Final report of project 373-14

MULTIMODAL MAPPING OF VISUAL MOTION PERCEPTUAL DECISION: DISSECTING THE ROLE OF DIFFERENT MOTION INTEGRATION AREAS IN VISUAL SURFACE RECONSTRUCTION

Relatório Final de execução do projeto (relatório de despesas no final do documento)

Concerning the Project "MULTIMODAL MAPPING OF VISUAL MOTION PERCEPTUAL DECISION: DISSECTING THE ROLE OF DIFFERENT MOTION INTEGRATION AREAS IN VISUAL SURFACE RECONSTRUCTION" the project has accelerated and finalized its execution faster than was expected.

General Summary

Background
Neural models of perceptual decision are often studied using bistable perceptual decision paradigms. One can address this issue by taking advantage of the known problem that the brain needs to disambiguate local motion signals that might arise from single or multiple surfaces.
Aim of the study
We first asked whether hMT+ is pivotal for perceptual integration of motion signals in terms of bottom-up vs top-down interactions. Moreover, if hMT+ is indeed a causal hub in the decision-making network, then it should also provide long range integration at the inter hemispheric level, which is a testable prediction. We tested whether one can find fingerprints of perception related neural coherence. Finally, we aimed to elucidate the general relation between sensory and decision modules within saliency and frontoparietal networks.
Methods
We combined EEG and fMRI methods, to understand perceptual decision mechanisms, their neural correlates and functional connectivity (with a focus on interhemispheric interactions)
Results
We found out that human hMT+ is a causal hub which contributes to maintain perceptual representations when other competing percepts are available for cognition. We further confirmed the prediction that it should also subserve long range perceptual integration, through increased interhemispheric connectivity between left/right .hMT+. EEG data revealed that bound perceptual interpretations relate with parietal beta power under ambiguous conditions. Together with our findings using other decision paradigms inside and outside the visual domain, we show a modular architecture of perceptual decision-making network.
Conclusions

Our work provides a clearcut functional segregation at different time scales, between sensory representations, and the role of the general decision modules within saliency and frontoparietal networks.

Conceptual advances:

Milestone 1 – identifying a causal hub in perceptual decision: the visual complex hMT+, which is critical in maintenance of perceptual respresentations, in a bottom-up manner

Question 1: Inferring two-stage decision models (from local to global pattern motion at the interhemispheric level) and their neural correlates from bistable perceptual decision: linking levels of analysis and multiple methods.

Concerning this research question, we were able to answer the question which brain regions subserve motion integration and surface reconstruction. In this work we were also able to unravel the role of top-down regions in the parietal and frontal lobe (Duarte et al., published in Human Brain Mapping in 2017, as one of the main results of this project). We found that hMT+ is involved in perceptual maintenance. Granger causality analysis showed that this region shows directed influences to higher brain regions during stable perception periods. Perceptual switches may be triggered by activity in higher level regions, which seem therefore to have a role only during transitions.

The rationale of study stems from the well known problem that the visual brain needs to solve disambiguation problems, as instantiated by local motion signals that might arise from single or multiple surfaces. The hMT+ complex is pivotal for perceptual integration of local within-hemisphere motion. However, the role of distinct visual regions in decision at the higher inter hemispheric level and their top-down modulation also needed to be elucidated. We could prove that interhemipheric integration is also promoted by this region, further proving its role as a causal hub.

Neuroimaging helped us validate which neural regions and, at a fined scale, columns (using high field scanners at 7T, Sousa et al., under submission to the Journal of Neuroscience, see milestone 2) were critical in such perceptual decision mechanisms.

Milestone 2

Question 2: Can neuroimaging test perceptual decision mechanisms at the columnar level?

We aimed to further map bistable perception on MT columns, using our paradigm. One outstanding question was whether one can relate the switches between the two perceptual representations to the known columnar organization of the mammalian cortex. Testing occurred at 7 T (facilities at Maastricht Brain Imaging Center) and we found evidence that perceptual decision domains are present in human MT complex, which are related to columnar motion direction domains. The test of perceptual decision making mechanisms at the columnar level provided a tantalizing link between neuroimaging and neurophysiological models. MT is involved in the decision between either single or multiple perceptual solutions, suggesting that its

columnar motion maps can hold uni or multi-modal (2) active representations. This allowed to test at the columnar level the hypotheses tested in exp. 1.

