Attention and processing of relevant visual information while driving: a MEG study

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Context

Defaults of attention in driving

=> Major contributory factor to traffic crashes

Studied by:

- Surveys
- Behavioral on road and simulator experiments
- Naturalistic observations
- Neuroimagery

What is MEG ?

Magnetoencephalography (MEG)

- imaging technique used to measure the magnetic fields produced by electrical activity in the brain
- magnetically shielded room used to reduce the magnetic background noise

Why MEG?

- To better understand what happens before the subject's response to an event
- To localize the neural clusters involved in attentional and decisional processes and to examine the time-course of their activities:

Where ? When ? How ?

Objectives

- To better understand the impact of change in mental workload on cerebral activities while driving
- To shed light on which steps in information processing are more affected by an increase in mental workload while driving
- Feasibility of MEG recording during simulated driving

Hypothesis

In multi-tasking situation

$\Rightarrow$ a decrease of focused attention on relevant cues for the driving task

$\Rightarrow$ modulation of brain responses related to visual information processing (visual perception, anticipation, categorization, decision and motor response)

Protocol (1/3)

Subjects

Twelve right-handed male volunteers (mean 25.4 ± 2,1)

Simulator

- Car simulator designed taking into account the MEG constraints
- 18 driving scenarii (5 min each) presented in a pseudo-random order

Protocol (2/3)

Stimuli of interest

Yellow traffic light

Arrow on panels

Task

- To brake each time the traffic light turns from green to yellow
- To use the indicator adequately each time a direction panel appears

Protocol (3/3)

Attention modulation

- A radio broadcast was sent with each driving scenario

- Two experimental conditions:

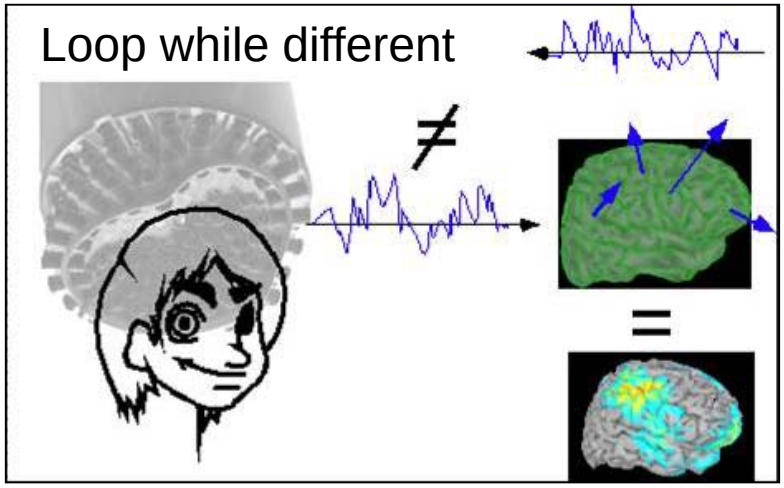
  - Simple task (ST): subject could ignore the broadcast
  - Dual task (DT): subject had to actively listen to the broadcast in order to answer 3 questions

    - ➢ Questions asked before the start of the driving scenario and the broadcast
    - ➢ Answers given at the end of each scenario

Data acquisition and analysis

Principle of analysis

Estimation of the neuronal network specifically activated by a specific information from magnetic fields recorded outside the brain and by modelling: source-space activity (weighted minimum norm estimate)



