PySilsub—a toolbox for silent substitution

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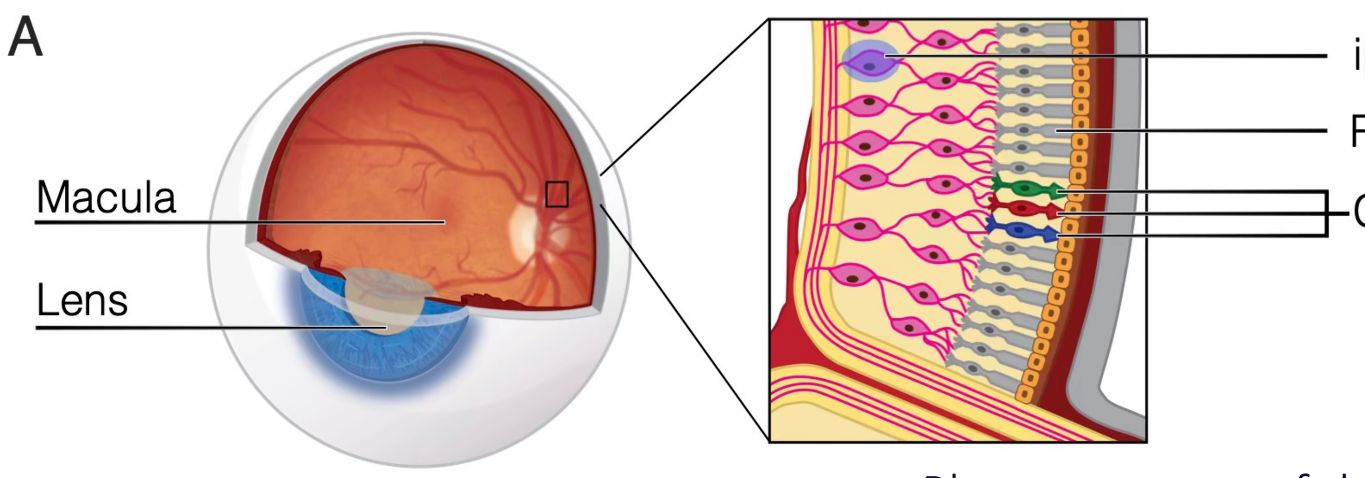
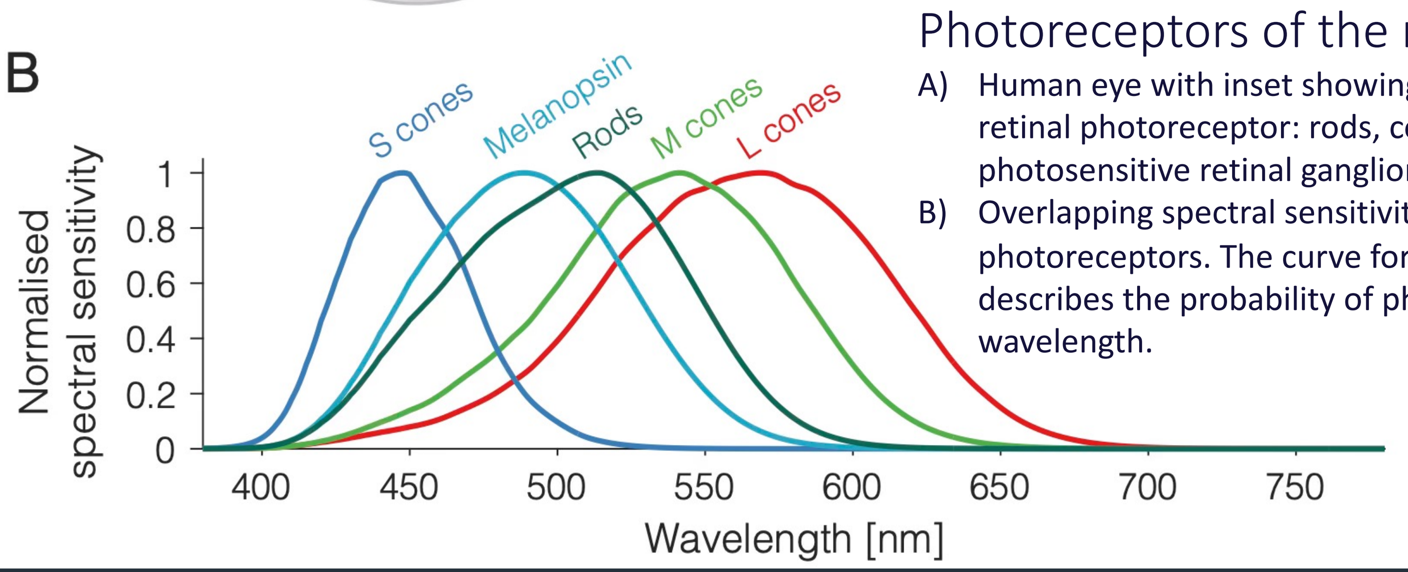
Introduction

