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# Analyzing Emotional Facial Expressions' Neural Correlates Using Event-Related Potentials and Eye Fixation-Related Potentials

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## Objectives

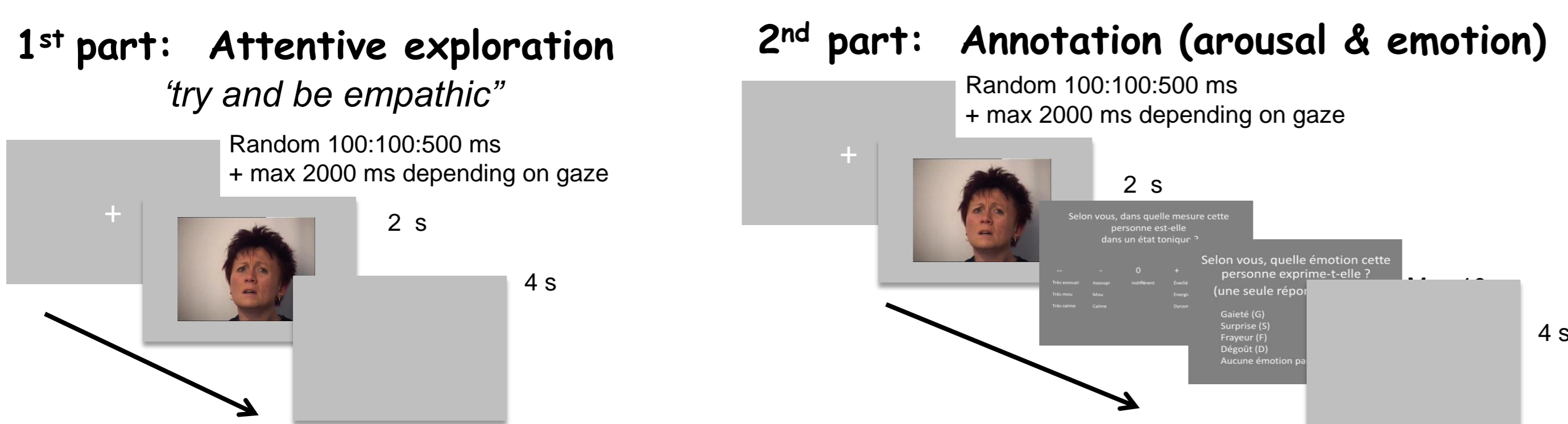
- Study the **Emotional Facial Expressions** (EFE) processing: experimental data based on EEG activities synchronized with ocular fixations;
- Observations: **Event-Related Potential** (ERP) at the stimulus onset and **first Eye Fixation-Related Potential** (EFRP);
- Methodology: Estimation using the **General Linear Model** (GLM) because of responses **overlap** (Kristensen, et al., 2017) between the ERP at the stimulus onset and the first EFRP;
- Components linked to emotional processing: N170, EPN (Early Posterior Negativity), LPP (Late Positive Potential), (Schupp, et al. 2003; Recio, et al., 2011);
- **Focus on LPP**: elaborative processing and conscious recognition (Schupp et al., 2003).

## Assumptions

- The **LPP latency** includes the **first fixation onset**;
- The LPP amplitude estimated by average on the signal time-locked at the stimulus onset is also function of the response at the first fixation that begins the **visual exploration** of the Emotional Facial Expression;
- **By GLM**: to be able to split what is due to the perception of the stimulus presentation **without eye movement** and what is due to the perception of the **first gazed region**;

## Experiment

- 22 participants between 20 and 40 years old
- **DynEmo database**: actual people (not actors) expressing their emotions  
→ **ecological material** (Tcherkassof et al., 2013)
- **Static stimuli**: Apex of the emotional dynamic response, evaluated by 20 judges.
- **Four conditions**: Disgust (12 stimuli), Surprise (12), Happiness (12), Neutral (24)



## Co-registration: EEG and Eye-movements

### Data acquisition

#### EEG

- BrainCap - 64 active electrodes  
Reference FCz - Ground AFz
- Sampling frequency: 1000 Hz

#### Eye-Tracker

- Eyelink 1000 (SR Research)
- Sampling frequency: 1000 Hz

### Data pre-processing

#### Synchronization

- Time-alignment with common hardware triggers

#### Artifacts rejection

- *Semi-automated procedure*
- Frequency filtering: 1-70 Hz + 50 Hz notch filter
- Channels: Visual inspection & interpolation
- Ocular artifacts: SOBI algorithm, cancelation of sources most correlated to EOG
- Epochs: rejection (0.8% in average) based on a variance criterion (if > mean + 3 sd)

### Statistical tests

- Repeated-measure ANOVA & Tukey post-hoc tests

*EEG analysis on the first part using the labels of the recognized emotions from the second part*

