# Investigating natural statistics and sexual signalling patterns with deep learning

Yseult Héjja-Brichard

E3CO team

*Isaac Szabo - Engbretson Underwater Photo*

# Background

**Bsc**
**Psychology**
*Grenoble & Leipzig*

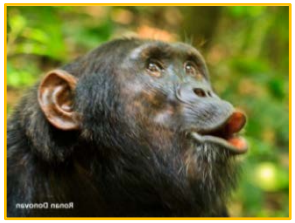
**Msc**
**Cognitive**
**Psychology**
*Grenoble*

**Msc + PhD**
**Cog & Behav**
**Neuroscience**
*Toulouse*

MAX PLANCK INSTITUTE FOR HUMAN COGNITIVE AND BRAIN SCIENCES LEIPZIG

LPNC

CerCo UMR5549



*ManyPrimates*

# PhD studies in one blink

CerCo
UMR5549

"Spatial and temporal integration of binocular disparities"

*How does the (primate) brain compute a depth percept?*

- Stereomotion / motion-in-depth
- Optic flow (fMRI & connectivity)
- Symmetry processing
- Disparity gradients x natural statistics

- Modelling binocular disparities

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**Neuroscience**
*Toulouse*

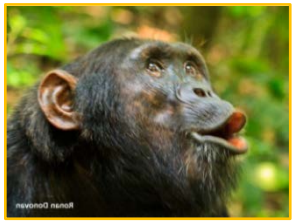
**PostDoc**
*Montpellier*
*& Baltimore*

MAX PLANCK INSTITUTE FOR HUMAN COGNITIVE AND BRAIN SCIENCES LEIPZIG

LPC

CerCo UMR5549

Centre d'Ecologie Fonctionnelle & Evolutive



*ManyPrimates*

# Outline

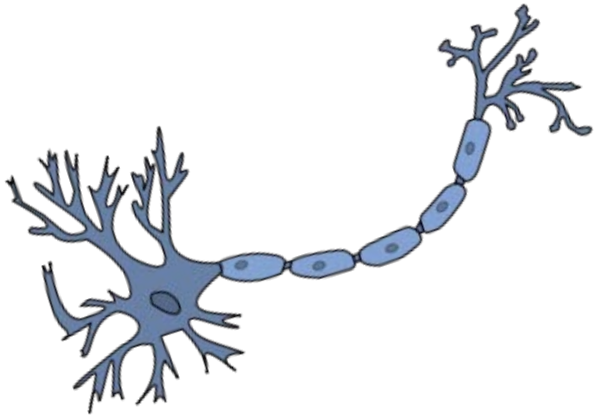
Natural statistics and efficient coding
Sensory drive and signal efficacy
Processing bias and fluency
The case of darter fishes

Neural style transfer
Fish experiment – *E. caeruleum*

Some initiatives of interest

# Natural statistics and efficient coding

→ Hypothesis: **Sensory neurons are adapted**, through both evolutionary and developmental processes, **to the statistical properties** of the signals to which they are exposed.



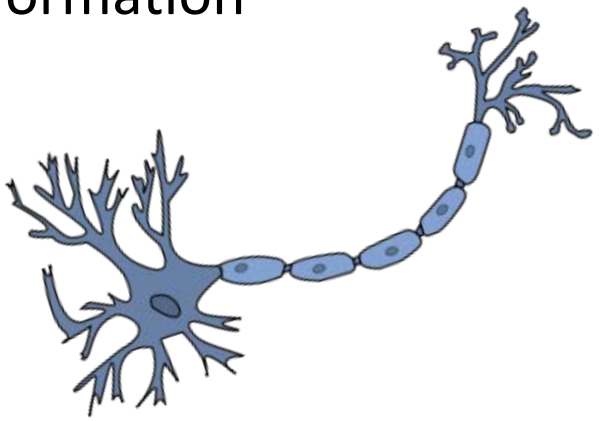


*Attneave, 1954; Barlow, 1961; Simoncelli & Olshausen, 2001*

# Natural statistics and efficient coding

→ Hypothesis: Sensory neurons are adapted, through both evolutionary and developmental processes, to the statistical properties of the signals to which they are exposed.

→ **Information theory**: a group of neurons should encode as much information as possible in order to most effectively utilise the available computing resources.
= **efficient coding**/processing of information