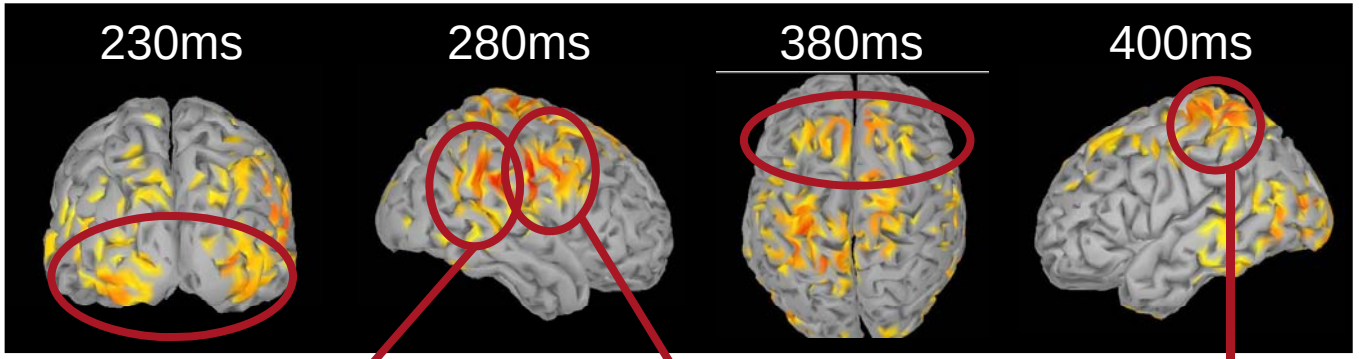
In a time window from -200 ms to 1000 ms from the stimulus of interest

Group analysis:
– Projection of individual cortical activities on a generic brain template
– To perform statistical analysis (t-test on [ST-DT])

First results: traffic lights (1/3)

Main neural network activated:

Simple Task



Visual areas

Motor areas

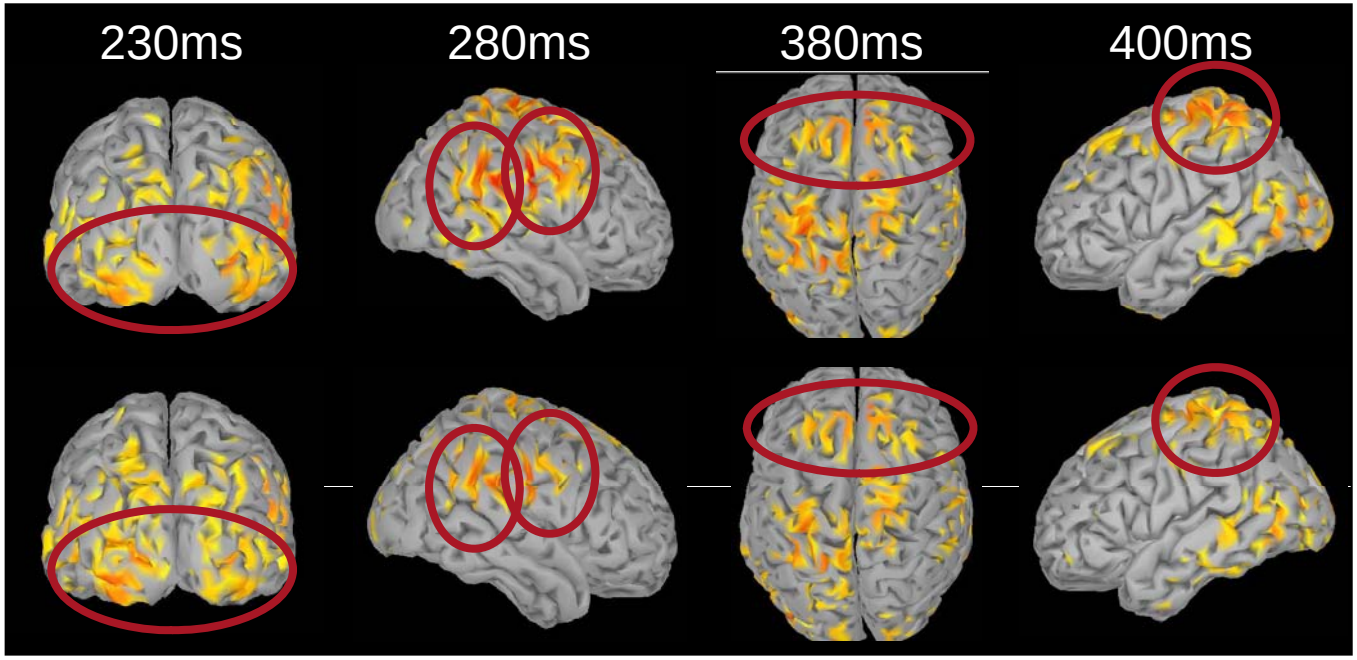
Right temporo-parietal junction **Right posterior frontal areas**