## ERP and EFRP estimations by GLM

### Estimation with GLM: ERP at the stimulus onset

- Overlap: ERP at the stimulus onset ( $s(t)$ ) and EFRP at the first fixation onset ( $a_1(t)$ )
- Model for the  $i^{th}$  trial:  
$$x_i(t) = s(t) + a_1(t - \tau_i^{(1)}) + \sum_{f=2} a_{2+}(t - \tau_i^{(f)}) + n(t)$$
- Matrix formulation:  
$$x = D_s \cdot s + D_1 \cdot a_1 + D_{2+} \cdot a_{2+} + n$$

### Input data ( $N$ trials)

- $\{x_i(t), i = 1..N\}$ : observed time locked signals at the stimulus onset
- $\{\tau_i^{(1)}, i = 1..N\}$ : latencies of the first fixation
- $\{\tau_i^{(f)}, f > 2, i = 1..N\}$ : latencies of the following fixations

$D = [D_s, D_1, D_{2+}]^\dagger$   
Toeplitz matrices with their respective latencies

### Signals to estimate

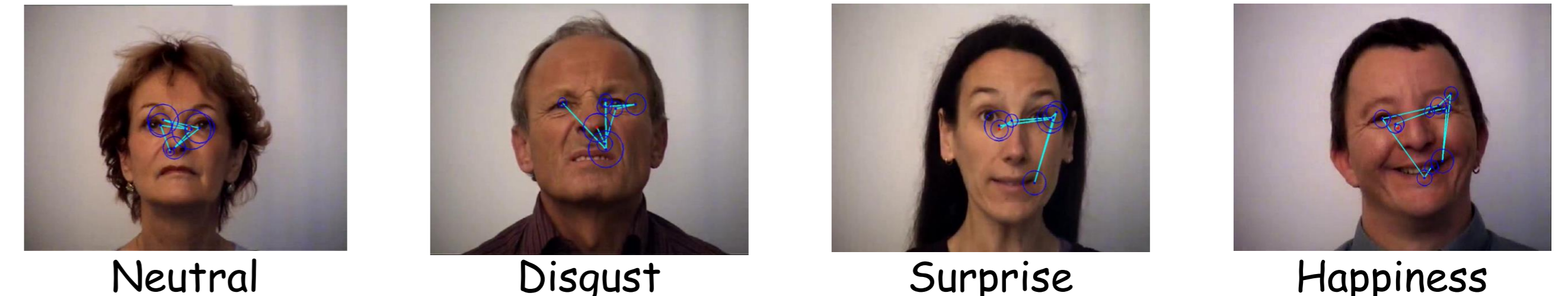
- $s(t)$ : potential evoked at the stimulus onset (ERP)
- $a_1(t)$ : potential evoked at the stimulus onset (First EFRP)
- $a_{2+}(t)$ : potential evoked at the stimulus onset (following EFRP)

$\hat{a}^{GLM} = [s^\dagger, a_1^\dagger, a_{2+}^\dagger]^\dagger$

**Solution**  $\hat{a}^{GLM}$  such as  $\min(\|n\|_F^2) = \min(\|x - D_s \cdot s + D_1 \cdot a_1 + D_{2+} \cdot a_{2+}\|_F^2)$   
→  $\hat{a}^{GLM} = (D^\dagger \cdot D)^{-1} \cdot D \cdot x$

## Behavioral results

### Examples of scanpaths



Recognition rate, Fixations duration and first fixation latency → mean (sd)

	Neutral	Disgust	Surprise	Happiness
Recog. rate [%]	67.07 (18.74)	66.52 (17.66)	56.39 (16.64)	96.28 (5.26)
Fix. duration [ms]	309.00 (66.38)	309.77 (65.08)	310.86 (66.30)	297.67 (65.87)
1st fix. latency [ms]	275.03 (49.16) → before LPP latency [400-600] ms			

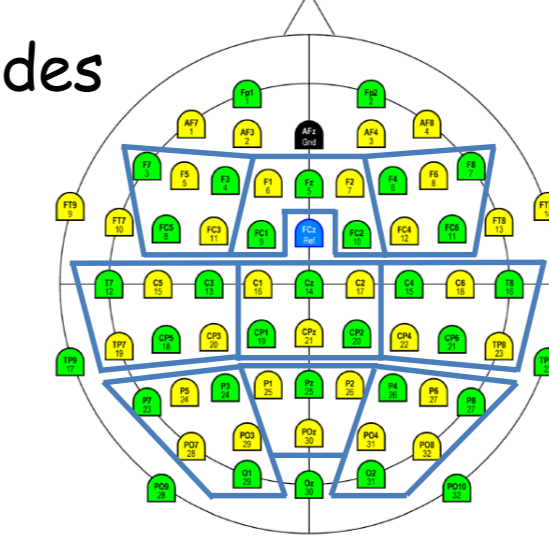
## N170, EPN, LPP on $s(t)^{Av}$ and on $s(t)^{GLM}$