- Human retinae are packed with photosensitive cells—rods for low-light vision, three types of cone for daylight vision, and intrinsically photosensitive retinal ganglion cells (ipRGCs) for controlling non-image forming functions (e.g., circadian photoentrainment, pupil size)
- Significant overlap in spectral sensitivities means that most lights will stimulate all photoreceptors, but to varying degrees
- **Silent substitution** (Estévez & Spekreijse, 1982) **provides a principled basis for selectively stimulating individual classes of retinal photoreceptor(s)**, which is useful in research and clinical settings
- This works by modulating the light output from a multiprimary device to increase or decrease the response of one photoreceptor class, whilst keeping others constant
- ***PySilsub* is a novel Python package for silent substitution.** With accurate spectral measurements, it is easy to create stimuli.





Photoreceptors of the retina

A) Human eye with inset showing the three types of retinal photoreceptor: rods, cones, and intrinsically photosensitive retinal ganglion cells (ipRGCs).

B) Overlapping spectral sensitivities of retinal photoreceptors. The curve for each photoreceptor describes the probability of photon capture at a given wavelength.

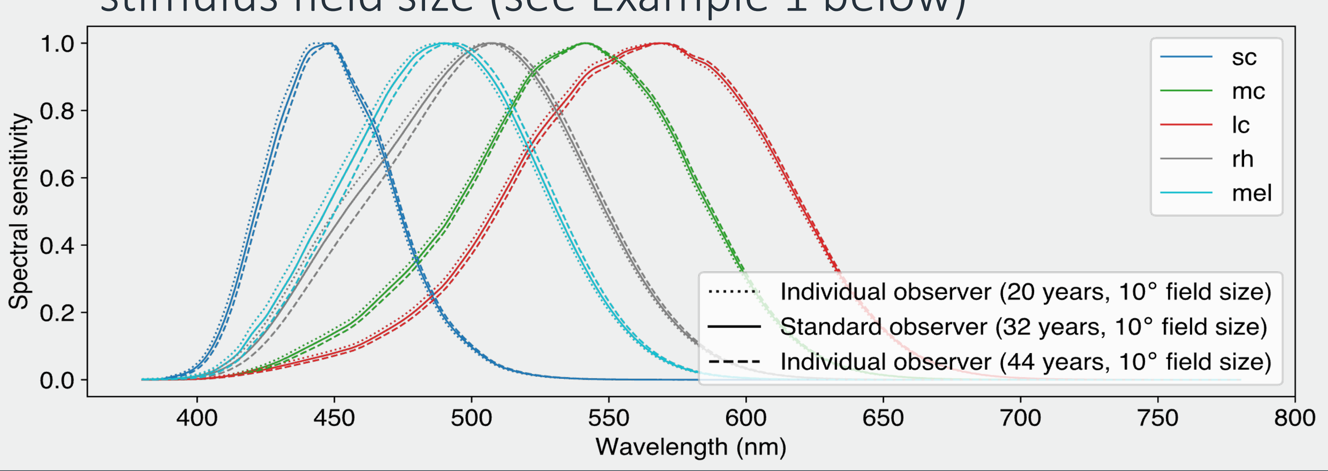
PySilSub – key modules

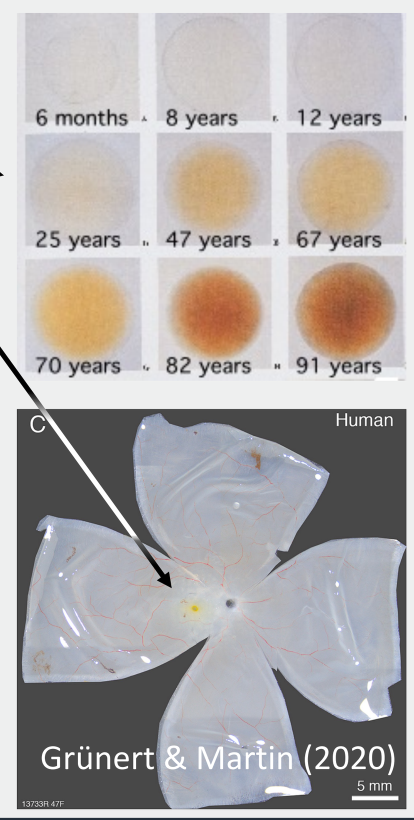
pysilsub.observers

- Generate spectral sensitivity functions for individual colorimetric observers
- Account for lens yellowing with age and stimulus field size (see Example 1 below)

Lens yellowing with age shifts the spectral response of photoreceptors

Macular pigment alters spectrally sensitivity of foveal receptors

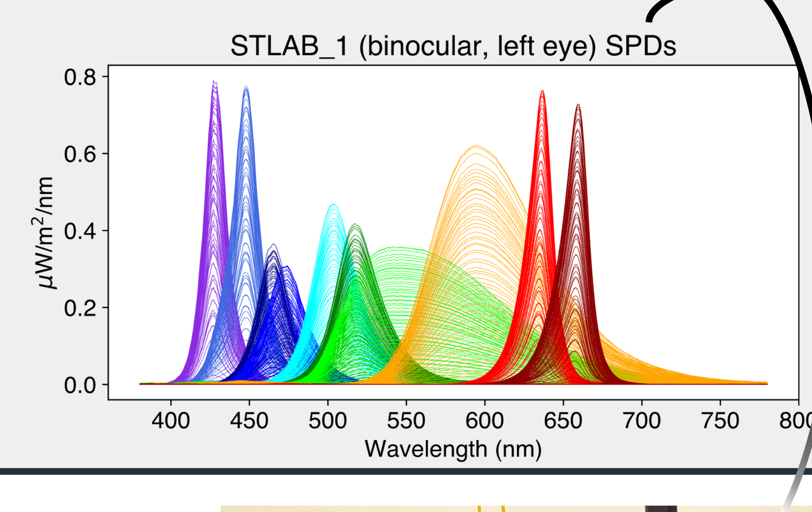


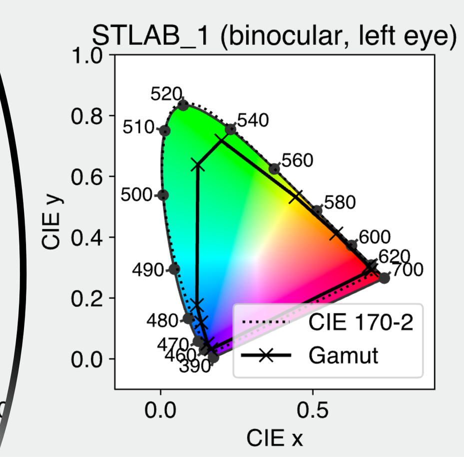


pysilsub.devices

- Create a forward model for any multiprimary stimulation system for which accurate spectral calibration data are available
- Predict output, perform gamma correction, convert to native device settings
- Match multiple devices for binocular scenarios

