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Current Opinions in Brain Imaging Methods and Applications

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Human Brain Imaging has rapidly developed in the past twenty years. It has enormously contributed to the current understanding of complex human brain functions during various perceptual, motor, and cognitive tasks and how these functions are altered in neurological and psychiatric diseases. Many brain imaging tools are available to neuroscientists to study the anatomy, the function and the metabolism of the brain, each of them having their intrinsic advantages and limitations in terms of specificity, spatial precision and temporal resolution. Computer-based analyses of the acquired data have become increasingly sophisticated and provide the researchers with a wealth of complex information that needs to be accurately interpreted. Modern neuroimaging laboratories, therefore, bring together researchers from many different disciplines: engineering, computer & data sciences, physics, mathematics, psychology, biology and medicine.

During the past fifteen years, researchers from these different fields met annually at the "Alpine Brain Imaging Meeting (ABIM)" in Champéry, Switzerland to present and discuss the various aspects of brain imaging from methods to applications in cognitive and clinical neuroscience. Both well established and emerging young scientists have spoken during this annual event and contributed to train and inspire the next generation of neuroimagers. To celebrate the 15th Anniversary of this meeting in January 2020, the organizers invited eminent keynote speakers from the past years to write a review article or opinion paper about the current state of research in their specific domain. This special issue is a collection of these articles that all underwent peer review. It aims at providing readers with an overview of the recent advances in neuroimaging techniques and their applications in the study of human cognition.

The first article in this series of reviews is a joint paper by two keynote speakers: *Lucina Uddin* and *Nathan Spreng* (Uddin et al., 2019), a nice example of the discussions and synergies generated during ABIM events. In their joint paper, they discuss one of the currently most challenging question in the emerging field of network neuroscience: the taxonomy of large-scale neurocognitive networks. In the introduction, the authors illustrate the inconsistency and incompleteness of the definition of functional brain networks, leading to a remarkable confusion in the mapping of brain structure and function and a proliferation of network naming schemes. Based on the existing literature, they then formally propose a consensus nomenclature for six reliable macro-scale brain networks composed of specific core brain regions. The

authors call for a consistent, anatomically grounded naming convention that will allow a more coherent comparison between different studies.

The second paper is written by *Marcel Brass* and his colleague Francois Quesque (Quesque & Brass, 2019) and discusses one specific core region of these functional networks: the temporoparietal junction (TPJ). The TPJ has been related to many different psychological functions such as attention reorientation, episodic memory, language processing and social cognition. The authors provide evidence that the TPJ may constitute a core region implicated in the distinction of the self from the others. It could be responsible for self-other distinction in a domain-general manner independent of whether the content of the representation is perceptual, motor, or mental.
The article from the group of *Deborah Talmi* (Riberto et al., 2019) looks into the neuronal network underlying emotional similarity perception. It is argued that research on similarity perception has largely ignored the cognitive and neural mechanisms that are involved when people perceive rich, life-like events with emotional valence. Based on the existing literature the authors make it clear that the representation of emotional concepts relies on activity patterns across many distributed brain regions that influence the perception of similarity. They advocate the use of complex stimuli in experimental designs that depict both emotional and neutral real-world scenes to unveil the neural underpinnings of emotional similarity.

Another paper touching on affective issues is the review of *Claus Lamm* and his colleague Igor Riečanský (Riečanský and Lamm, 2019), which is focusing on brain responses evoked when observing painful situations in others, with particular emphasis on activation of the somatosensory and motor system. These empathy-related sensorimotor activations occur at multiple levels and reflect the stimulation of the own defensive system even if the pain is only observed. The role of this activation in the context of empathic understanding and the motivation for prosocial actions is discussed.