### Two estimates

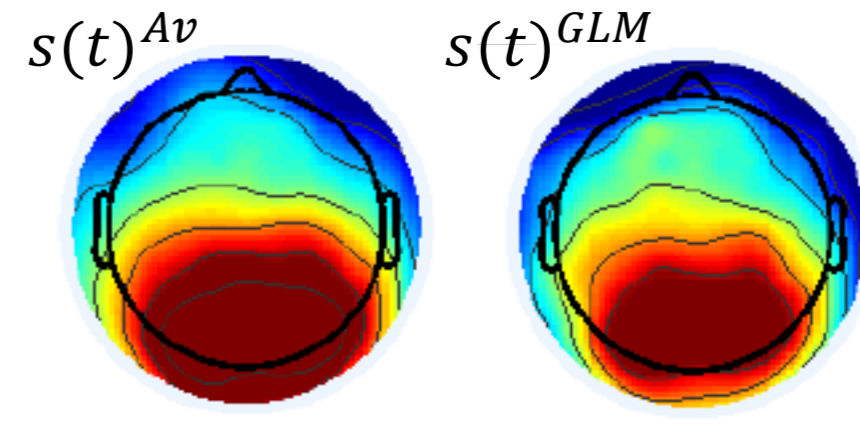
- $s(t)^{Av} = \bar{x}(t)$ : Estimation by Average of the potential evoked at the stimulus onset, including activities at the first fixation onset
- $s(t)^{GLM} = s(t)$ : Estimation by GLM of the potential evoked at the stimulus

### 9 virtual electrodes

LF	MF	RF
LC	MC	RC
LPO	MPO	RPO



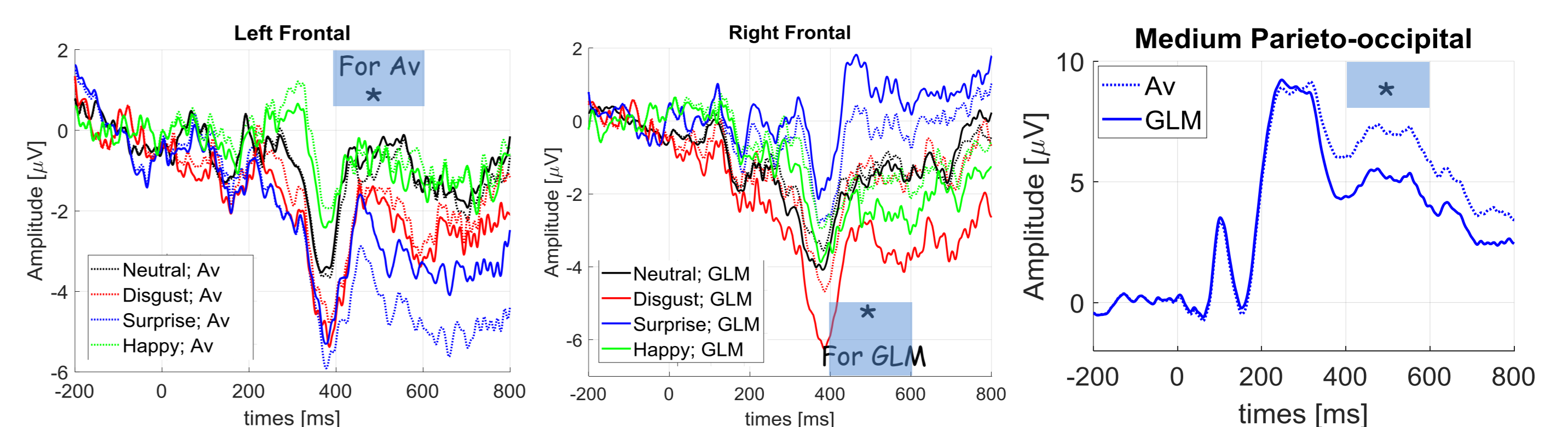
Neutral; [400-600] ms



Topographic map of the LPP component

Statistical test from all emotions → ANOVA (2 estimates x 9 virtual electrodes)

	N170 [140-180]	EPN [230-350]	LPP [400-600]
$s^{Av} \neq s^{GLM}$	No	No	Yes on RC, MC, LPO, MPO & RPO