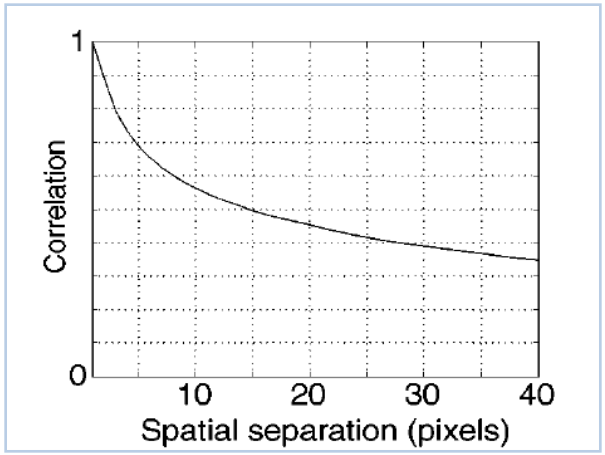


*Attneave, 1954; Barlow, 1961; Simoncelli & Olshausen, 2001*

# Natural statistics and efficient coding

→ Natural images are statistically redundant /spatial correlations

*Luminance*
*Contrast*
*Colour*
*Spatial structure*
*Range*
*...*

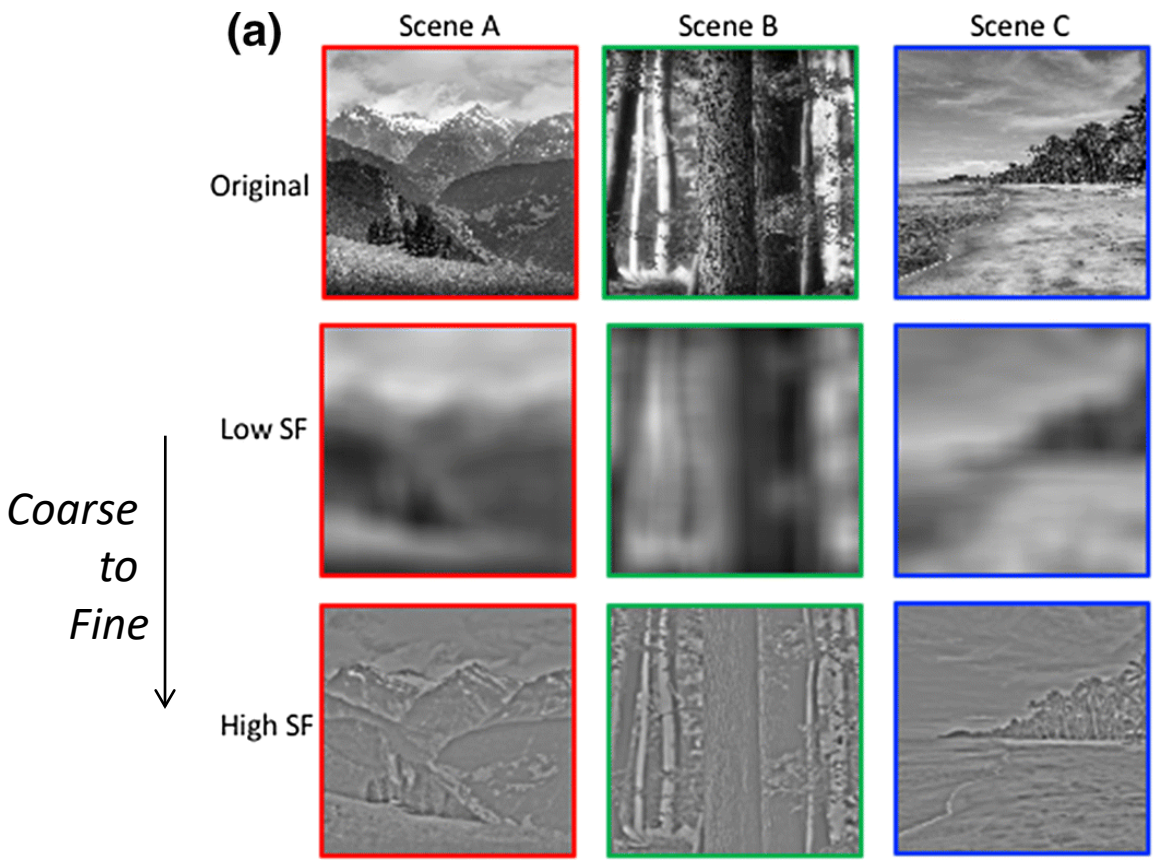



Autocorrelation function for pixel intensity

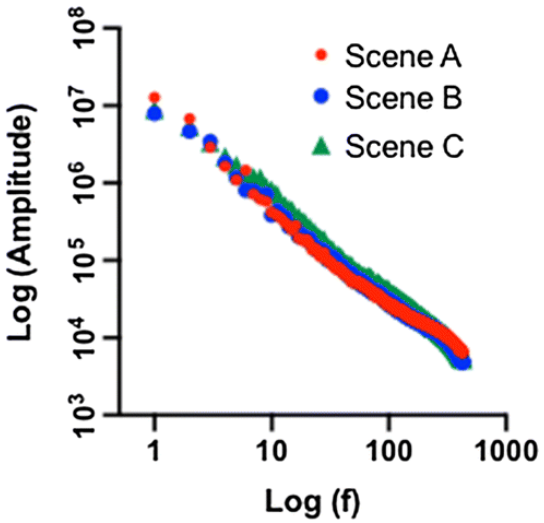



*Simoncelli & Olshausen, 2001; Geisler, 2008*

# Natural statistics: SFs and Fourier slope




**(b) Fourier slope (original images)**



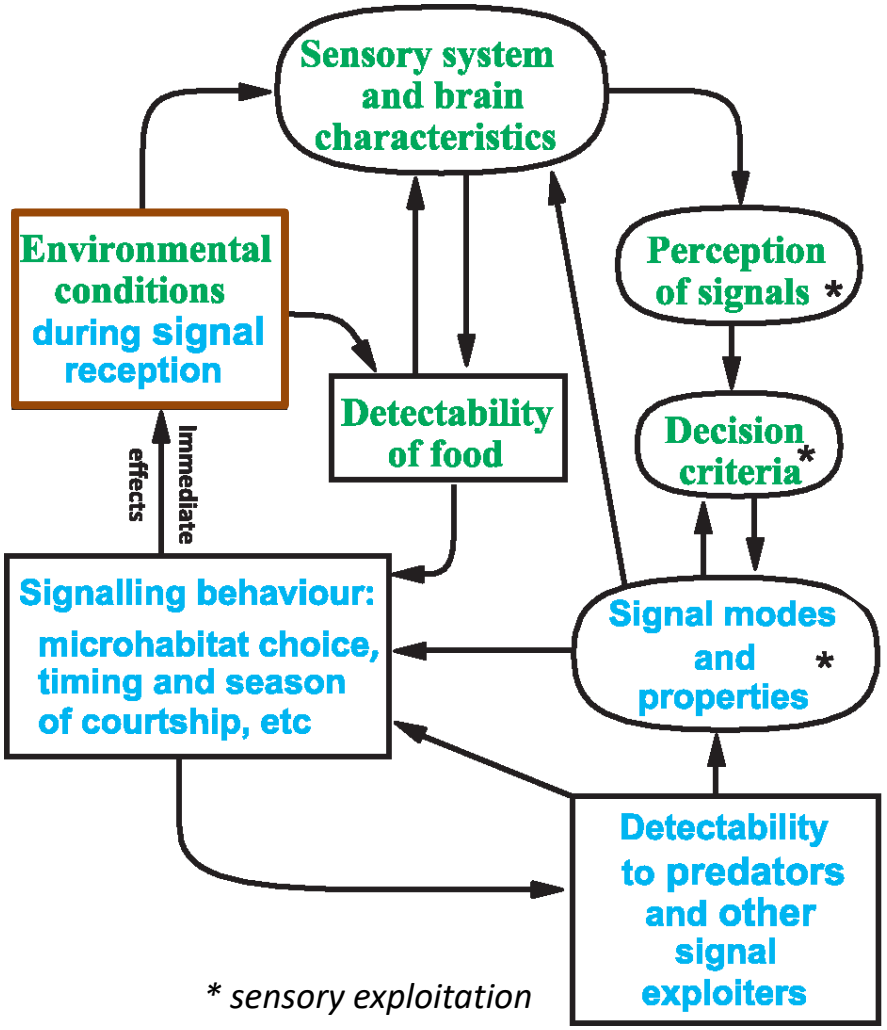



*Viengkham et al., 2019*

# Sensory drive and signal efficacy

→ **Sensory drive**: environmental features influence the evolutionary trajectory of both sensory and signalling traits in predictable directions.

