Moser, E. I. (2005). Microstructure of a spatial map in the entorhinal cortex. *Nature*, *436*(7052), 801–806.

[2] Banino, A., Barry, C., Uria, B., Blundell, C., Lillicrap, T., Mirowski, P., … Kumaran, D. (2018). Vector-based navigation using grid-like representations in artificial agents. *Nature*, *557*(7705), 429–433.

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II. Autonomous navigation

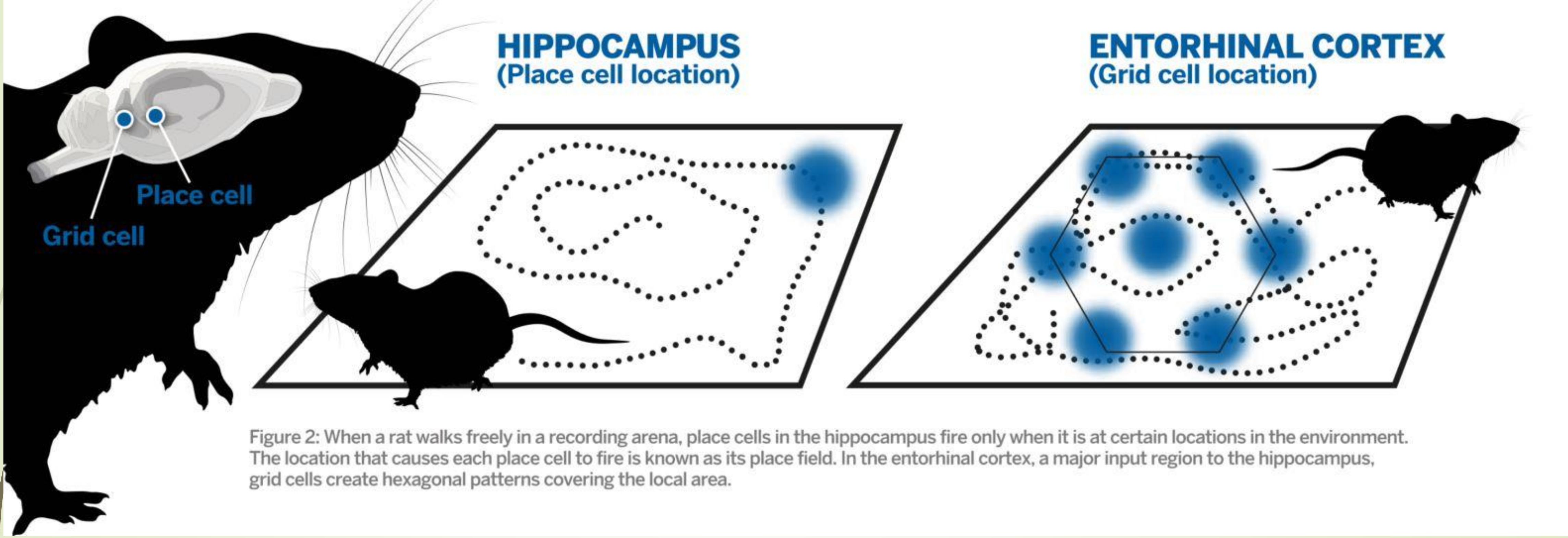
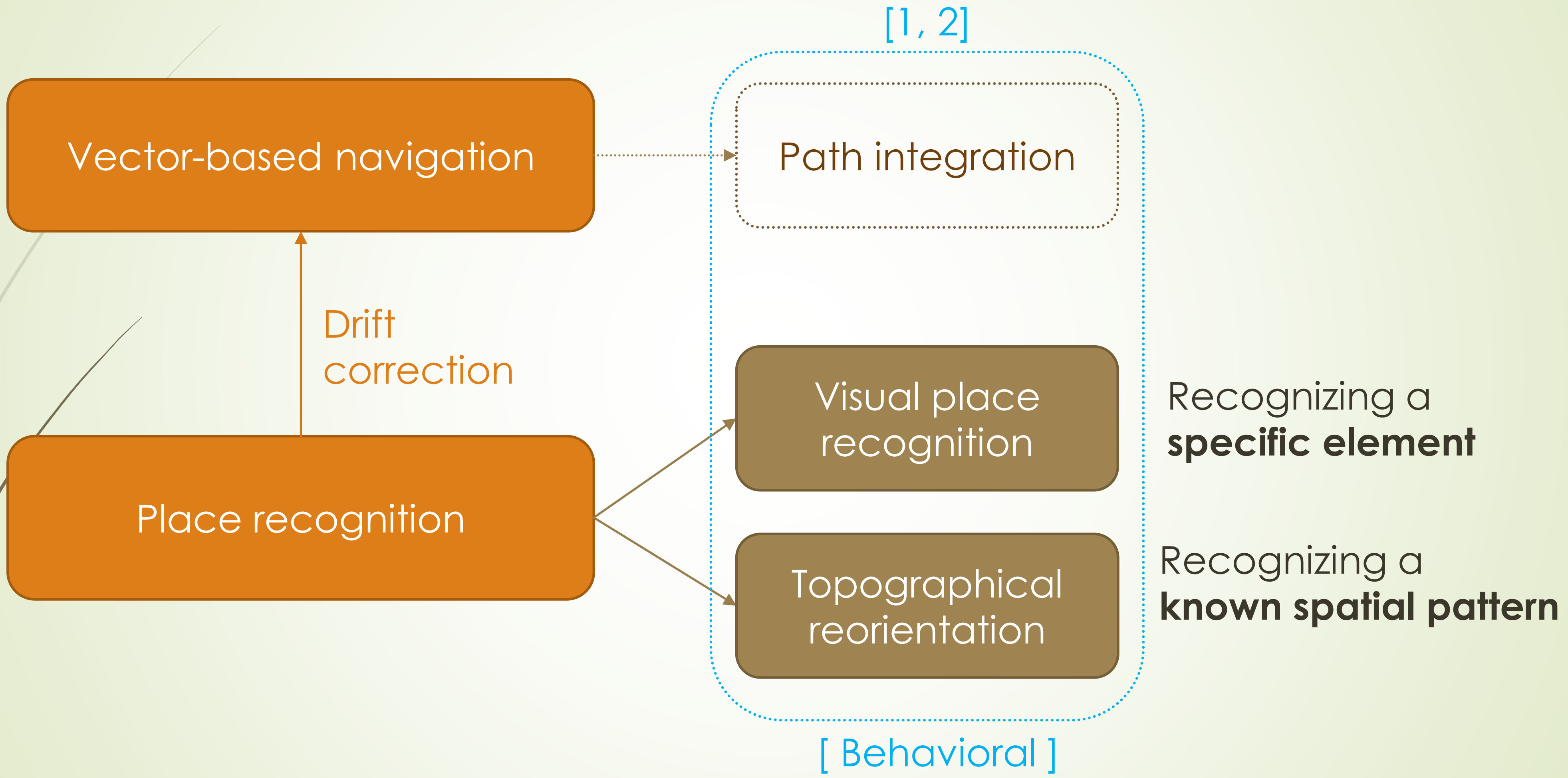


Figure 2: When a rat walks freely in a recording arena, place cells in the hippocampus fire only when it is at certain locations in the environment. The location that causes each place cell to fire is known as its place field. In the entorhinal cortex, a major input region to the hippocampus, grid cells create hexagonal patterns covering the local area.