Consistent with a right fronto-parietal network involved during tasks requiring orientation of attention to relevant cues

Left superior parietal areas sensorimotor integration, visuo-spatial attention

First results: traffic lights (2/3)

Main neural network activated:

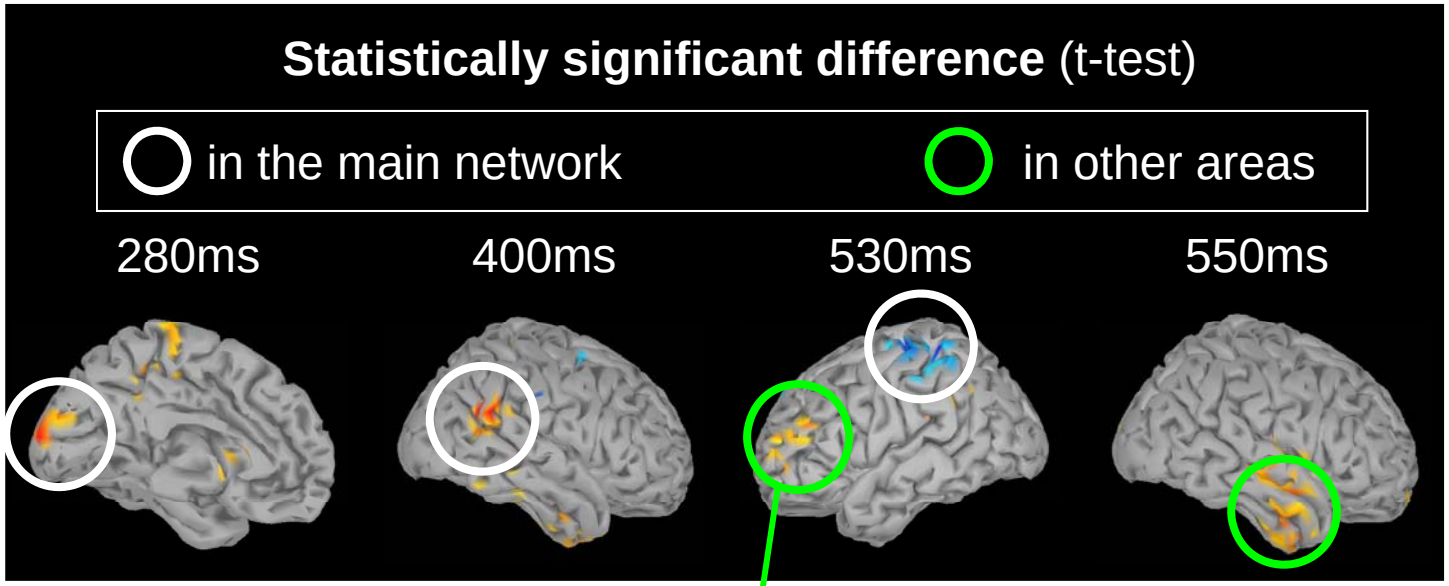


The main network activated by traffic light changes from green to yellow involves:
- **sensory visual areas**
- **parietal and frontal regions known to play a role in selective attention**
- **motor areas**

First results: traffic lights (3/3)