→ **Signal efficacy**: detection bias and detectability advantage



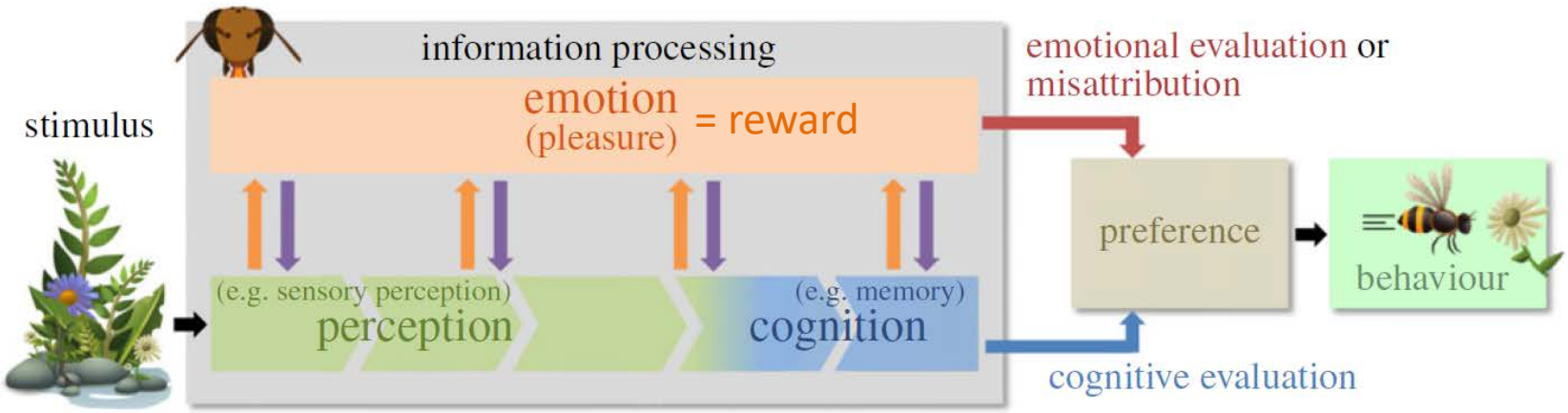



*Cummings & Endler, 2018*

# Processing bias and fluency

→**Processing bias**: preferences are influenced by the **emotional system** as it monitors the progression of information processing.

Attractive signals have **effective designs and/or efficient designs**

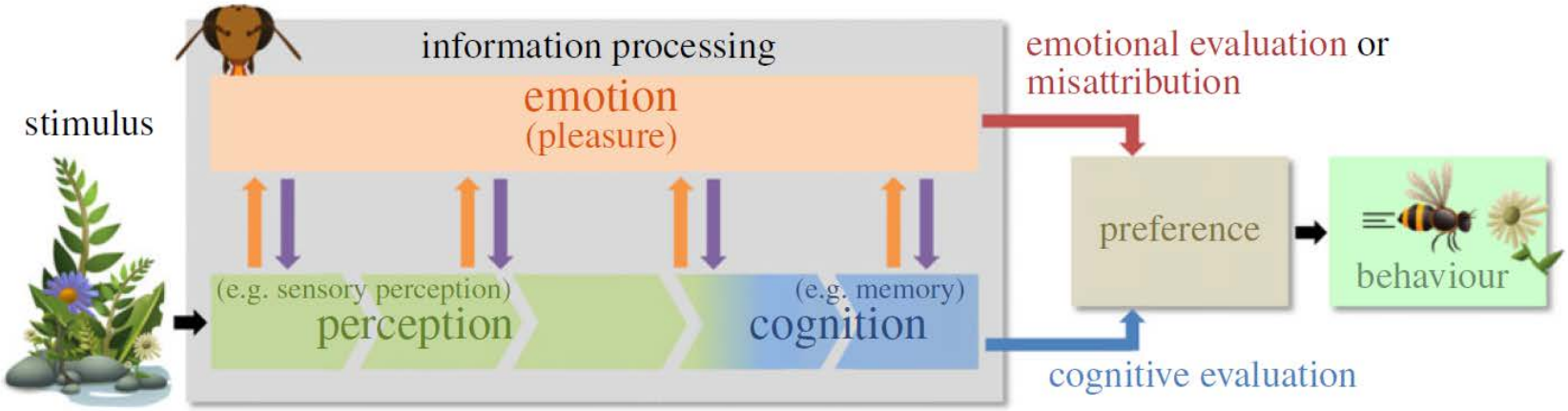





*Renoult & Mendelson, 2019*

# Processing bias and fluency

→ **Fluency effect**: feeling of ease, sense of familiarity that arises when processing some types of stimuli.
Plays a role in judgment or decision making, as it makes a stimulus more attractive.