II. Autonomous navigation



[1] Wang, R. F., & Spelke, E. S. (2002). Human spatial representation: Insights from animals. *Trends in Cognitive Sciences*, 6(9), 376–382.

[2] Lee, S. A., & Spelke, E. S. (2010). Two systems of spatial representation underlying navigation. *Experimental Brain Research*, 206(2), 179–188.

II. Autonomous navigation

Substituted representation
(Gist) [1]

∅

Path integration

Point of Interest

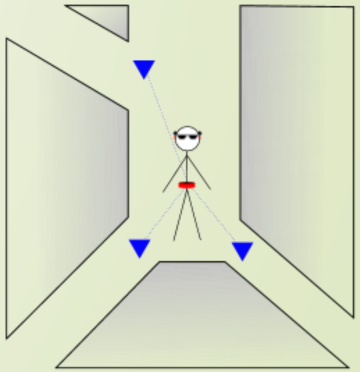
Visual place recognition

Recognizing a **specific element**

Nodes

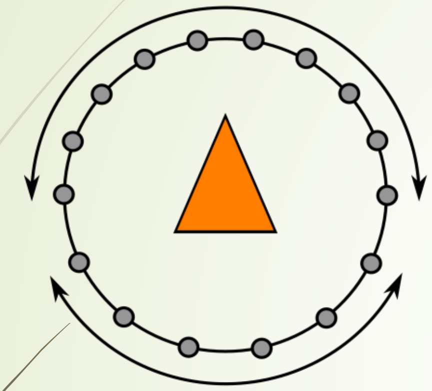
Topographical reorientation

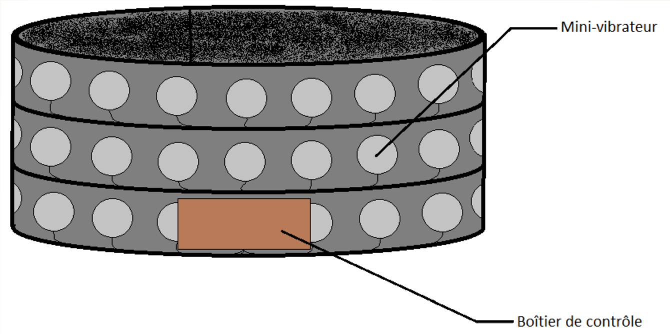
Recognizing a **known spatial pattern**



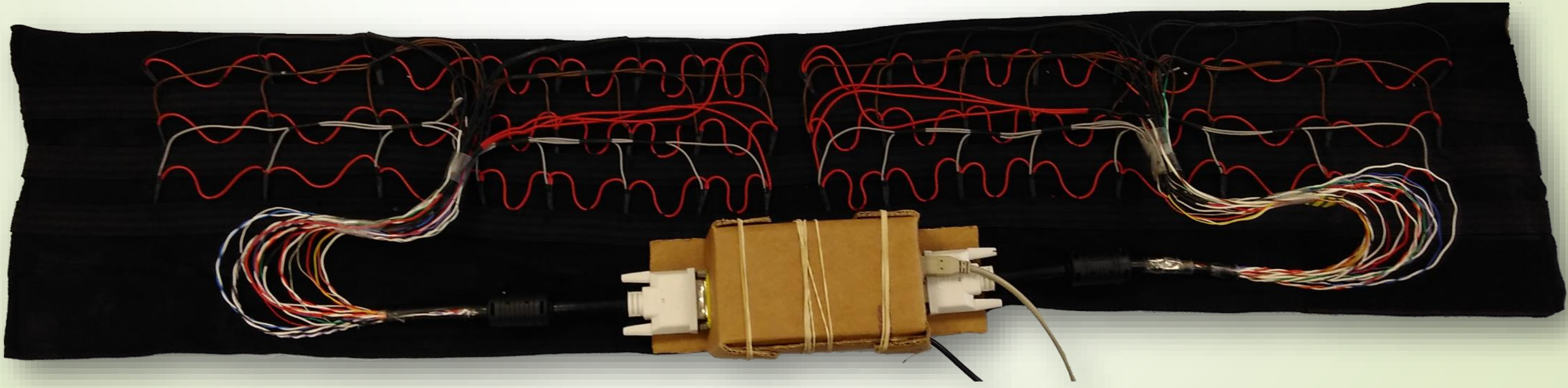
[1] M.-A. **Rivière**, S. Gay, and E. Pissaloux, “TactiBelt: integrating spatial cognition and mobility theories into the design of a novel orientation and mobility assistive device for the blind,” in *Lecture Notes in Computer Sciences*, vol. 10897, K. Miesenberger and G. Kouroupetroglou, Eds. Springer International Publishing, 2018, pp. 1–4.

