Automated Design of fMRI Paradigms

Katherine Esper   Felipe Meneguzzi†

†Pontifical Catholic University of Rio Grande do Sul, Brazil
katherine.esper@edu.pucrs.br
felipe.meneguzzi@pucrs.br

Guangzhou, August 2021

SCHOOL OF
TECHNOLOGY

# Table of Contents

functional MRI

Funcional Magnetic Resonance Imaging

- Neuroimaging techniques to **assess brain activation** patterns;
- fMRI experiments rely on the precise and effective paradigm design, selecting **the best sequences of stimuli** to activate specific brain regions.
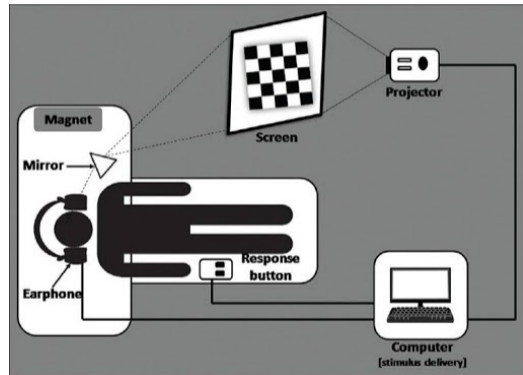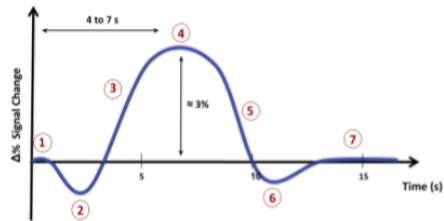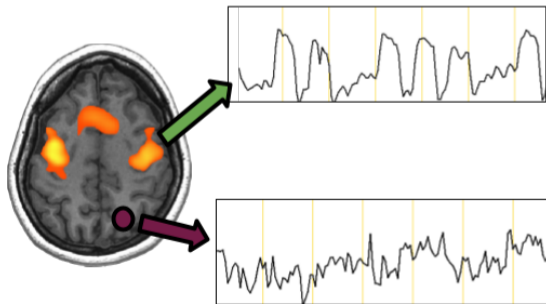
Paradigm

- Activities performed or stimuli received by the subject during a study to evoke a brain activation in certain brain areas.
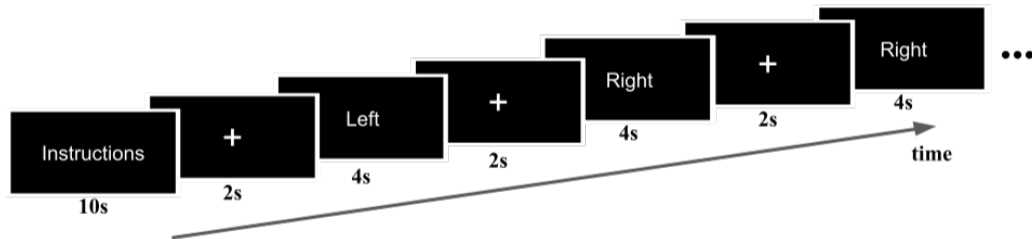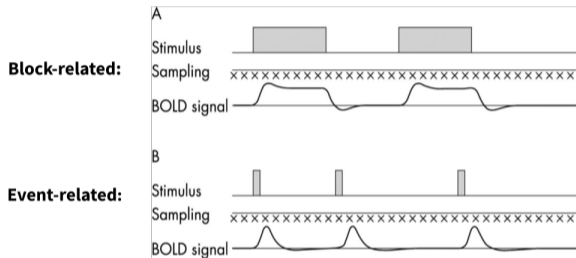
BOLD Signal
Blood Oxygen Level Dependent

Paradigm design: important challenge for neuroimaging studies and presurgical planning.
Currently: based on adapting previously developed paradigms

Presurgical Planning
What is it?