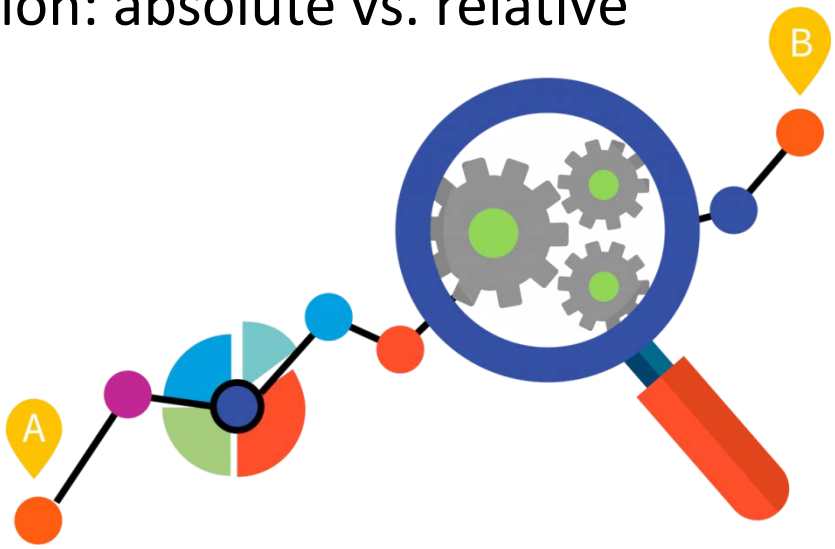



*Renoult & Mendelson, 2019*

# Testing rationale

*How can we disentangle perceptual, cognitive, and emotional processes from each other?*

- Link between sexual signalling and habitat statistics
- Preference for a pattern that reproduce habitat statistics
- Role of contextual information: absolute vs. relative preference