Milestone 3
Question 3- Can we find fingerprints of perception related neural coherence at different time scales? Experiment 3
We took advantage of the combination of methods, EEG and fMRI, to have a integrated understanding of perceptual decision mechanisms, their neural correlates and functional connectivity (with a focus on interhemispheric interactions) at two time scales (second - fMRI and millisecond - EEG), within and across hemispheres. We could in this way relate neural activity patterns with models of perceptual inference. Both EEG/ERP and fMRI analyses were performed on epochs covering event onset (perceptual switches). Periods of stable perception (coherent/non-coherent were analysed with a block design model in relation with beta and gamma activity patterns studied by time frequency analysis. These results were published in the Journal of Cognitive Neuroscience as one landmark paper from these project). The main finding of this part of the project is that beta power increases in the parietal lobe is tightly linked with bound perceptual configurations.

Finally, our work helped substantiate the modular architecture of perceptual decision making networks, from sensory and perceptual levels, to evidence accumulation, and action selection networks under ambiguous/conflicting conditions.

Publications

Costa GN, Duarte JV, Martins R, Wibral M, Castelo-Branco M. Interhemispheric Binding of Ambiguous Visual Motion Is Associated with Changes in Beta OscillatoryActivity but Not with Gamma Range Synchrony. J Cogn Neurosci. 2017 Jun 27:1-16. doi: 10.1162/jocn_a_01158. [Epub ahead of print] PubMed PMID: 28654360.

Duarte JV, Costa GN, Martins R, Castelo-Branco M. Pivotal role of hMT+ in long-range disambiguation of interhemispheric bistable surface motion. Hum Brain Mapp. 2017 Jun 28. doi: 10.1002/hbm.23701. [Epub ahead of print] PubMed PMID:28660667.

Intaitė M, Duarte JV, Castelo-Branco M. Working memory load influences perceptual ambiguity by competing for fronto-parietal attentional resources. Brain Res. 2016 Nov 1;1650:142-151. doi: 10.1016/j.brainres.2016.08.044. PubMed PMID: 27590722.

Duarte IC, Afonso S, Jorge H, Cayolla R, Ferreira C, Castelo-Branco M. Tribal love: the neural correlates of passionate engagement in football fans. Soc Cogn Affect Neurosci. 2017 Feb 23. doi: 10.1093/scan/nsx003. [Epub ahead of print] PubMed PMID: 28338882.

Sousa T, Amaral C, Andrade J, Pires G, Nunes U, Castelo-Branco M. Pure visual imagery as a potential approach to achieve three classes of control for implementation of BCI in non-motor disorders. J Neural Eng. 2017 May 3. doi:10.1088/1741-2552/aa70ac. [Epub ahead of print] PubMed PMID: 28466825.

Castelhano J., Duarte IC, Abuhaiba S, Rito M., Sales F. , Castelo-Branco M. Cortical functional topography of high-frequency oscillations relates to perceptual decision: an Intracranial study Under second revision in PlosOne

Castelhano J., Tavares P., Mouga S., Oliveira G., Castelo-Branco M. Stimulus dependent neural oscillatory patterns show reliable statistical identification of Autism Spectrum Disorder in a face perceptual decision task Submitted to Clinical Neurophysiology

Sousa T, Duarte J, Costa GN,. Kemper VG, Martins R, Goebel R, Castelo-Branco M Tracking perceptual decision mechanisms through changes in interhemispheric functional connectivity in human visual cortex under submission to The Journal of Neuroscience

Conference Presentations

1. João Castelhano, Isabel Duarte, Pelle Federica, Stefano Francione, Francisco Sales, Miguel Castelo-Branco Using stereo-electroencephalography to study the role of high-frequency oscillations during neuropsychological behavioral tasks 28º Encontro Nacional de Epileptologia, Auditório da Biblioteca Almeida Garret – Porto, 11 e 12 de Março 2016
2. Costa G.N., Duarte J.V., Martins R., Wibral M., Castelo-Branco M. Human Brain Mapping 2016 Geneve, Switzerland Binding of ambiguous visual stimuli is associated with changes in beta power but not with synchrony Human Brain Mapping 2016 Geneve, Switzerland
3. Marian Schneider, Rainer Goebel, Valentin Kemper, An Vu, Miguel Castelo Branco, Kamil Ugurbil, Essa Yacoub, Federico de Martino Responses in Mesoscopic Clusters of Human MT+ Reflect the Perceived Direction of Ambiguous Motion Human Brain Mapping 2016 Geneve, Switzerland
4. Teresa Sousa Valentin G. Kemper, Gabriel Costa, João V Duarte, Ricardo Martins, Rainer Goebel, Miguel Castelo-Branco Long-range perceptual integration of visual motion revealed at high resolution 7T fMRI Human Brain Mapping 2016 Geneve, Switzerland
5. João Duarte e Miguel Castelo-Branco Maintenance of perceptual stability of interhemispheric surface motion is associated with bottom-up influences generated within hMT+ 7th Iberian Congress On Perception July 6 -7 th, 2017 Coimbra, Portugal
6. João Castelhano e Miguel Castelo-Branco Cortical functional topography of high-frequency oscillations 7th Iberian Congress On Perception July 6 -7 th, 2017 Coimbra, Portugal