II. Autonomous navigation

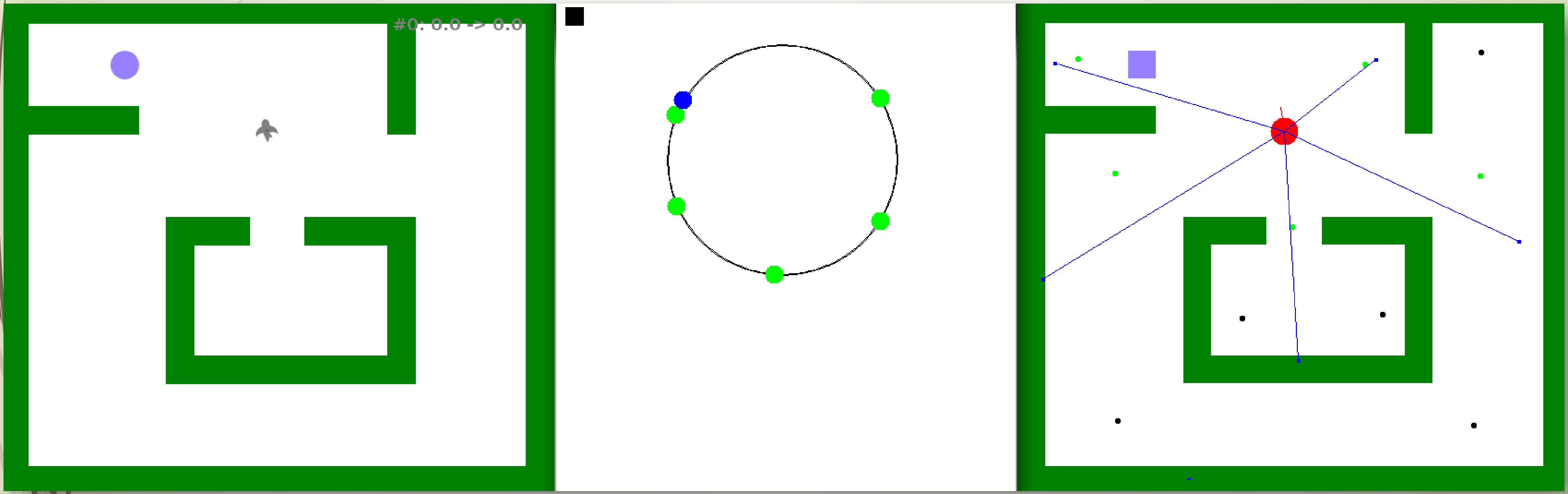




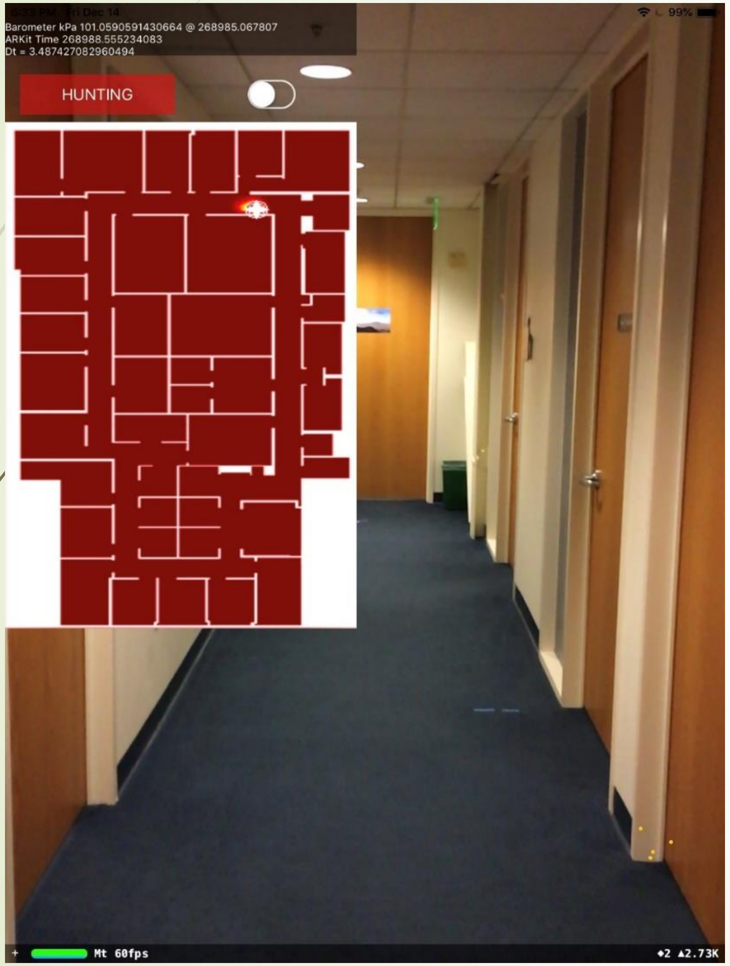
Tactibelt



II. Autonomous navigation: evaluation



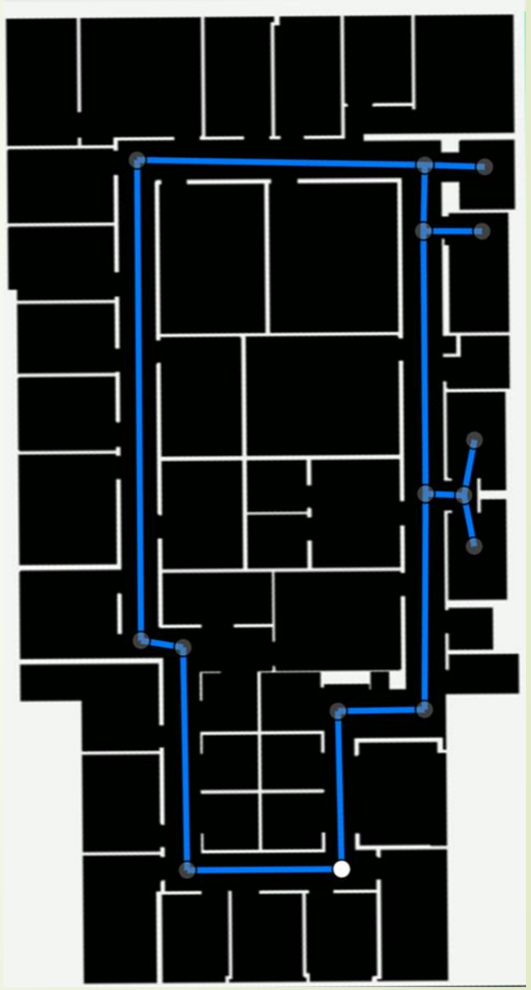
II. Autonomous navigation: localization



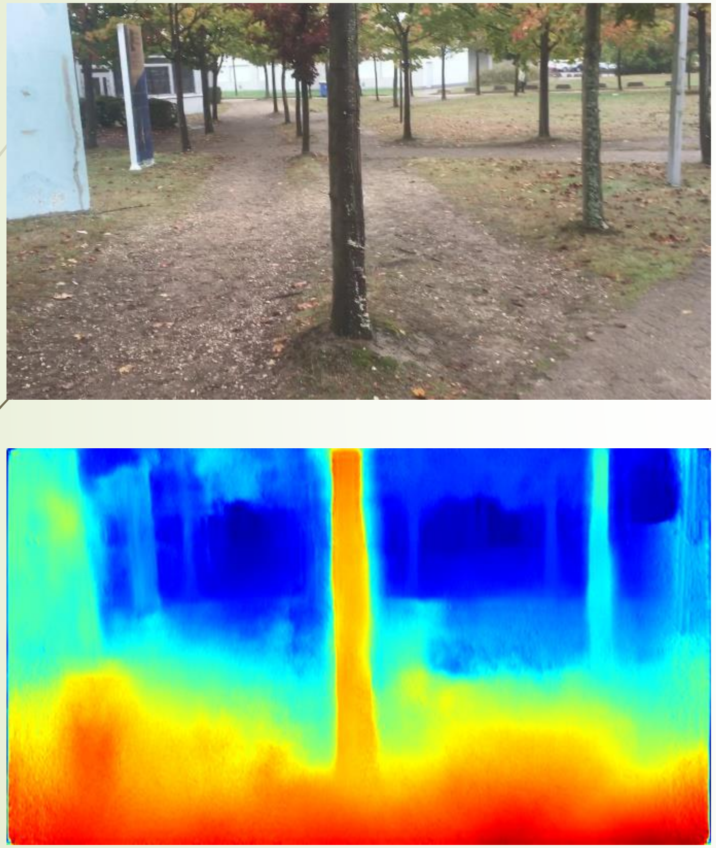
iLocalize
(Fusco & Coghlan, 2018)