- Localization of important cortical and subcortical areas at risk of injury during the surgical removal of brain lesions;
- Important to avoid permanent damage to neurological function;
- Preoperative counseling:
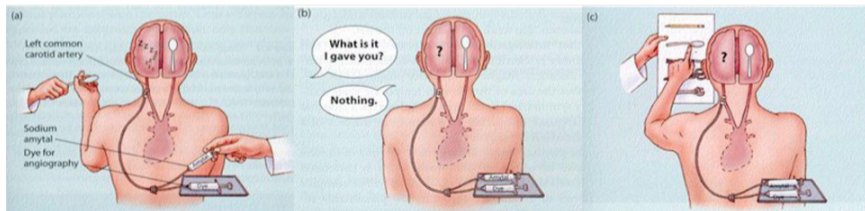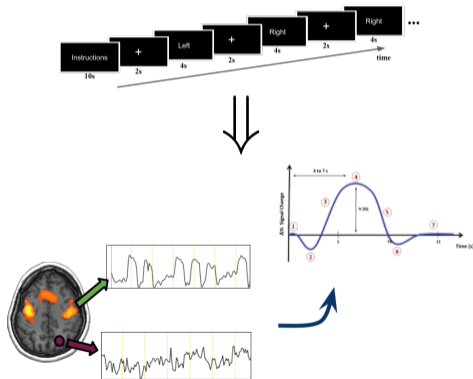 - Brain tumor, vascular lesions, intractable epilepsy, and other resectable lesions.

Table of Contents

Key Goal, fMRI activation model in PDDL+

$\Rightarrow$

```
(:action ST_Pseudo
    :parameters (?t - timing)
    :precondition (and
        (instructions)
        (rest)
        (paradigm_words)
    )
    :effect (and
        (increase (intensity_IOG) 10)
        (increase (intensity_MOG) 10)
        (increase (intensity_CUN) 10)
        (increase (intensity_ACC) 10)
        (increase (intensity_MFG) 10)
        (increase (intensity_INS) 10)
        (increase (intensity_SPL) 10)

        (increase (total ?t) 5)
        (finish_experiment)
        (not (rest))
    )
)
```

A PDDL+ model of fMRI activation
Why?

Applications of the model:

- Neuroscience research design
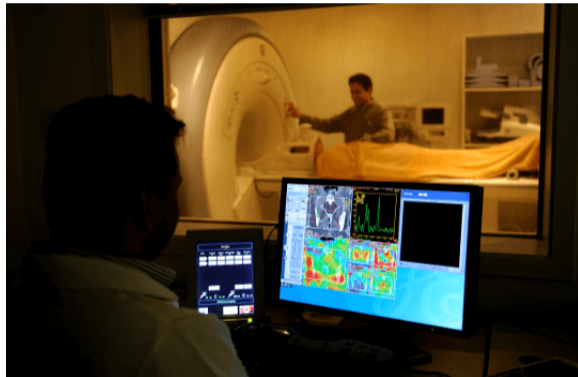- Pre-surgical planning

Applications of the model:

- Neuroscience research design
- Pre-surgical planning

A PDDL+ model of fMRI activation
Why?

Applications of the model:

- Neuroscience research design
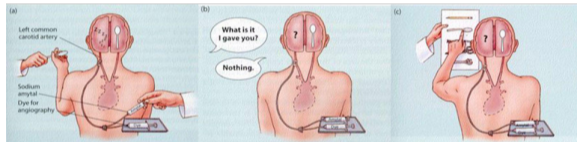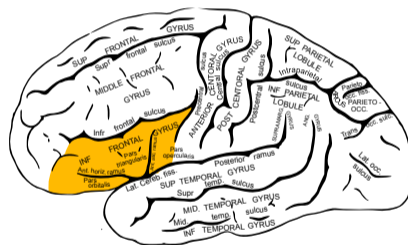- Pre-surgical planning

Key features in the formalization:

Predicates

PDDL+ formalization

Key features in the formalization:

- Numeric activation intensities for each anatomic region:
  (intensity_IFG)

Predicates
PDDL+ formalization

Key features in the formalization:

- Numeric activation intensities for each anatomic region:
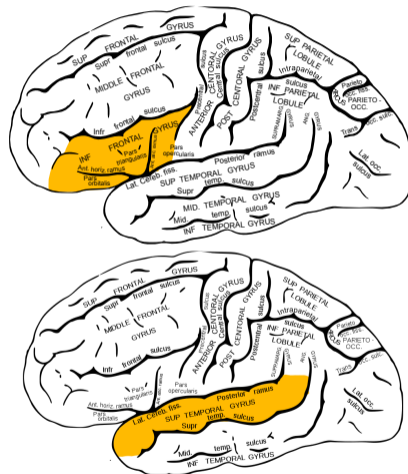 `(intensity_IFG)(intensity_STG)`

Predicates
PDDL+ formalization

Key features in the formalization:

- Numeric activation intensities for each anatomic region:
  (intensity_IFG)(intensity_STG)

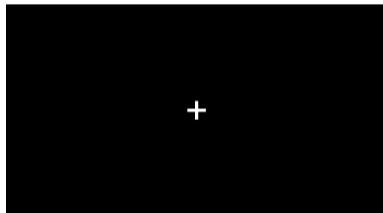- Whether the subject has gone through a *rest* period: (rest)

Predicates

PDDL+ formalization

Key features in the formalization:

- Numeric activation intensities for each anatomic region: (intensity_IFG)(intensity_STG)

- Whether the subject has gone through a *rest* period: (rest)

- Whether the subject has visualized *instructions*: (instructions)

Welcome and thank you for participating!

This is a language experiment.
For each word that appears on the screen,
select whether it exists (right button) or not (left button).

If you want to stop the experiment,
press the panic button (red).

Actions
PDDL+ formalization

Key actions in the domain:

Key actions in the domain:

- Instructions

Welcome and thank you for participating!

This is a language experiment.
For each word that appears on the screen,
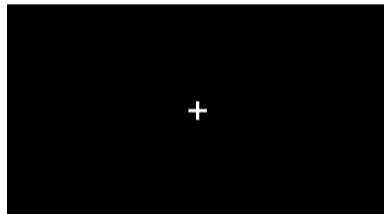select whether it exists (right button) or not (left button).

If you want to stop the experiment,
press the panic button (red).

Key actions in the domain:

- Instructions
- Baseline Rest

Actions
PDDL+ formalization

Key actions in the domain:

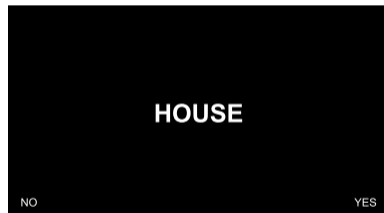- Instructions
- Baseline Rest
- Stimuli

Table of Contents

- Case report of an adolescent patient with an **intractable epilepsy**;
- Left congenital temporal **lobe tumor**, a structural abnormality near cortical language areas;
- Brain activation during **reading task** on a clinical case. The tumor is indicated by the arrow.
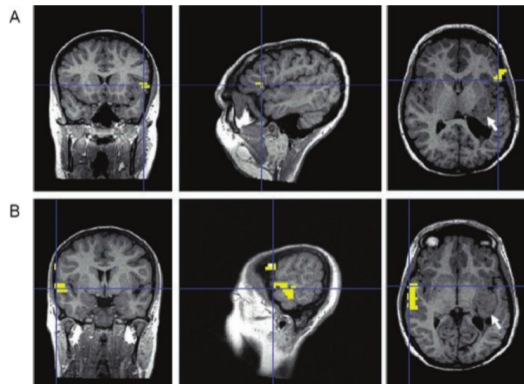

Figure: [Ries et al., 2004]

Left congenital temporal lobe tumor near cortical **language areas**.
Planner's Goal: Left Inferior Frontal Gyrus (LIFG)

