Non-visual Impacts of Light on Effective Connectivity Associated to Executive Brain Responses : 7-Tesla fMRI Study

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Introduction

- Light has both visual and non-visual effects.
- Non-visual effects are mainly driven by intrinsically photosensitive Retinal Ganglion Cells (**ipRGCs**), which are maximally sensitive to **Blue** Light (**~480 nm**).
- Blue light exposure can affect the activity of task-dependent cortical and subcortical areas.
- How light affects the connectivity between brain areas to trigger the non-visual effects is not established.
- The thalamus has been reported to be activated by short exposure of blue light while there's an ongoing cognitive activity.
- Thalamus has been suggested to be among the regions mediating the transfer of non-visual information to the cortex.

Questions of the study:

- → Does blue light modulate the thalamo-cortical connectivity?
- → Does the "intensity" of light matter?
- → Does "time of day" matter?

Method

- **42** healthy participants (15-30y: 22.2±4.3y; 60% female) underwent a morning/evening 7-Tesla functional MRI recording (GRE-EPI sequence, TR = 2340 ms, TE = 24 ms , voxel size 1.4x1.4x1.4 mm³).
- The participants followed a loose sleep-wake schedule (±1h; verified with actigraphy) for 7 days prior to the scan.
- The participants performed an auditory working memory task (**N-back: 2-back and 0-back).**
- Light sequence during the task: **30-second** blocks of "active" **blue-enriched light** (37, 92, 190 melEDI lux) or monochromatic "control" **orange light** (0.2 melEDI lux) interleaved by 10-second dark periods (**Fig 1**).
- An overview of the fMRI data processing is provided in **Fig 2.**

Fig 1: A) Ultra high resolution 7T MRI scanner along with an MRI compatible lighting setup. B) Experimental design of the N-back task (2-back and 0-back).