→

Navigation graph

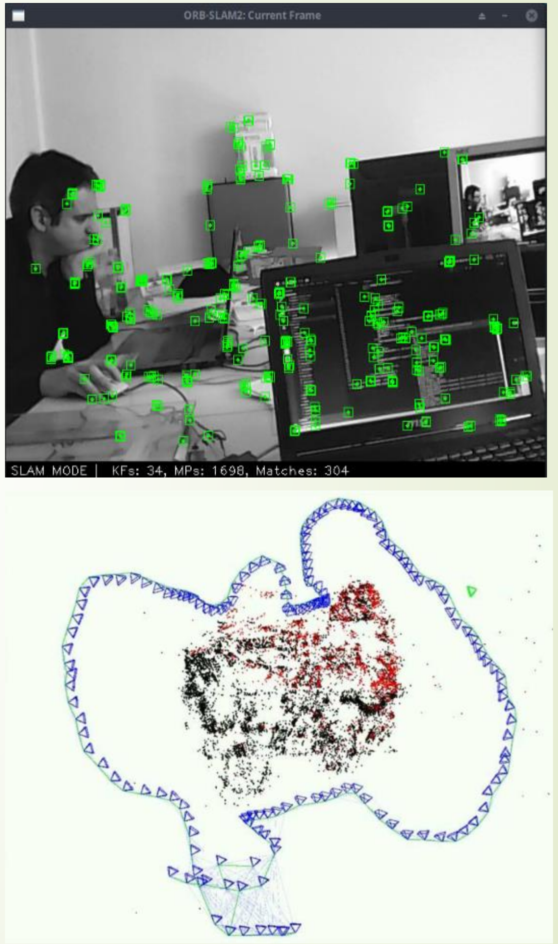


II. Autonomous navigation: mapping



MonoDepth

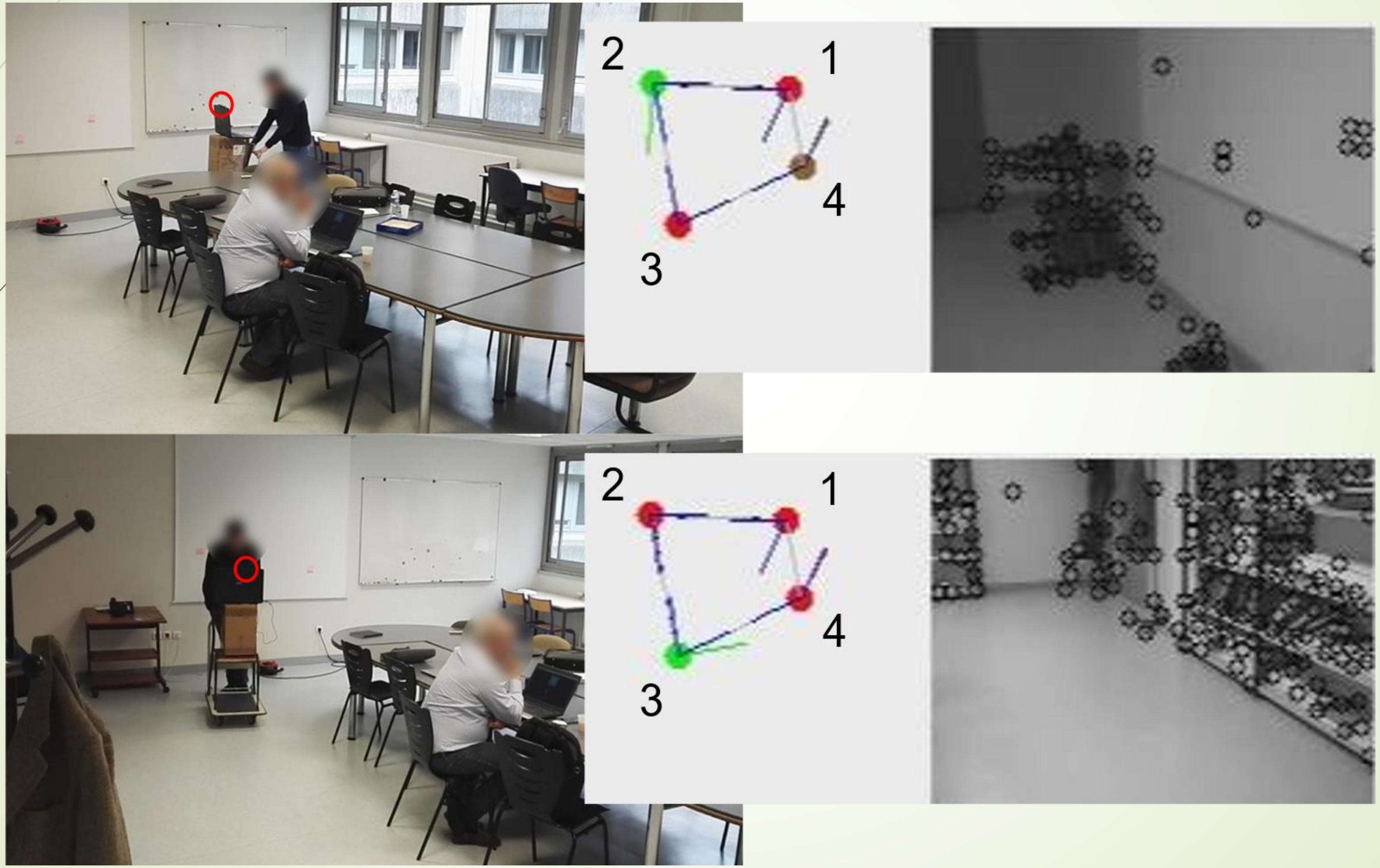
(Godard, Mac-Aodha, & Brostow, 2016)



ORB-SLAM 2

(Mur-Artal & Tardos, 2017)