Difference of activations between simple task and dual task

Difference maps [ST-DT]



visual areas

Temporo-parietal junction

Superior parietal cortex

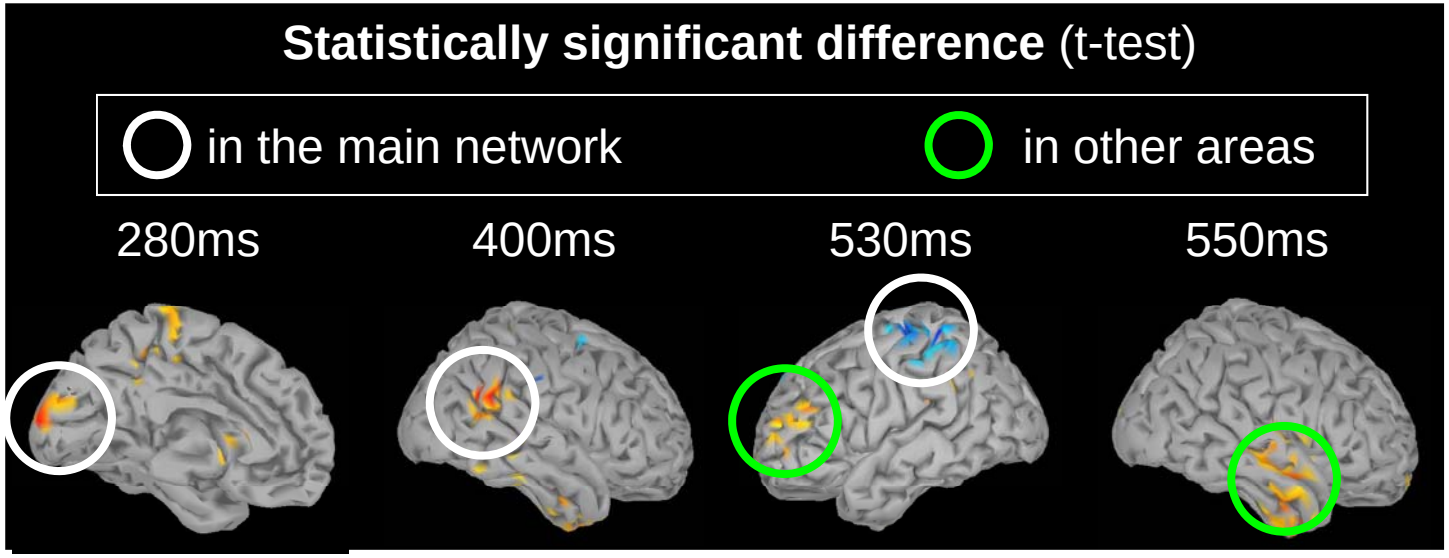
Middle temporal gyrus: Complex visual scene

Left dorsolateral prefrontal cortex:
perceptual decision making, preparation of forthcoming actions

First results: traffic lights (3/3)

Difference of activations between simple task and dual task

Difference maps [ST-DT]



Modulation of activity related to the perception of traffic light turning from green to yellow:

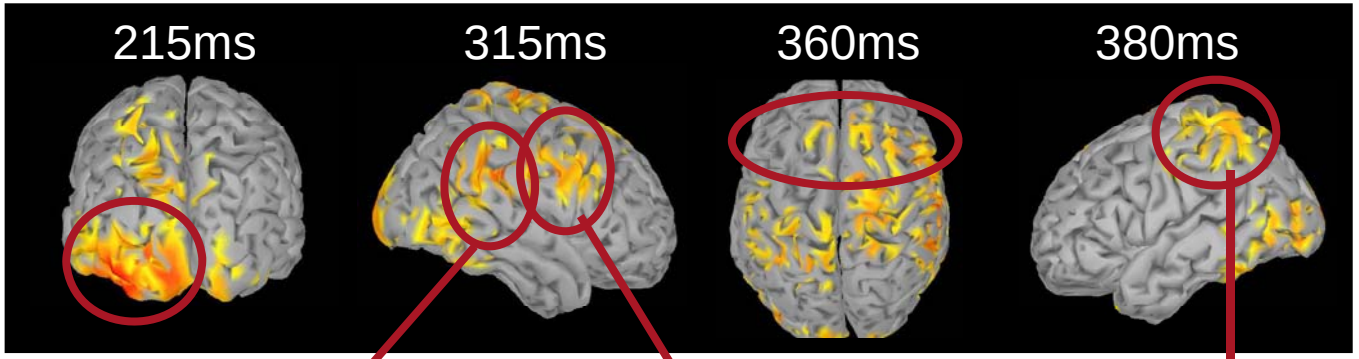
- In sensory visual areas (medial occipital cortex and middle temporal gyrus)