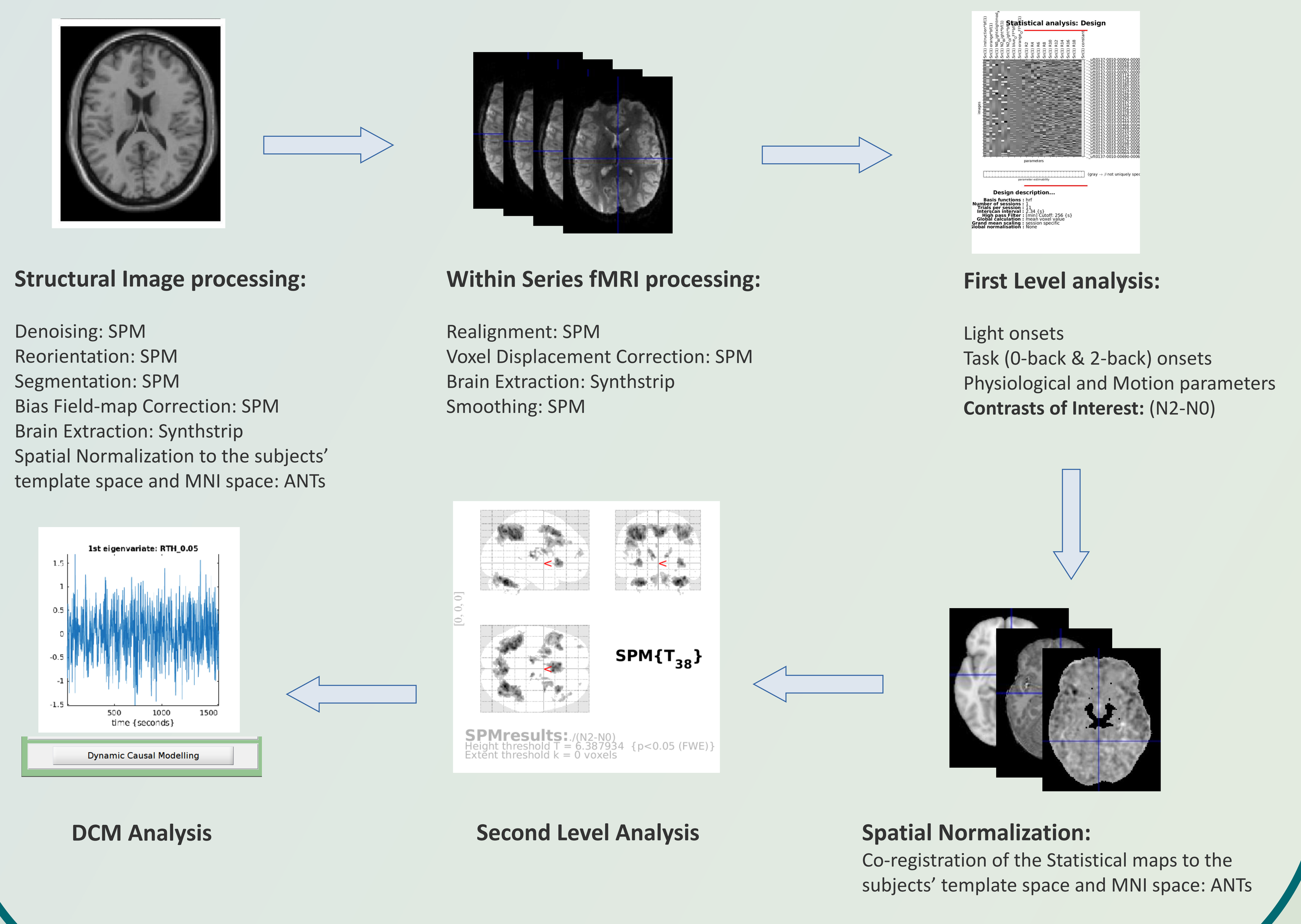


Fig 2: Data analysis pipeline

Results

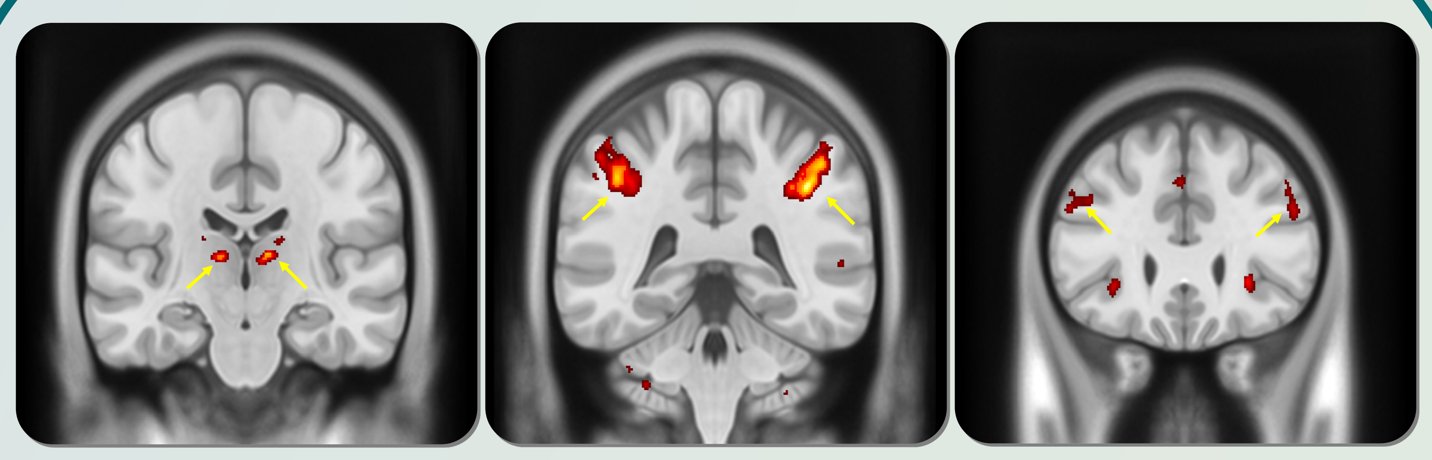
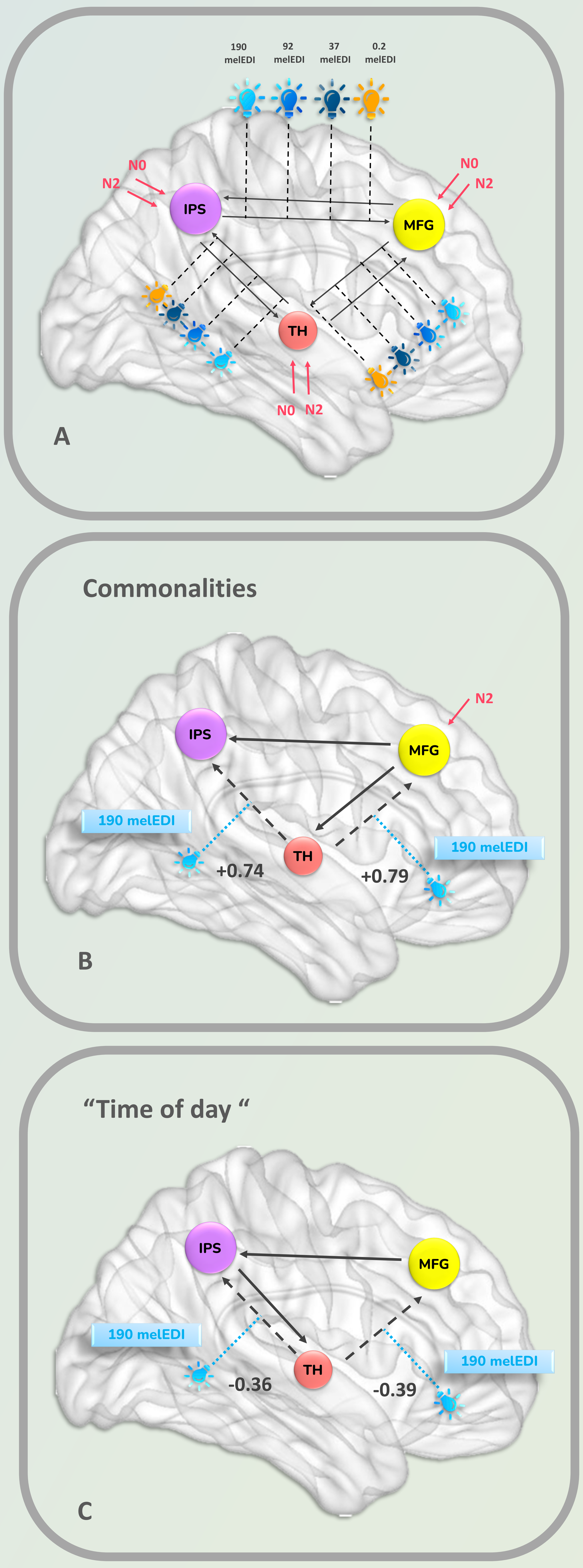