Emotion is also a prominent component linked to olfaction, more so than other sensory modalities. Two articles in this special issue discuss the current state of knowledge on brain networks involved in olfactory processing. The first paper comes from the group of *Moustafa Bensafi* (Mantel et al., 2019) and discusses the neural underpinnings of the hedonic and social dimensions of olfactory perception. Based on a comprehensive literature overview the authors demonstrate that hedonics are represented at each olfactory processing step and are modulated at a higher level by multisensory integration and cognitive processing. The authors also emphasize the importance of considering individual differences when studying the cerebral processes underlying the hedonic dimensions of olfaction and that new fMRI analysis methods are needed to better account for individual variability. The paper from the group of *Thomas Hummel* (Han et al., 2019) further emphasizes the importance of individual variability in olfaction, but in the context of disturbances of olfactory processing. It discusses the current state of research on olfactory dysfunction using fMRI. It shows that olfactory dysfunction leads to a widespread reduction of activity and functional connectivity in olfactory and non-olfactory networks but also to anatomical changes in different brain areas. This work highlights that the specificity of such changes for different sub-categories of olfactory dysfunctions is far from clear due to the heterogeneity of the studied patients. The authors discuss new analysis methods that are needed to identify fMRI response patterns as individual “biomarkers” for diagnosis of olfactory dysfunction in clinical routine.

The last four papers cover specific brain imaging techniques and advanced functional and structural analysis methods. The group of *Philippe Peigneux* (Pan et al., 2019) provides a

review on the use of functional near-infrared spectroscopy (fNIRS) to study fatigue, sleep deprivation, and social cognition. It first discusses the limitations of the technique in a comprehensive way and then describes several applications where the main advantage, (namely the portability) of the system is demonstrated. This is supported by studies on the impact of fatigue in different crucial life situations (drivers, pilots, traffic controllers, etc.) and the effect of sleep deprivation in healthy and pathological conditions. An interesting aspect is the use of fNIRS to study social interaction, as the technique is particularly adapted for hyperscanning approaches.

Christoph Hermann and his colleague *Florian Kasten* (Kasten and Hermann, 2019) discuss an emerging new technology: the combination of transcranial alternate current stimulation (tACS) to entrain neural oscillations and the EEG to measures these effects. The particular problem arising from this combination is the disturbance of the EEG signal during the electrical stimulation. As for the concomitant EEG-fMRI, methods are needed to correct for the artifact induced by the stimulation. This is not a trivial task and is currently largely debated. The authors discuss the underlying concepts of the existing approaches to recover the EEG (or MEG) signals during tACS. They show the limitations of the different approaches and critically examine the methodological and interpretational drawbacks.

The groups of *Mark Woolrich* and *Kia Nobre* (Quinn et al., 2019) describe an analysis approach that allows to automatically detect transient spectral events in EEG or MEG signals. It is increasingly recognized that such short-lasting events of different morphology, duration and frequency have an important role in human brain functioning, but the detection and estimation of their temporal metrics is challenging. The authors propose a method based on hidden Markov models to operationalize and estimate transient spectral events of different types.

The last paper in this special issue comes from the group of *Jean-Francois Mangin*, who participated to the first edition of ABIM in 2006. It discusses cortical folding and its inter-subject variability. The paper advocates for a deeper understanding of a specific kind of cortical features, the 'pli-de-passage' (PdP). It first gives a historical overview of the concept of PdP and then relates it to a dual concept of sulcal roots. It points out the idea that cortical organization might be the result of mechanical action during development associated with genetic binding. The paper shows that understanding the concept of PdP can be used to explain and better understand cortical surface folding and its variability.

In sum, this series of review articles and opinion papers of leading scientists in different fields of neuroscience illustrates the enormous potential of the different neuroimaging tools to understand human brain anatomy and brain function. These papers reflect the breadth of brain imaging research, its widely diverse applications, as well as the continuing development and refinement in methods since early days of the field. Further, they also underscore the current challenges that we are facing today, now having all these tools at disposal, and the care that is needed to properly use, analyze, and interpret the data that they provide.

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