- In areas involved in attentional processing and executive functions (temporo-parietal and frontal areas)

First results: arrows (1/3)

Main neural network activated:

Simple Task



Visual areas

Motor areas

Right temporo-parietal junction

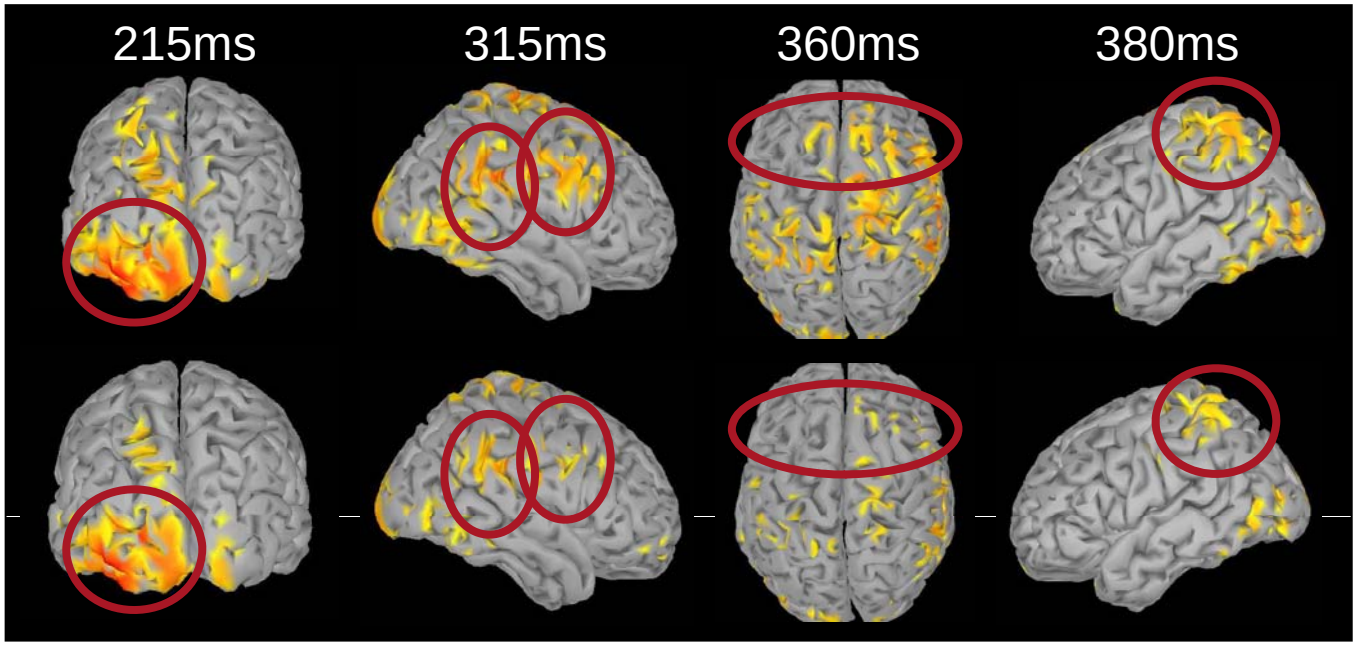
Right posterior frontal areas

Consistent with a right fronto-parietal network involved during tasks requiring orientation of attention to relevant cues