LEDMOTIVE STLab – a 10 primary light engine with spectral switching time of 10 ms





pysilsub.problems

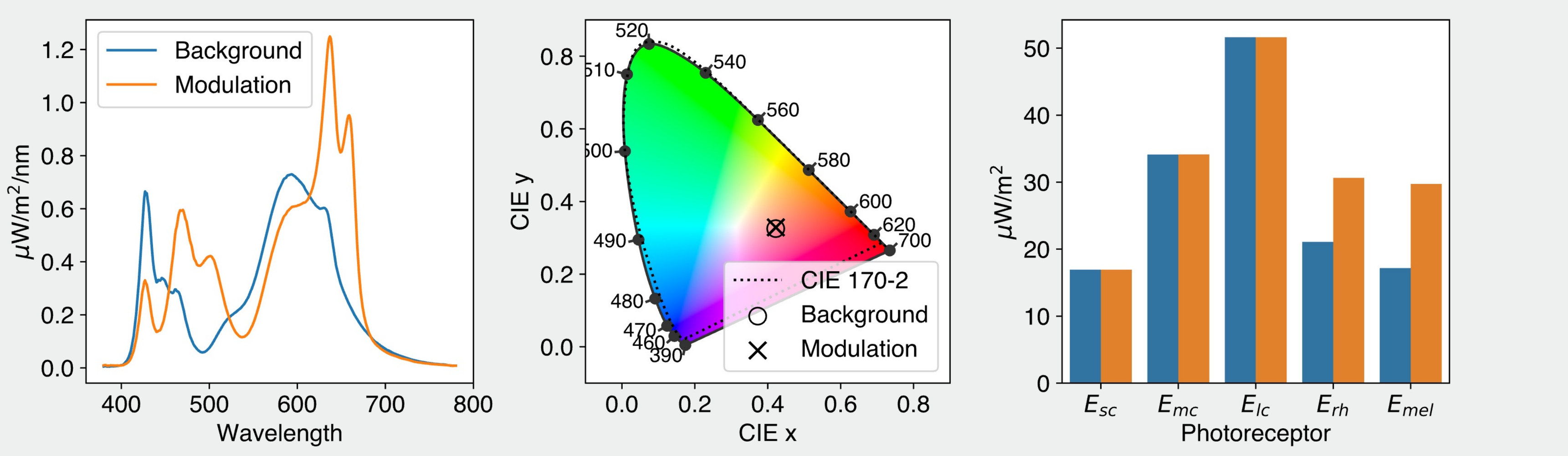
- Intuitive interface for defining silent substitution problems and solving them with linear algebra or numerical optimization

```
from pysilsub.problems import SilentSubstitutionProblem as SSP
from pysilsub.observers import IndividualColorimetricObserver as ICO

problem = SSP.from_package_data('STLAB_1_York')  # Load example data
problem.observer = ICO(age=42, field_size=10)  # Assign custom observer model
problem.ignore = ['rh']  # Ignore rod photoreceptors
problem.minimize = ['sc', 'mc', 'lc']  # Minimise cone contrast
problem.modulate = ['mel']  # Target melanopsin
problem.target_contrast = 1.0  # With 100% contrast
solution = problem.optim_solve()  # Solve with optimization
fig = problem.plot_solution(solution.x)  # Plot the solution
```

Example 1

Target melanopsin with 100% contrast (no background specified), whilst ignoring rods and minimizing cone contrast, for a 42-year-old observer and field size of 10 degrees.