- LIFG plays a key role in the cerebral cortical network that supports reading and visual word recognition [Cornelissen et al., 2009];
- One of the regions responsible for language processing, comprehension, and production [Marslen-Wilson and Tyler, 2007].
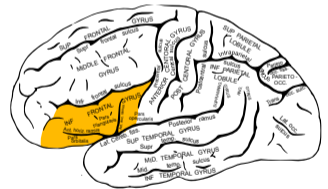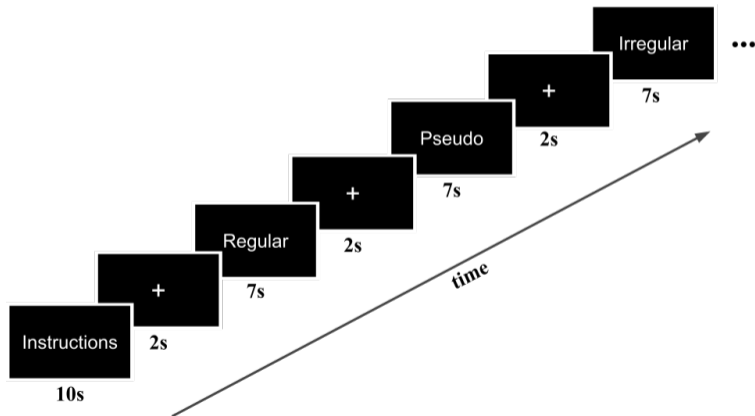

Figure: Inferior Frontal Gyrus

Automated Planning for Presurgical Planning

Experiment 1 - Left Inferior Frontal Gyrus

Planner's Goal:
$intensity(LIFG) >= 100$

Automated Planning for Presurgical Planning
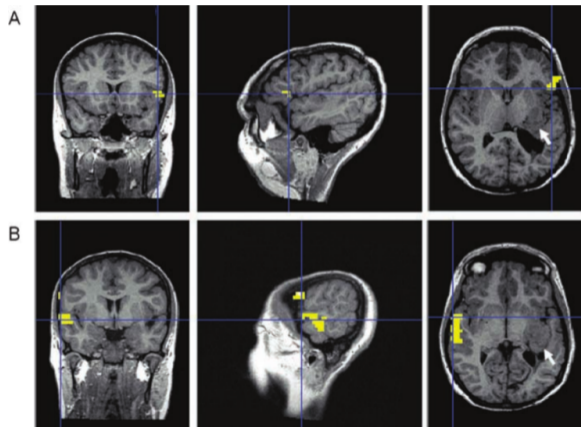Experiment 1 - Left Inferior Frontal Gyrus

Figure: Presurgical clinical case
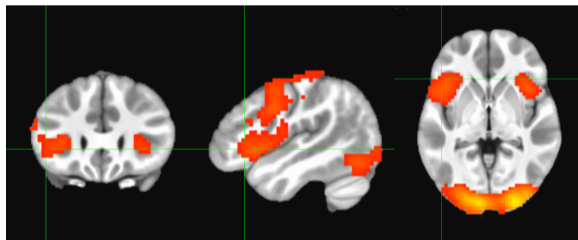

Figure: Our paradigm planner

Planner's Goal: Superior Temporal Gyrus (STG)

- STG is part of auditory association cortex (and a site of multisensory integration) and thus necessarily plays some role in spoken word recognition.
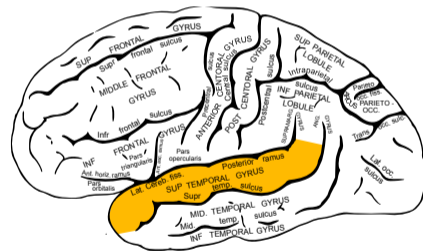

Figure: Superior Temporal Gyrus

Automated Planning for Presurgical Planning

Planner's Goal:
$intensity(STG) >= 100$

Figure: Activations obtained by the stimulus

Figure: Auditory stimulus paradigm

Table of Contents

Conclusions and Future Work
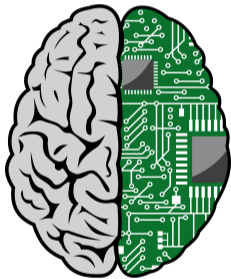
- We developed a specific application in PDDL+ to **planning neuroimaging paradigms**
  - aimed at solving the dual problem of effective paradigm design and scan cost minimization;
- Potentially useful tool for **Neuroscientific Research** and as a supporting resource for presurgical planning;
- Moving forward:
  - General method to derive activation values (e.g. ML);
  - Linearization of non-linear activation functions.