Left superior parietal areas sensorimotor integration, visuo-spatial attention

First results: arrows (2/3)

Main neural network activated:

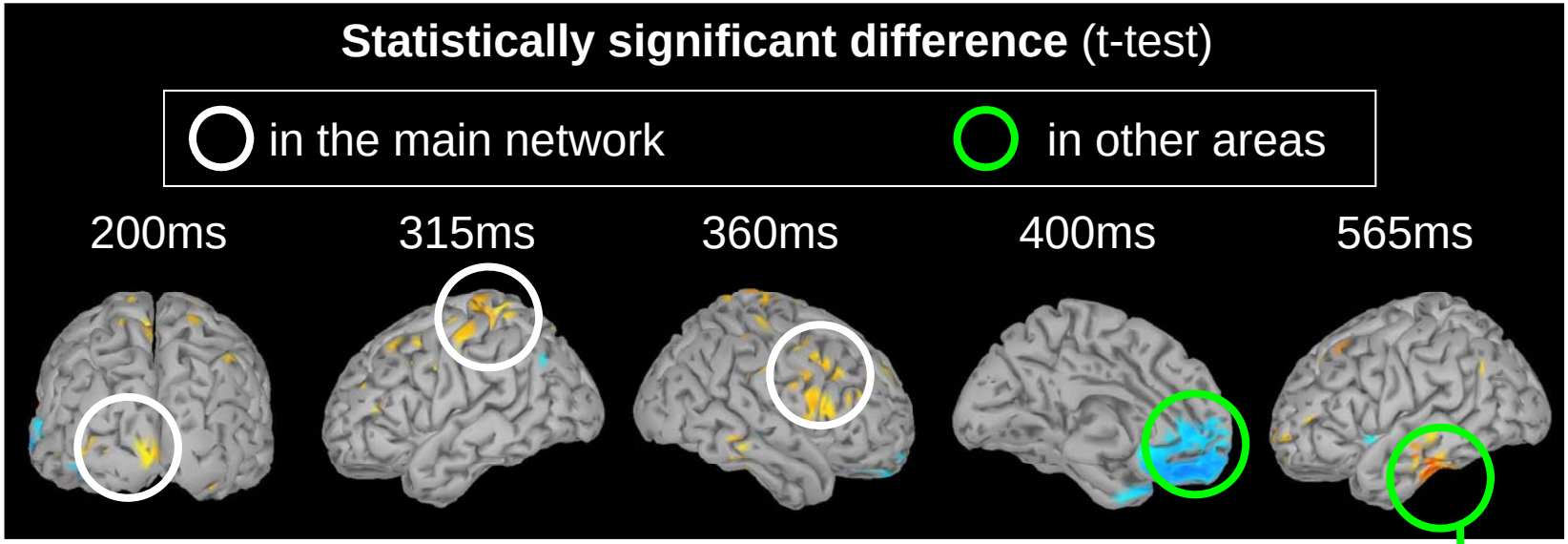


The occurence of arrows involves the same network than the one activated by traffic lights:
- sensory visual areas
- parietal and frontal regions known to play a role in selective attention

First results: arrows (3/3)