# Sexual signalling and habitat statistics

*E. camurum*

*E. gracile*

*E. caeruleum*

*E. olmstedi*

*E. blennioides*

*E. swaini*

*E. zonale*

*E. pyrrhogaster*

*E. chlorosomum*

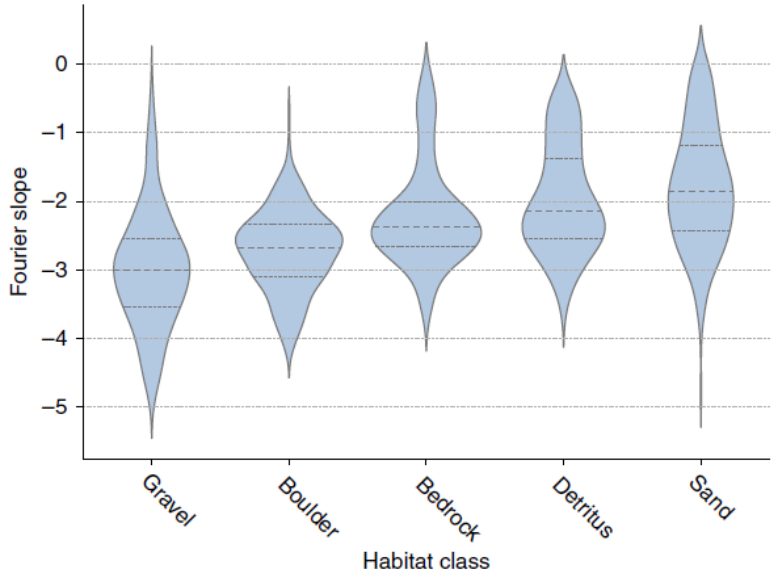
*E. barrenense*

***Genus: Etheostoma***
***Small fresh water fishes***
*Male individuals*



*Hulse, Renoult, Mendelson, 2020*

# Sexual signalling and habitat statistics

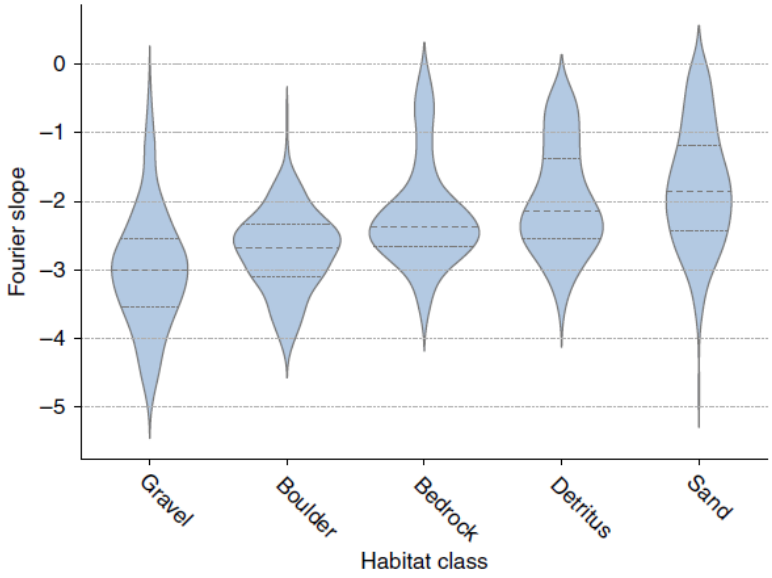


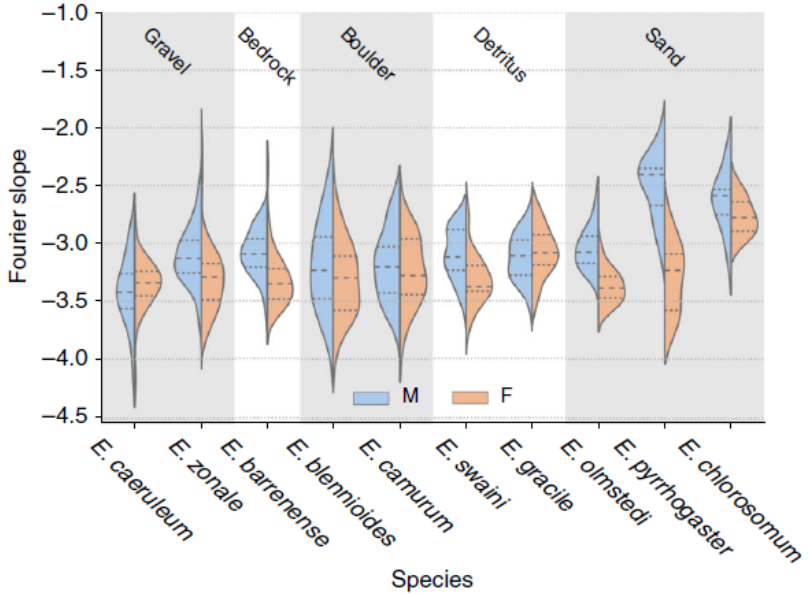

→Variation in habitat and darter Fourier slope (distribution of spatial frequencies)



*Hulse, Renoult, Mendelson, 2020*

# Sexual signalling and habitat statistics



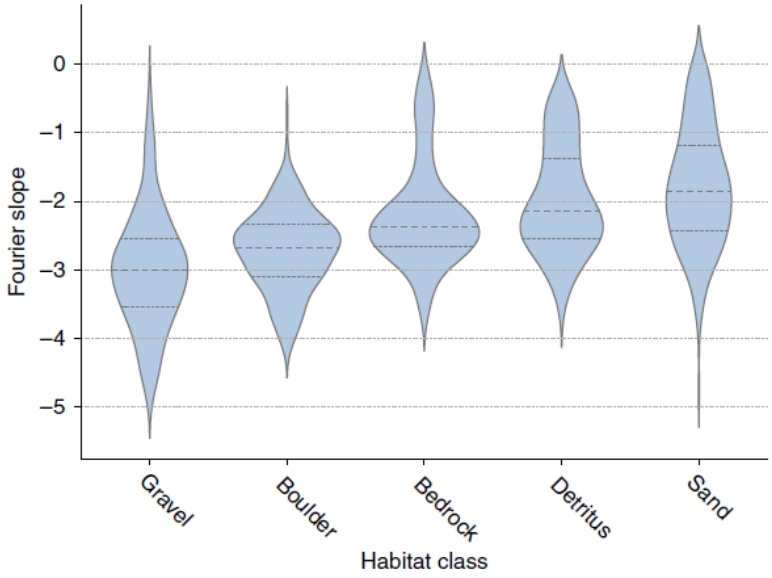



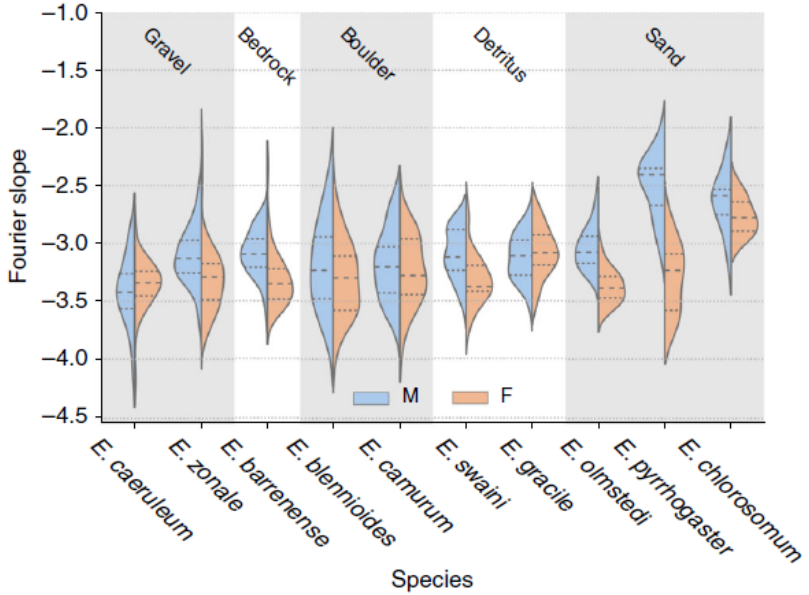

→Variation in habitat and darter Fourier slope (distribution of spatial frequencies)



*Hulse, Renoult, Mendelson, 2020*

# Sexual signalling and habitat statistics




→Variation in habitat and darter Fourier slope

→ Correlation between the distribution of Fourier slope of habitat images and of male visual patterns



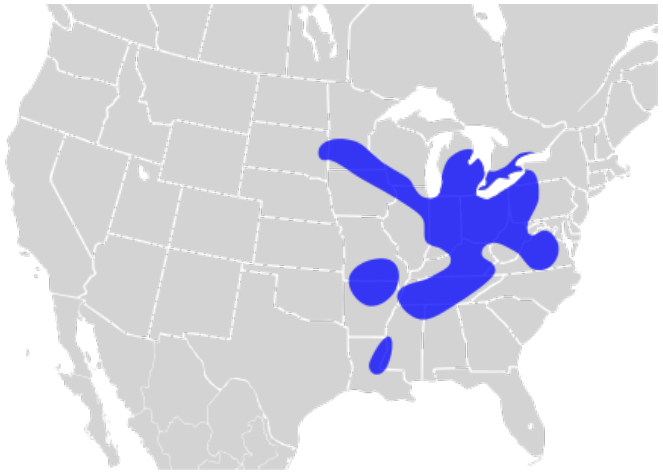
*Hulse, Renoult, Mendelson, 2020*

# Beyond the Fourier slope

→ Correspondence between a fish sexual signalling pattern and the habitat statistics

- What about the role of other spatial statistics?
- How does it affect a fish's behaviour or preference for a mate?