II. Autonomous navigation: mapping



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litis

cnrs

CesamS

uB
UNIVERSITÉ DE BOURGOGNE

ccaH
Association reconnue d'utilité publique

FIRAH
Fondation Internationale de la Recherche Appliquée sur le Handicap

ESSE · QUAM · VIDERI

Thank you

SKERI

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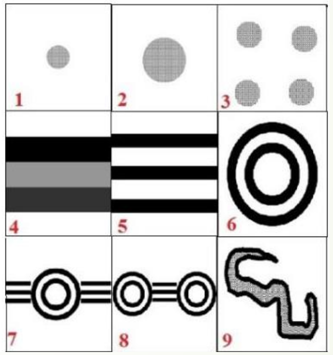
Project 2:
Access to Art

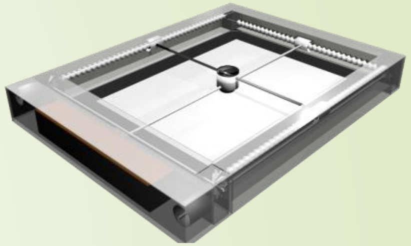
III. Access to Art

Audio-tactile representation or Art

Segmentation

Spatial / Shape





Tactile Interface

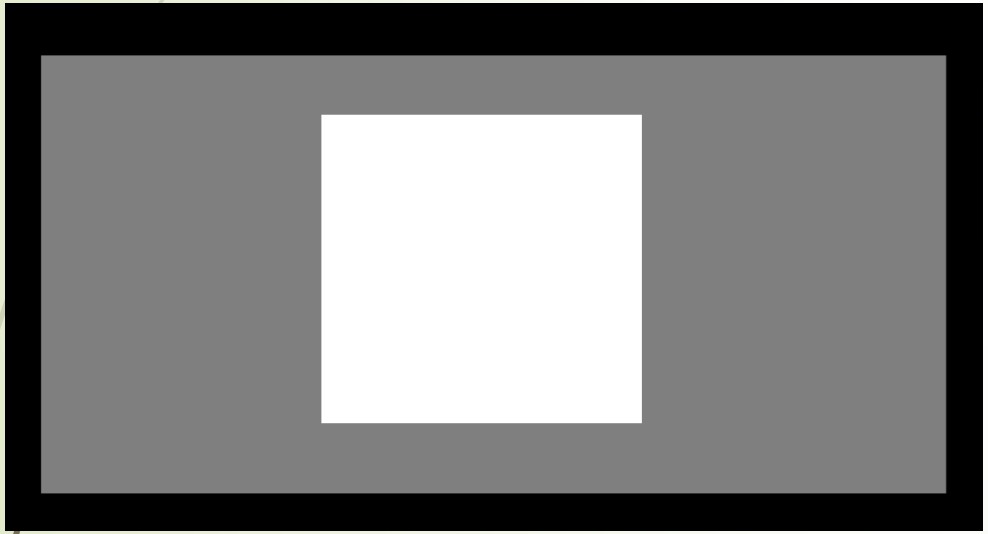
Semantic description

III. Access to Art: audition

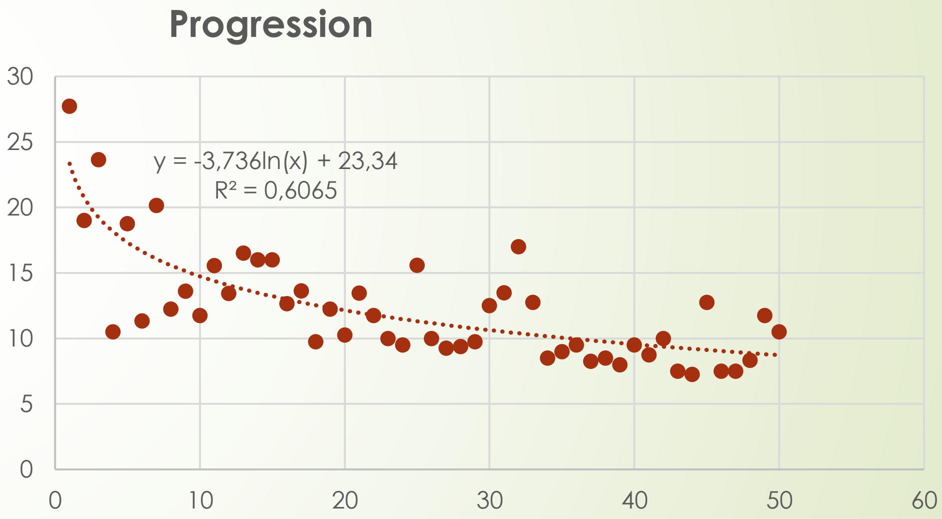
Audio-visual substitution 2D interface (AdViS)

- Finger-guided exploration with audio feedback
  - Color → pitch
  - Edges → sound transition

III. Access to Art: audition



Shape recognition :
91%
12,2 secs (± 4.2)

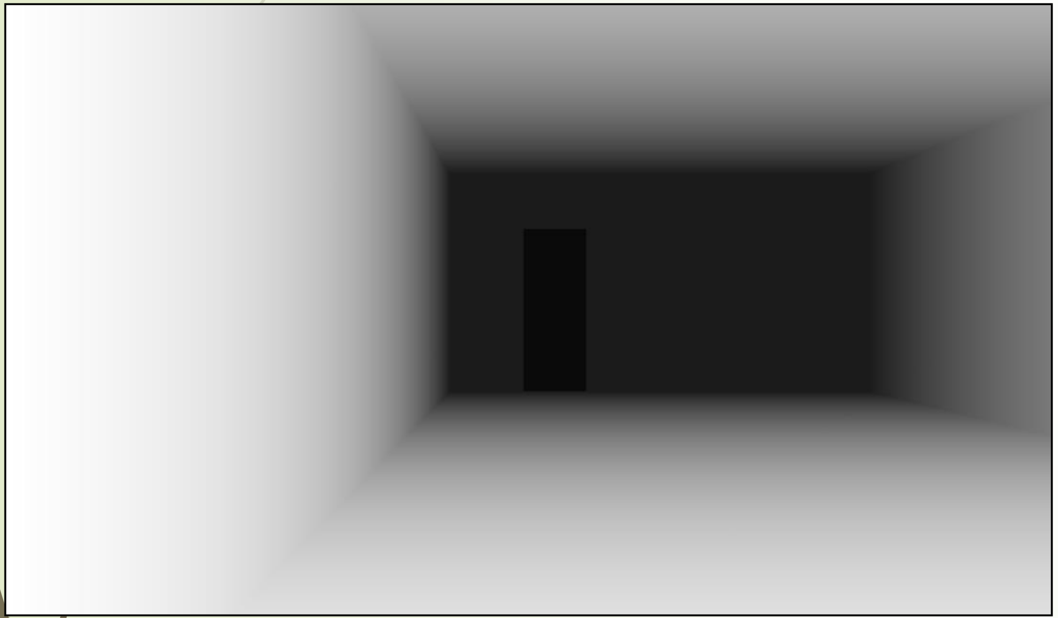


<u>10 first trials</u>
μ = 16,9 s (± 5.6)