Difference of activations between simple task and dual task

Difference maps [ST-DT]



visual areas

superior parietal cortex

frontal cortex

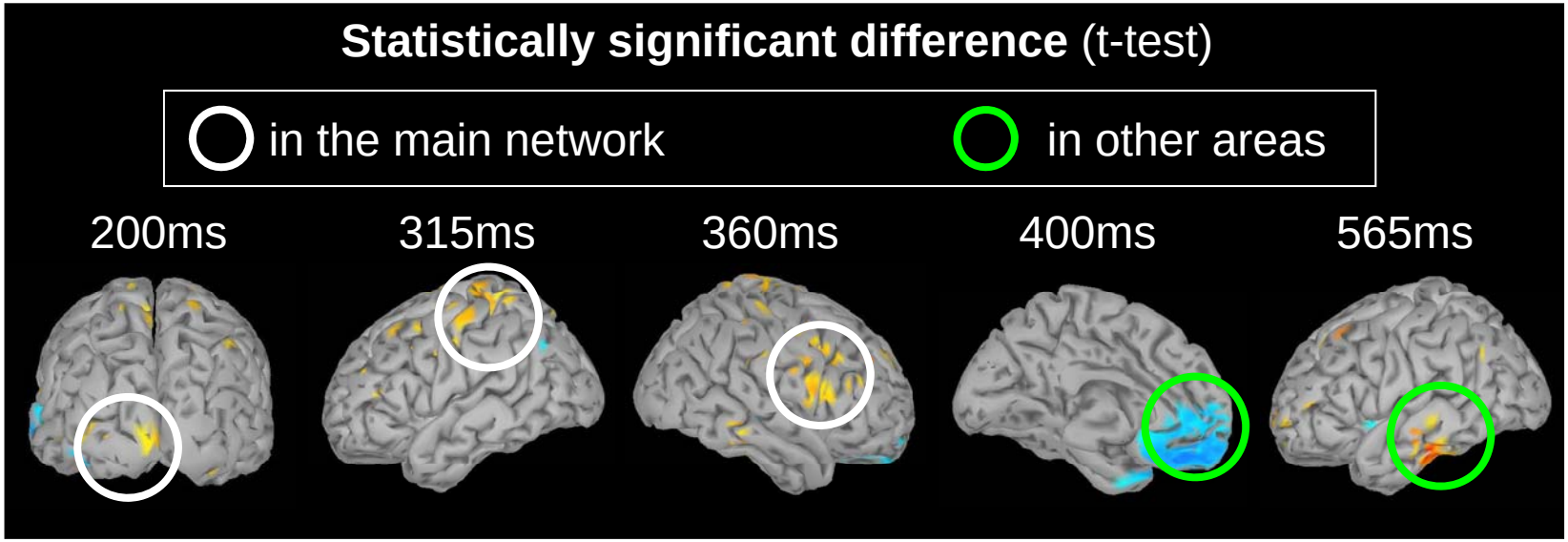
left fronto-polar cortex: multitasking

Inferior temporal gyrus: complex visual scene

First results: arrows (3/3)

Difference of activations between simple task and dual task

Difference maps [ST-DT]



Modulation of activity related to the occurrence of arrows:
- **In sensory visual areas** (medial occipital cortex and middle temporal gyrus)
- **In areas involved in attentional processing** (temporo-parietal and frontal areas)
- **In the left frontopolar cortex involved in reasoning, problem-solving, decision-making and robustly engaged in multitasking behaviours**

Conclusions

Feasibility

The increase in attentional workload from ST to DT induces:

- Lower brain activities in DT than in ST :
  - ⇒ in primary visual areas suggesting a deterioration of the early visual process by the DT
  - ⇒ in areas involved in the processing of complex scenes suggesting a deterioration of later visual process by the DT
- Modulation of activities in attentional neural networks :
  - ⇒ Lower activity in DT than in ST in the network involved in orientation of attention suggesting a deterioration of the orientation
  - ⇒ Lower activity in DT than in ST in the dorsolateral prefrontal cortex suggesting a deterioration of perceptual decision making for traffic lights
  - ⇒ Higher activity in DT than in ST in the fronto-polar cortex for the panels consistent with the multi-tasking activity
- Differential effect according to the processed stimuli (traffic light or arrow)

More analysis needed:

- Modulation of activities related to anticipatory activities ? To motor preparatory activities ?

Collaborators

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Thank you for your attention