# Rainbow darter (E. caeruleum)



♂

♀

*Gravel habitat*

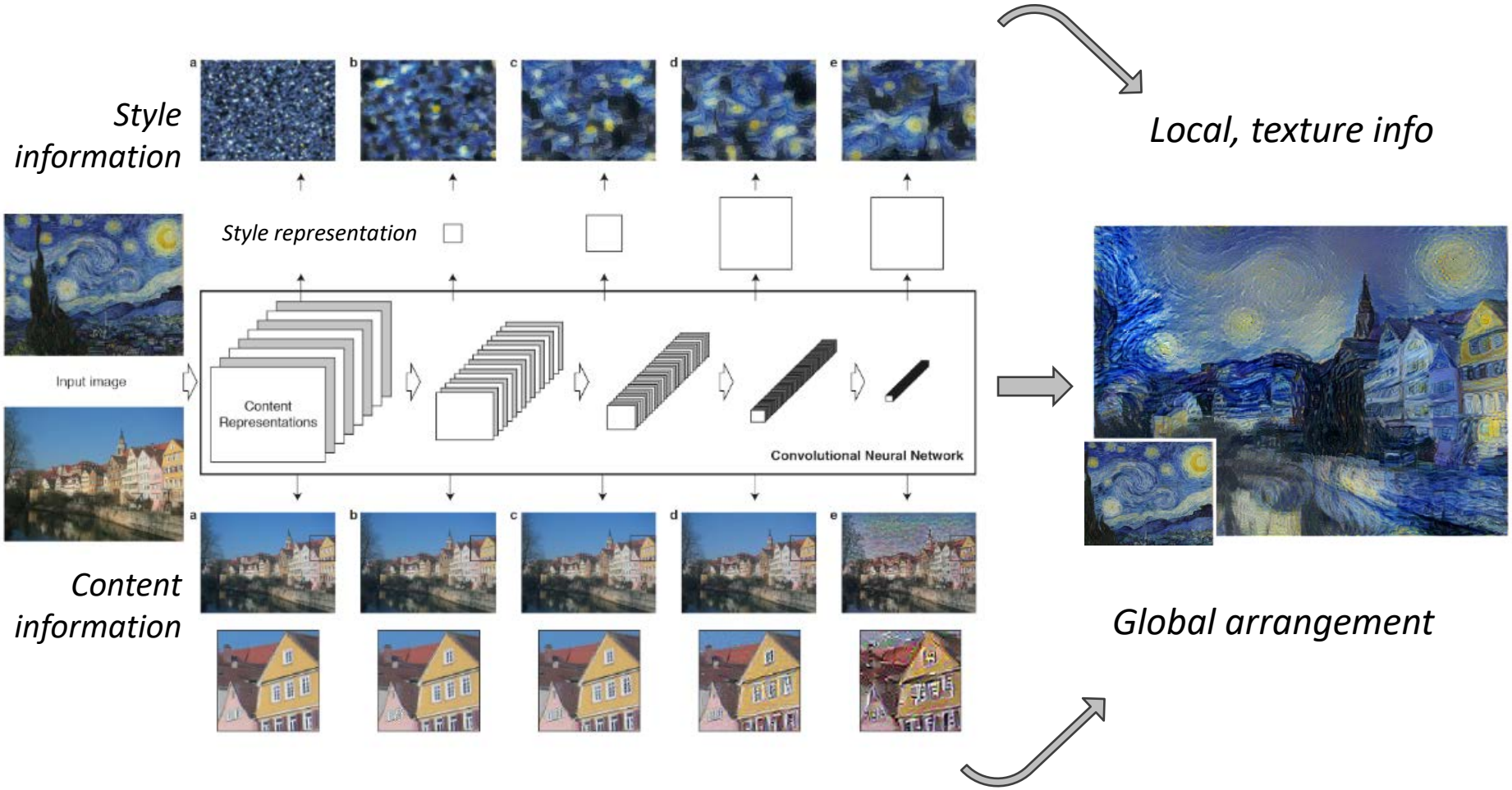
# Neural Style Transfer

**NST = Process of using CNNS to render a content image in different styles**




*Jing et al., 2018*

# NST: How does it work?






Gatys et al., 2015

# NST and fish?

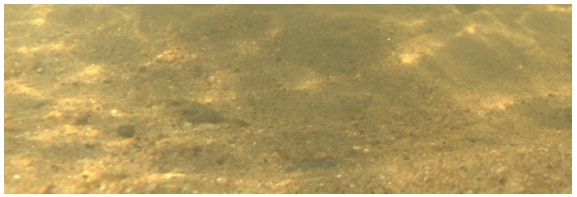

Content image = **male** fish

*E. caeruleum*

Style image = Habitat

*E. caeruleum habitat (gravel)*

*E. olmstedi habitat (sand)*



# Results of the style transfer

*original*

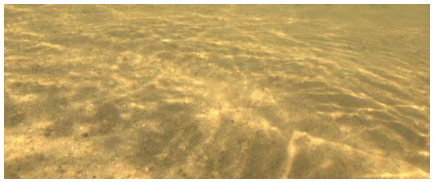
+

*gravel*

=

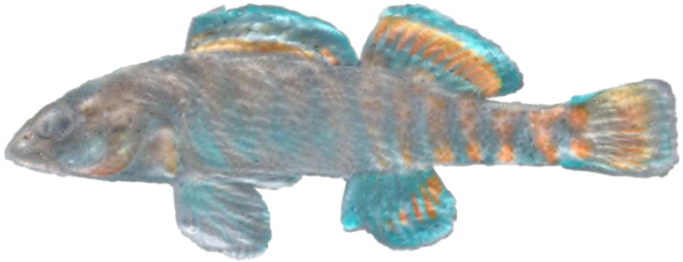
*original*

+



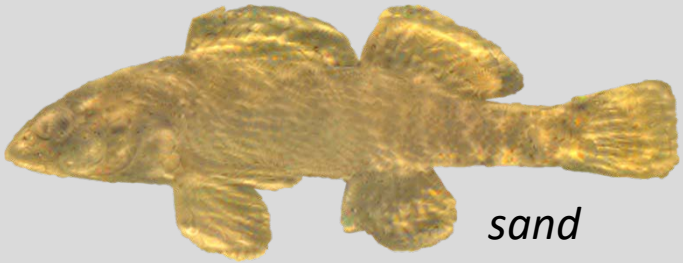
*sand*

=



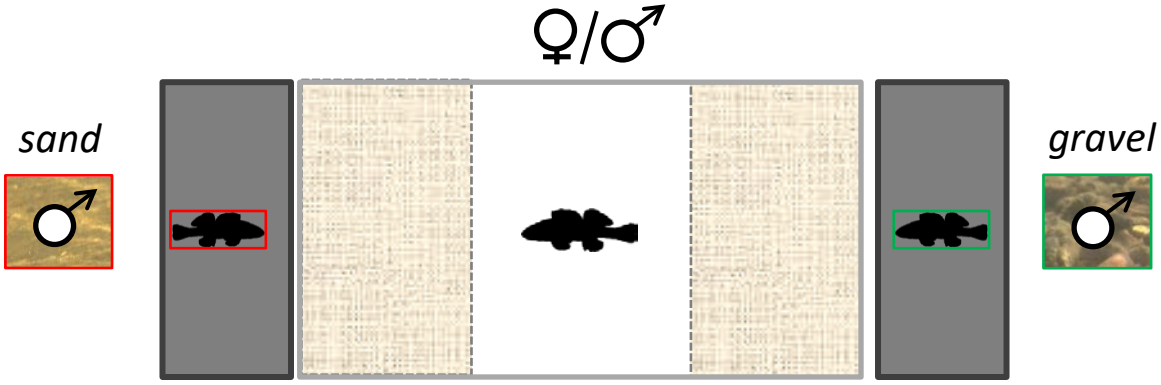
Colour control