Fig 3. Bilateral activation (Contrast: (N2-N0), p-value(FWE-corrected)<0.05) in 3 task-dependent brain regions picked for DCM analysis (yellow arrows). Left to right: Thalamus, Intraparietal sulcus, Medial frontal gyrus.



- Initial model (PEB model) consisted of 9 connections, 4 modulators modulating 6 connections and 2 driving inputs (0-back and 2-back, separately) to all the 3 regions in the right hemisphere (Fig 4-A)
- Only blue light has a modulatory impact on connectivity (Fig 4-B).
- Not all the blue light conditions but only the highest intensity of blue light has the modulatory effect (Fig 4-B).
- Not all the connections but only the ones going from the subcortical region (thalamus) to the cortical regions, get affected by blue light (Fig 4-B). (Pp>0.90)
- Blue light strengthened the connections going from the thalamus to IPS and MFG (table 1). (Pp>0.90)
- The modulatory effect of the highest intensity blue light on the thalamo-cortical connections was stronger in the morning compared to the evening (Fig 4-C). (Pp>0.90)

Fig 4. Representation of the input model (A) along with the winning models for the Commonalities (B) and Time off day (C) (Pp>0.90)

	Baseline connectivity		Highest Intensity Blue Light Modulation	
	BMA	PEB	BMA	PEB
Thal-to-IPS	0.000	-0.033	0.741	1.285
Thal-to-MFG	0.000	-0.045	0.790	0.996

Table 1. Bayesian Model Average (BMA) and Posterior expectations of second level parameters for the commonalities, without (baseline) and with light modulation.

Conclusion

- Our preliminary results are in line with an initial non-visual impact of light on the information flow going from subcortical to cortical areas.
- In the context of an executive task, blue, but not orange, light, seems to affect thalamo-cortical loop connectivity.
- Not all blue light intensities appear to be able to affect the connections from the thalamus to the cortex, suggesting that this modulatory impact may be dependent on blue light intensity levels.

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