7. Teresa Sousa e Miguel Castelo-Branco High-resolution 7T fMRI data on the perceptual long-range segregation vs. integration of bistable moving stimuli 7th Iberian Congress On Perception July 6 -7 th, 2017 Coimbra, Portugal
8. Alexandre Sayal Campos e Miguel Castelo-Branco Study of motion adaptation and its role in deciding between competing surface representations 7th Iberian Congress On Perception July 6 -7 th, 2017 Coimbra, Portugal
9. Gabriel Costa e Miguel Castelo-Branco Beta oscillations during motion integration and segmentation: evidence of binding or perceptual bias? 7th Iberian Congress On Perception July 6 -7 th, 2017 Coimbra, Portugal
10. Teresa Sousa' João V. Duarte, Gabriel Costa, Valentin G. Kemper, Ricardo Martins, Rainer Goebel, Miguel Castelo-Branco The Perceptual Integration of Visual Motion Revealed by hMT+ Interhemispheric Connectivity International Conference for Cognitive Neuroscience (ICON) August 2017 Amsterdam,
11. João Duarte, Gabriel Costa, Ricardo Martins, Miguel Castelo-Branco Long-range interhemispheric binding of bistable surface motion reflects bottom-up processes generated within hMT International Conference for Cognitive Neuroscience (ICON) August 2017 Amsterdam,
12. Marta Teixeira, Sérgio Nascimento Vasco Almeida & Miguel Castelo-Branco Neural signatures of Conscious Visual Perception: An EEG/ERP Study International Conference for Cognitive Neuroscience (ICON) August 2017 Amsterdam,
13. Maria Ribeiro and Miguel Castelo-Branco The Noradrenergic System And Its Relationship With Cortical Processing International Conference for Cognitive Neuroscience (ICON) August 2017 Amsterdam,
14. Gabriel Nascimento Costa, João Valente Duarte, Ricardo Martins, Miguel Castelo-Branco Beta oscillations reflect perceptual experience under ambiguous stimulation but not in the absence of conflict International Conference for Cognitive Neuroscience (ICON) August 2017 Amsterdam,
15. Joao Castelhano, Paula Tavares, Susana Mouga, Andreia Pereira, Guiomar Oliveira Miguel Castelo-Branco Abnormal neuronal oscillations in ASD are specific to stimuli requiring holistic processing Human Brain Mapping Meeting 2017 Vancouver, Canada 25-29 June 2017
16. Intaite, M; Castelo-Branco, M; Heinrich, S; Bach, M; Kornmeier J. Visual working memory load reduces the perceptual orientation bias of the Necker cube European Conference on Visual Perception ECVP August 2017

Main Talks

Castelo-Branco M
Neural correlates of decision-making in health and disease.
February 25, 2016
Champalimaud Foundation Lisbon

Castelo-Branco M
Neurociências

Bringing neurophysiology and neuroimaging into the therapeutic domain: the BRAINTRAIN consortium
Encontro Com A CiêNcia E Tecnologia Em Portugal
Centro de Congressos de Lisboa 4 a 6 Julho, 2016

Castelo-Branco M
Functional imaging and translational research in neuroscience
Keynote lecture and Conference Chair
ENBENG'2017 - 5th Portuguese Meeting in Bioengineering (Coimbra, 16 a 18 de Fevereiro de 2017).

Castelo-Branco M
Neuroimaging and Biomedical Engineering
XII Encontro Nacional de Estudantes de Engenharia Biomédica, 2 e 5 de Março de 2017, Coimbra

Castelo-Branco M
Neurociência: a Ciência Aplicada à Medicina
Horizontes da Física 7
Auditório da Reitoria
Universidade de Aveiro, 8 de Março de 2017, 21 h 30 m

Castelo-Branco M
Vision Sciences Advanced Course_Health Sciences PhD Program_FMUC_2017
March 6: Neurophysiology of vision: retinocortical processing

Castelo-Branco M
New insights on the putative role of oscillatory synchrony in perceptual decision-making
ESI, Max-Planck Institute
Frankfurt, 20 de Abril de 2017

Castelo-Branco M
The role of neuroimaging in basic and clinical neuroscience: what are the limits?
BRAIN WEEK 2017- Semana do Cérebro e da Neurorradiologia
30 de Maio de 2017

PhD Thesis

Teresa Sousa (Programa Doutoral em Engenharia Biomédica da UC) From parametric decoding of simple mental states to neurofeedback: insights into the neuroscience of cognitive control 2016

Ricardo Martins (Programa Doutoral em Engenharia Biomédica da UC) Development of Techniques for Multimodal Object Exploration
-2017