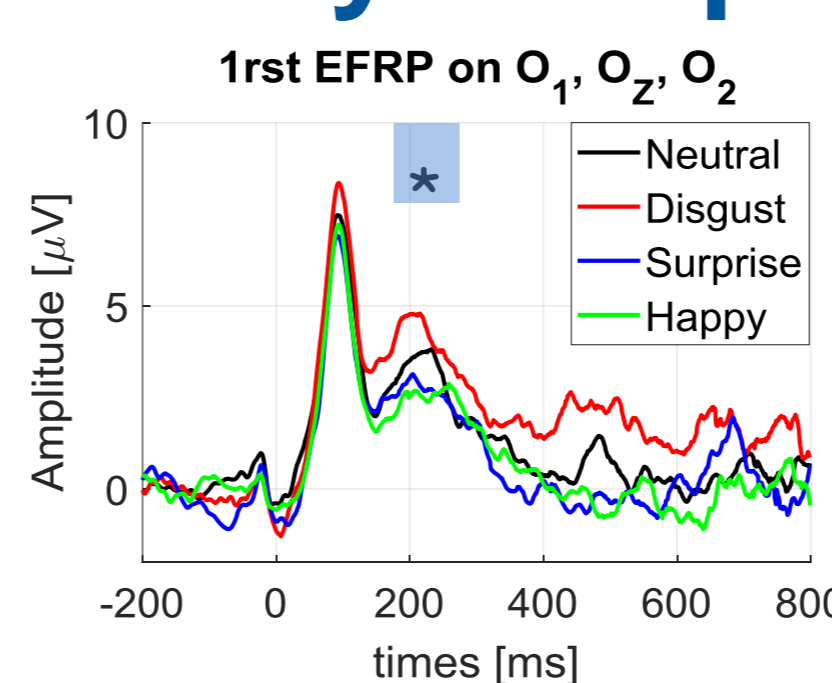


Statistical tests per estimate → 2 ANOVA (4 emotions x 9 virtual electrodes)

	$s^{Av}$	$s^{GLM}$
LPP [400-600]	Surprise < (Neutral = Disgust = Happiness) on Left frontal	Surprise > Disgust on Right Frontal
EMO x VE	F(24, 504) = 3.89; p < 0.001	F(24, 504) = 1, 93; p = 0.005

- Differences on emotions in Left Frontal site with  $s(t)^{Av}$  and in Right Frontal site with  $s(t)^{GLM}$

## Early components on the first EFRP $a_1(t)^{GLM}$



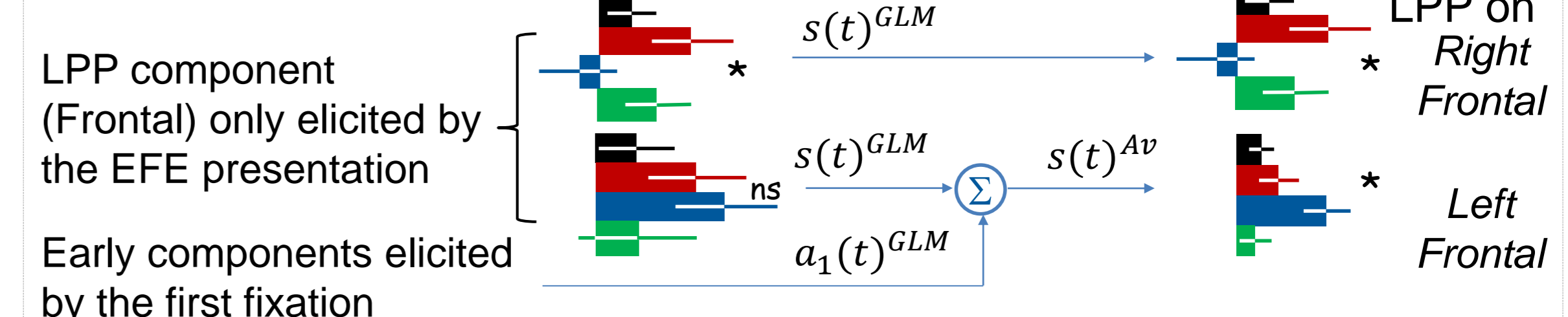
Statistical results: ANOVA (3 emotions)

$\lambda$ [70-110]	P2 [190-230]
No effect	Disgust > Happiness
ns	F(3,63) = 3.85; p = 0.013

- On occipital sites, the P2 component elicited at the first fixation is larger for Disgust than for Happiness

## Conclusions

- It is the first attempt to distinguish in the LPP response what comes from the stimulus presentation alone ( $s(t)^{GLM}$ ). In contrast, the usual estimation ( $s(t)^{Av}$ ) includes the very beginning of the EFE exploration (first fixation).
- Cognitive processing from the first fixation onset strengthens an activities pattern at left frontal site -more involved for positive EFE (Ahern, Schwartz, 1979)- becoming significant across EFE. But, at right frontal site -more involved for negative EFE-, another activities pattern, only elicited by the stimuli presentation, is at once significant across EFE.
- These findings are in line with faster and facilitated perceptual processing for negative EFE (Schupp, et al., 2004).



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