- optional

*gravel*



*sand*

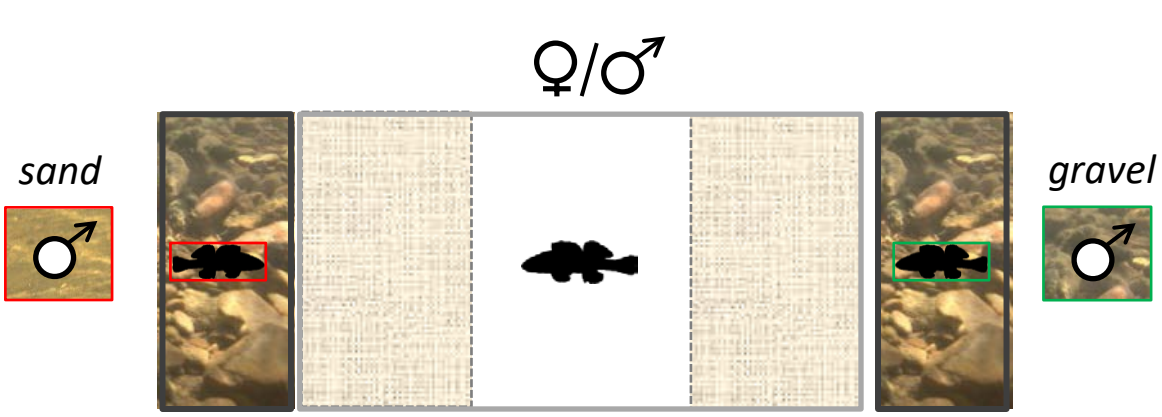
# Planned experiments in fish




| Treatments | Predictions |
|---|---|
| Style of male individuals: gravel vs. sand – *gray background* | Preference for the style of its own habitat, independently of the context* |

*during the mating period

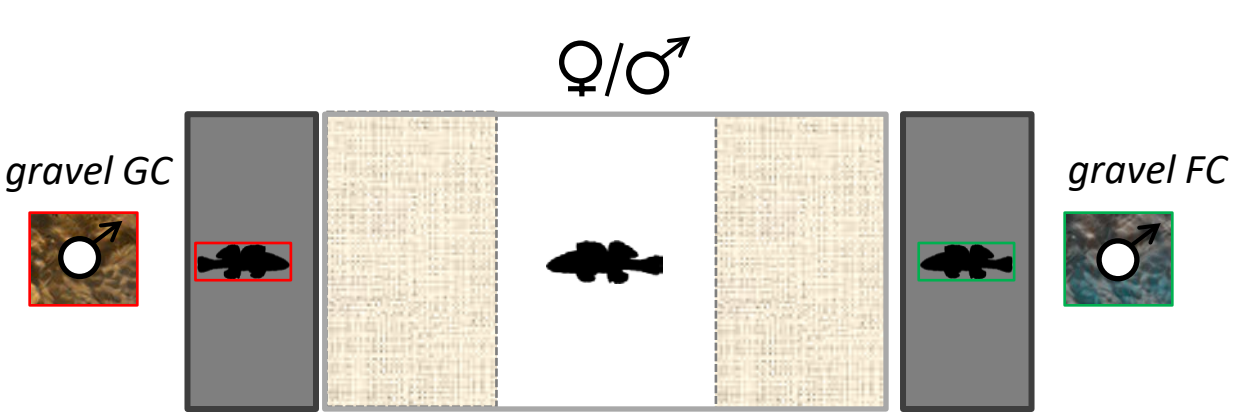
# Planned experiments in fish




| Treatments | Predictions |
|---|---|
| Style of male individuals: gravel vs. sand – *gray background* | Preference for the style of its own habitat, independently of the context* |
| Style of male individuals: gravel vs. sand – *sand or gravel background* | Preference for the style of its own habitat, with congruent vs. incongruent context* |