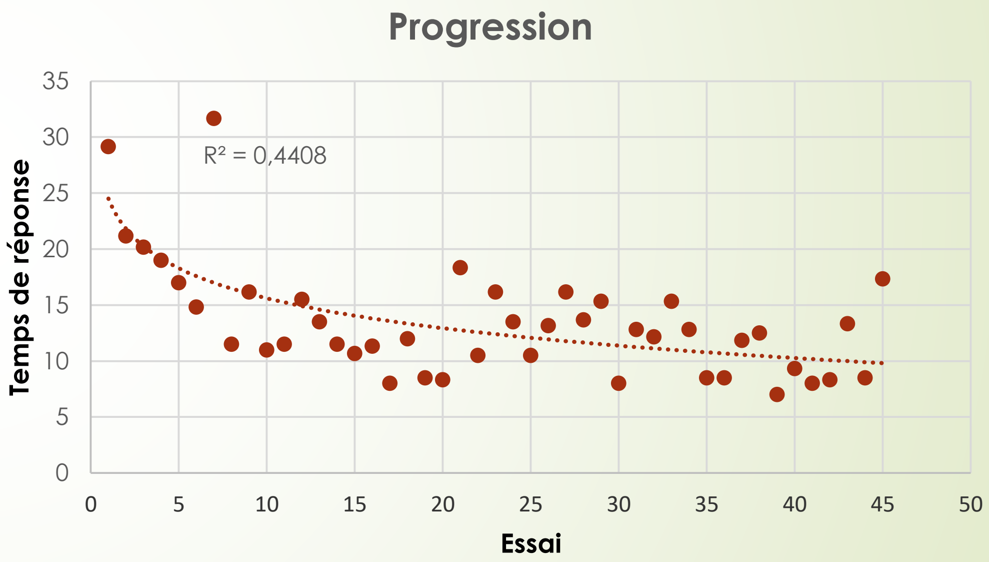
Wilcoxon unilatéral
$p = 0.003$*

<u>10 last trials</u>
μ = 9.2 s (± 1.9)

III. Access to Art: audition



Target relative localization:
89.8%
16,1 secs (± 10.7)

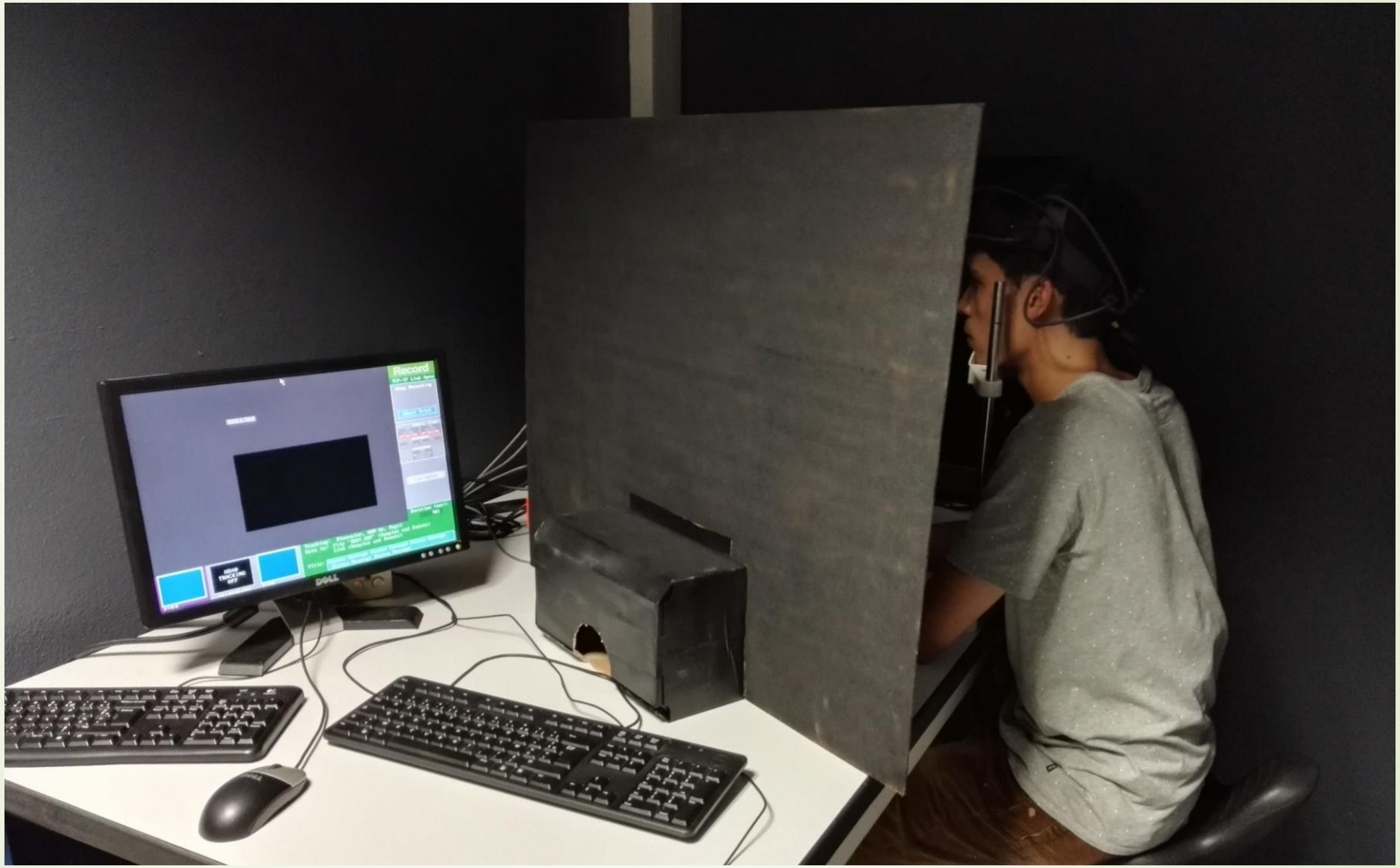


10 first trials
μ = 22,5 s (± 18,2)

Wilcoxon unilatéral
$p = 0.006$*

10 last trials
μ = 12.3 s (± 8.4)

III. Access to Art: audition + eye-movements



III. Access to Art: audition + eye-movements

<u>Preliminary evaluation</u> with the eye-tracker based guidance:

- Sighted participants in the dark
  - Late blind → still have some oculomotor control
- However, without visual feedback …
  - Difficulty to control the focal area’s movements
  - Difficulty to localize your current fixation location