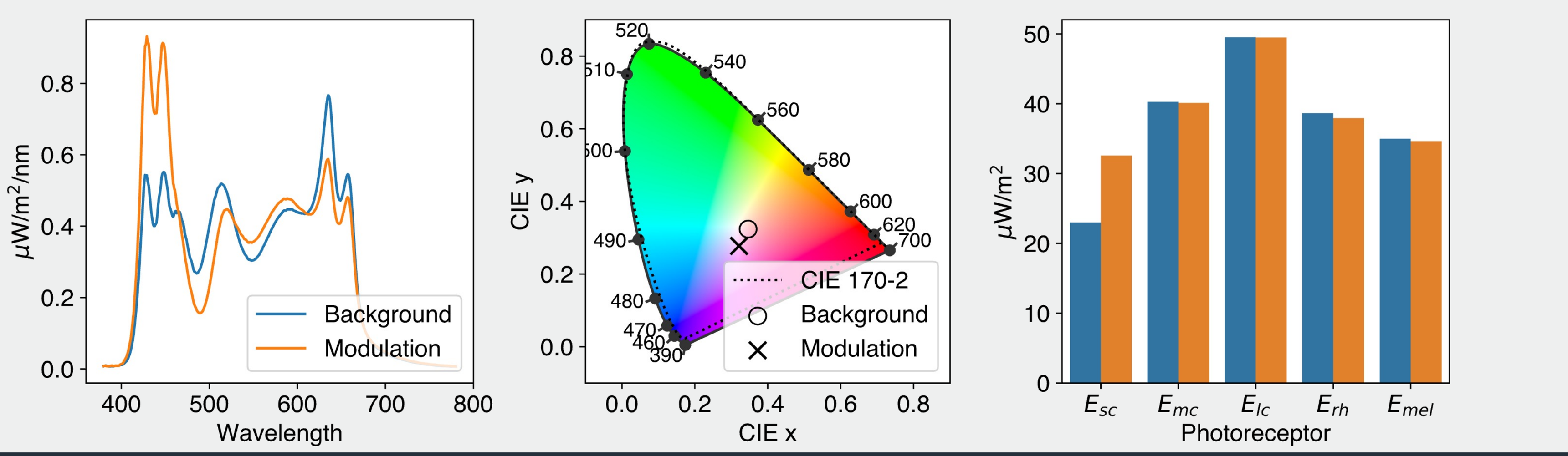



```
from pysilsub.problems import SilentSubstitutionProblem as SSP

problem = SSP.from_package_data('STLAB_1_York')  # Load example data
problem.background = [.5] * problem.nprimaries  # Specify background spectrum
problem.ignore = ['rh']  # Ignore rod photoreceptors
problem.minimize = ['mc', 'lc', 'mel']  # Minimise L/M cones and melanopsin
problem.modulate = ['sc']  # Target S-cones
problem.target_contrast = .45  # With 45% contrast
solution = problem.linalg_solve()  # Solve with linear algebra
fig = problem.plot_solution(solution)  # Plot the solution
```

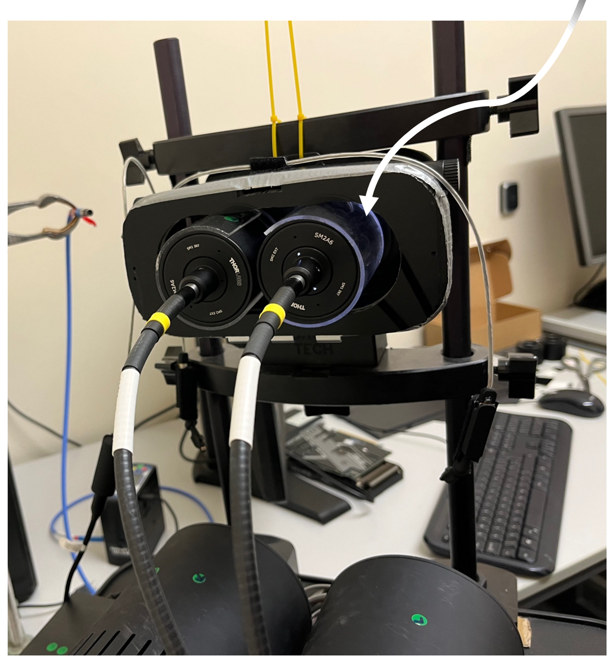
Example 2

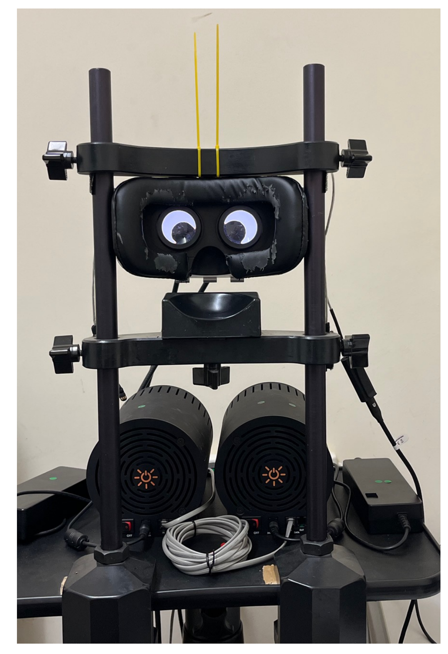
Target S-cones with 45% contrast against a specified background spectrum (all primaries, half max) whilst ignoring rods and minimizing contrast on L/M cones and melanopsin, assuming 32-year-old observer and 10-degree field size.