*during the mating period

# Planned experiments in fish




| Treatments | Predictions |
|---|---|
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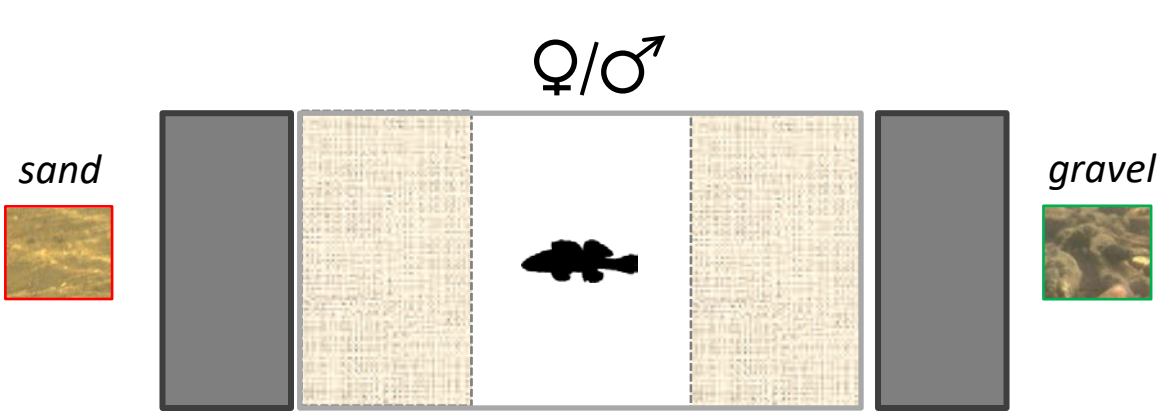
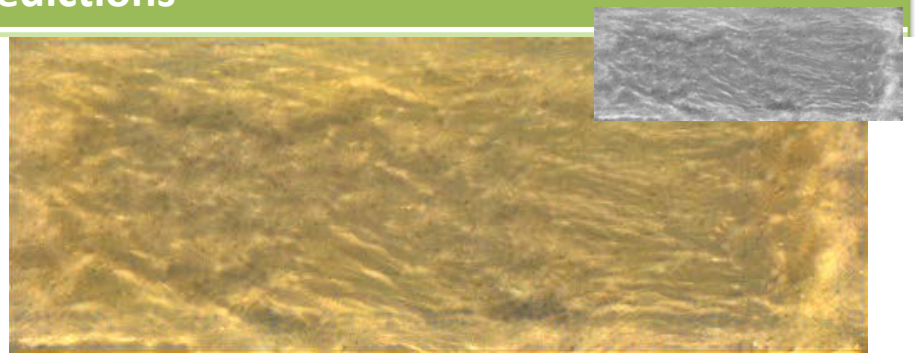
| Style of male individuals: gravel vs. sand – *sand or gravel background* | Preference for the style of its own habitat, with congruent vs. incongruent context* |
| Colour control: on vs. off (same style) | Preference for natural fish colours* |

*during the mating period

# Planned experiments in fish




| Treatments | Predictions |
|---|---|
|  |  |
| Style control: white noise x habitat (no fish) | Preference for the style of its own habitat |
| Habitat control: scrambled versions (no fish) | Preference for the statistics of its own habitat |

*during the mating period

# Some initiatives of interest

EcoEvoRxiv

PCI
peercommunityin.org

SORTEE
Society for Open, Reliable, and Transparent Ecology and Evolutionary Biology

Inaugural SORTEE Conference,
online July 12-14 (free)
https://www.sortee.org/events

crowdfight

https://crowdfight.org/micro-symposium/

**Symposium on the Science of Collaboration**
**online on June 15, 2021, at 16:00 CEST**

- What is the difference between collaborating and helping each other, and why it matters.
- The role of individual leadership in science (Should all scientists lead?)
- How are scientific collaborations established? What alternatives can we imagine?
- Should science be more or less specialized than it is now?
- How do our current incentives (e.g. authorship in publications) shape our culture?
- What opportunities to improve those incentives are offered by new technologies and by the cultural change imposed by the pandemic?
- What are the main challenges to improve our incentives?

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# Thank you for your attention!

# Attractiveness of camouflage

Take part in our soon-to-be online study!

## Attractivité du camouflage

Une équipe de recherche du *Centre d'Ecologie fonctionnelle et Evolutive* lance une étude sur le lien entre l'attractivité visuelle et le camouflage.

**Cette étude dure 15 minutes environ**

Cette étude scientifique s'intéresse à l'attractivité du camouflage. L'expérience dure environ 10 minutes. Dans un premier temps, vous aurez à détecter le plus rapidement possible la cible camouflée en cliquant dessus. Dans un second temps, vous aurez à choisir parmi deux images laquelle vous parait la plus attractive. Enfin, un très court questionnaire conclura votre participation à cette étude scientifique. L'étude est anonyme, aucune information vous concernant ne sera diffusée ou publiée. Vous aurez à tout moment un droit d'accès et de rectification sur les informations vous concernant, grâce à un numéro d'anonymat qui vous sera fourni à la fin de l'expérience.

***Pour des raisons de compatibilité, cette expérience n'est réalisable que sur un écran d'ordinateur.***

# White noise x Habitat

- What is actually transferred?