III. Access to Art: audition + eye-movements

- **Add some kind of global or positional information !**
  - Substitute eye movement estimation (visual odometry)
  - Provide fixation points

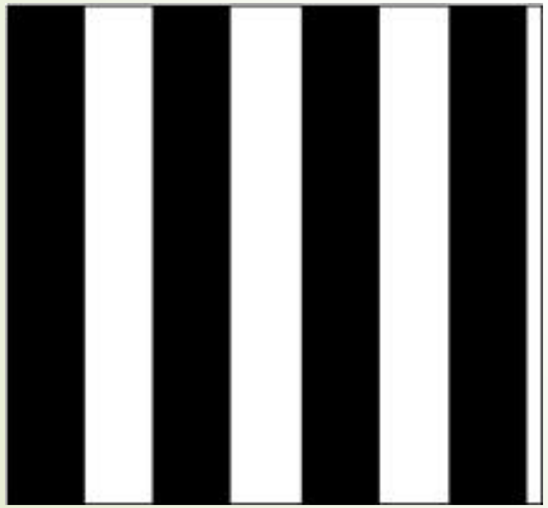
- Combine **local** (point-wise) with **global** information
  - *Analogy to peripheral & foveal vision*

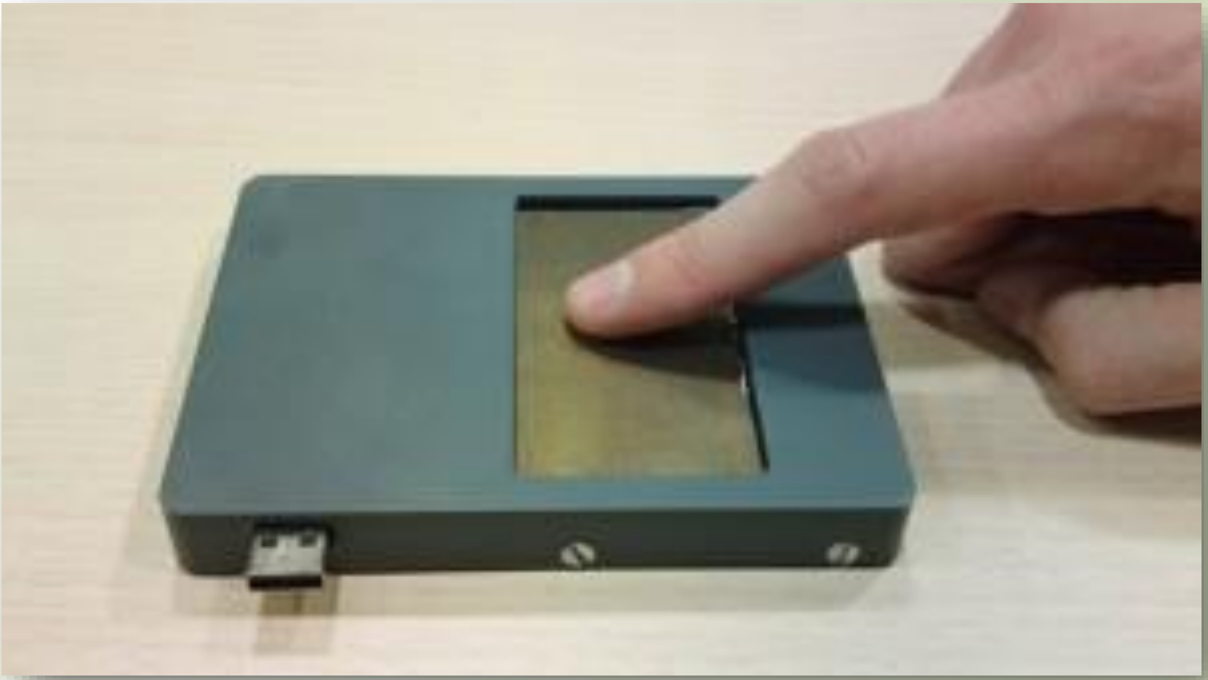
- Testing different pointing feedback in 3D virtual environment (Guezou-Philippe, Huet, Pellerin, & Graff, 2018)

III. Access to Art: tactile feedback

STIMTAC : ultrasonic vibrations tablet (Vezzoli et al., 2016)

- Modulates **friction**
- Can create "tactile textures"

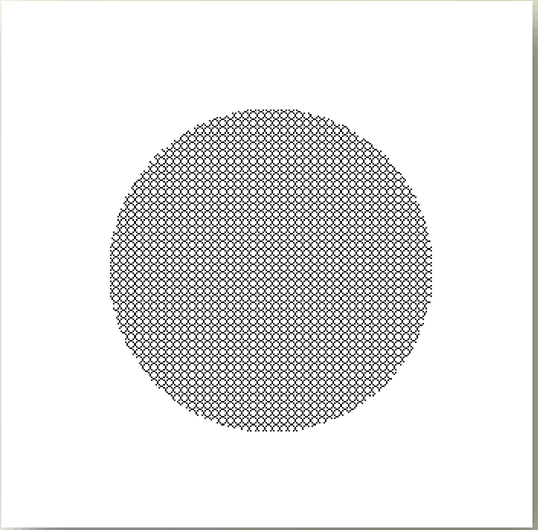




III. Access to Art: tactile feedback

<u>Preliminary evaluations</u> (**Rivière** et al., 2018)

- Simple shape recognition
- N = 12 (LB & CB)

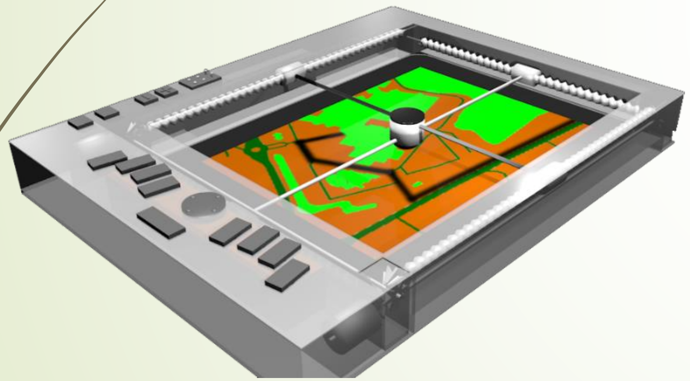


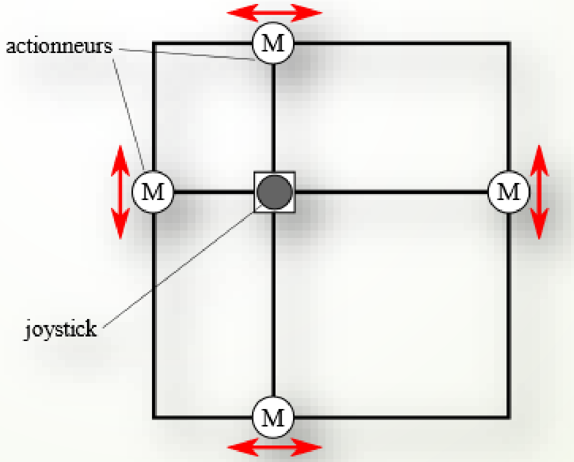
- **Results**:
  - Very poor recognition rates
  - Impossible to « follow » the edges of an object