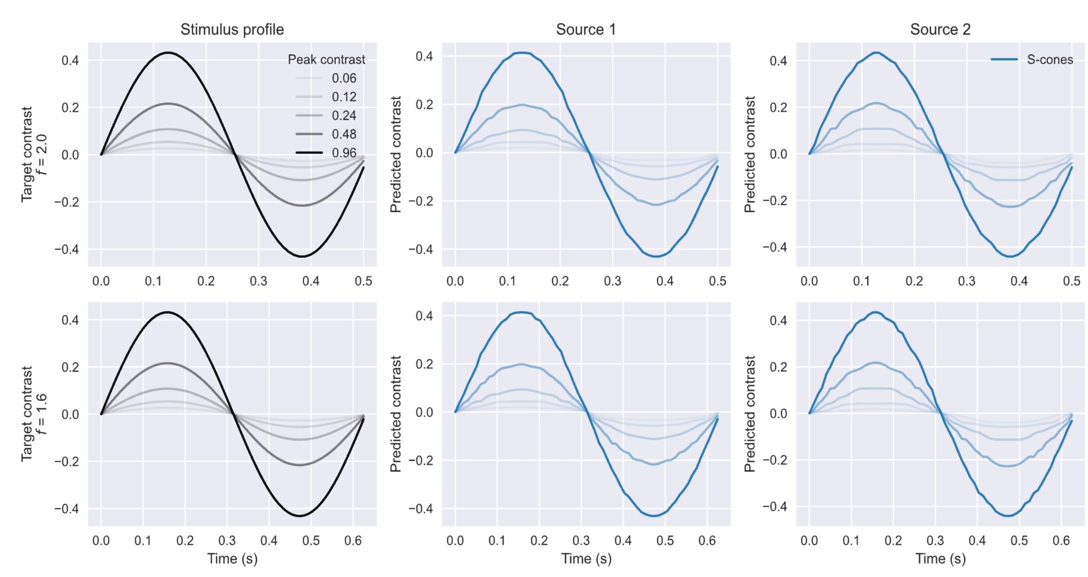
PySilSub – how are we using it?

We are using the toolbox with two 10-primary LEDMOTIVE STLab devices. This allows us to stimulate the two eyes independently, via a custom-built optical system (pictured right), to study binocular combination of signals within and between different photoreceptor pathways.



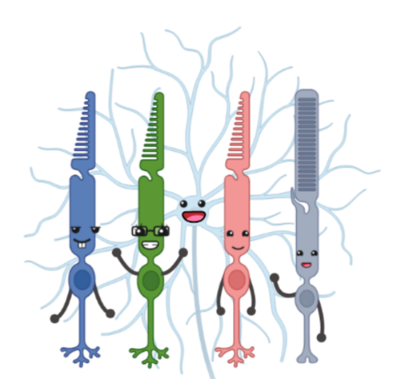


Our first experiments will measure pupil size and EEG responses to binocular, monocular and dichoptic frequency-contrast modulations for individual photoreceptors (example S-cone stimuli shown right)



We are currently developing an MRI-compatible version of the optical system.

Lots more info and examples online



PySilSub

A Python software for performing the method of silent substitution.

Welcome to PySilSub's documentation!

Its still in beta...

DOI 10.5281/zenodo.6817025 | pypi package 0.0.13 | Contributor Covenant 2.0 | license MIT | status beta

python Package Index

Feedback and contributions are warmly encouraged!

Try out the examples

`pip install pysilsub`

View code on GitHub!

https://github.com/PySilentSubstitution/pysilsub

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