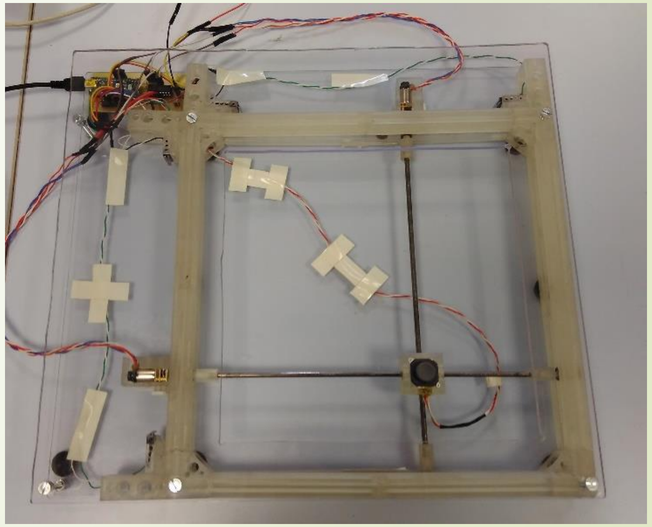
- Developed another type of interface

III. Access to Art: force feedback

- **F2T** : Force Feedback Tablet [1]
  - Active: joystick guides users' finger
  - Passive: resist or facilitate users' movements



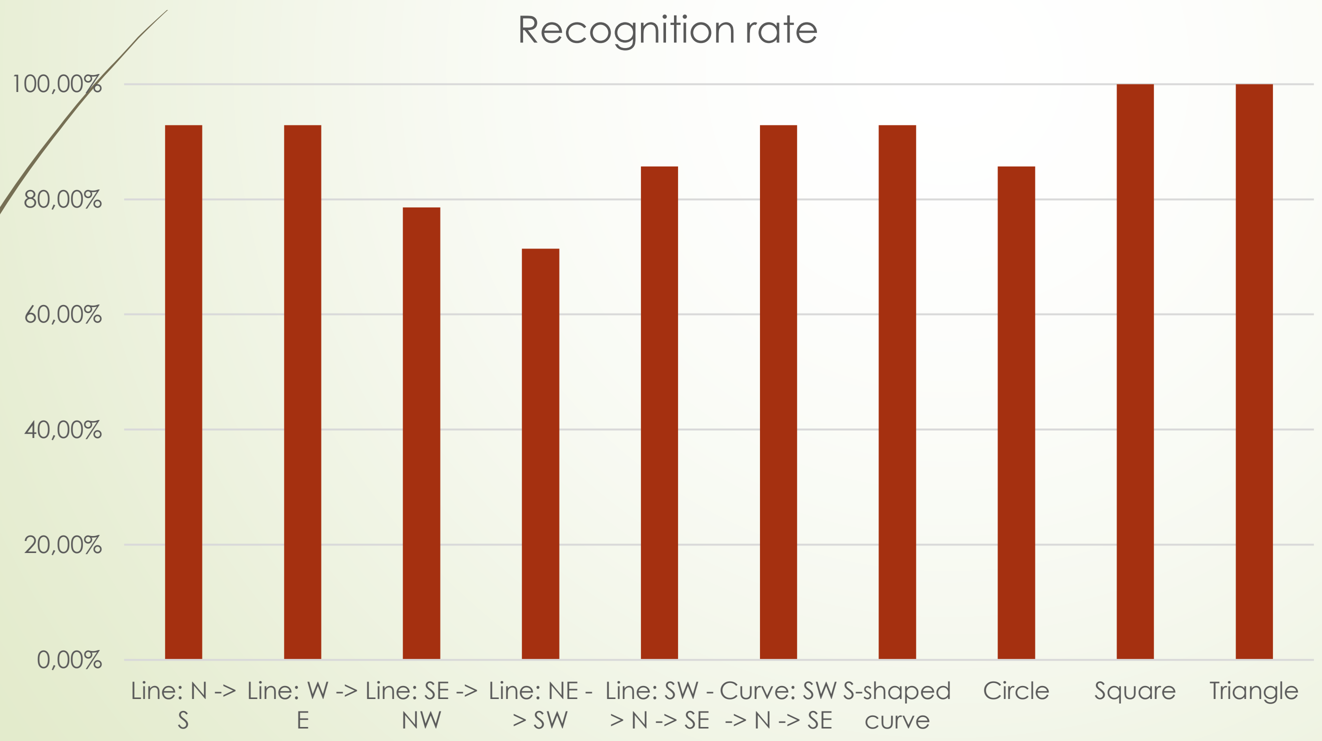




[1] Gay, S., **Rivière**, M.-A., & Pissaloux, E. (2018). Towards Haptic Surface Devices with Force Feedback for Visually Impaired People. In K. Miesenberger & G. Kouroupetroglou (Eds.), *Computers Helping People with Special Needs* (Vol. 10897, pp. 258–266). Cham: Springer International Publishing.

III. Access to Art: force feedback

- **Preliminary evaluation with VIP** (**Rivière** et al., 2019):
  - Simple directional stimuli (cardinal directions)
  - Simple geometrical shapes



Simple shape and movement recognition is very accurate :
μ = 89.3%

[1] **Rivière**, M.-A., Gay, S., Romeo, K., Pissaloux, E., Bujacz, M., & Strumillo, P. (In Press). NAV-VIR: an audio-tactile virtual environment to assist visually impaired people. *2019 9th International IEEE/EMBS Conference on Neural Engineering (NER)*, 4. San Francisco, California: IEEE.

III. Access to Art: force feedback

<u>Access to art and culture</u> : audio-tactile display of paintings

Preliminary evaluation (exploratory):

- N = 14
- Guided (active) exploration with synchronized audio description

Likert scale + semi-open questionnaire :

- Tactile info <u>facilitates the comprehension and mental representation</u> of the painting

III. Access to Art: image segmentation

Access to art and culture : audio-tactile display of paintings

- **Free exploration**
- **Automatic segmentation of the painting:**
  - Supervised method: CRF, Mask-R-CNN, …
  - Unsupervised methods: watershed, …
- Regions → different force-feedback