Go with the flow

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Appendix A

Impact Paragraph

> *"Every great advance in science has issued from a new audacity of imagination"*
> – John Dewey

The main goal of this doctoral thesis was to investigate how signals propagate within the vision-attention network, and how neuronal alpha oscillations play a role as a communication mechanism. After working for 4 years on this topic, the time has come for me to contemplate the potential impact of my, or rather our, efforts. Below, I share my personal views regarding the scientific, clinical, and educational impact of my (our) work.

The research reported in this thesis has been presented to different research groups and departments within the host university. It has furthermore been shared with the national and international cognitive neuroscience community through means of poster and oral presentations at several online and on-site conferences (see "*About the Author*" for a complete overview). In the General Introduction, I already emphasized that the methods of cognitive neuroscience are always evolving. Science in general does not only evolve in its ways of measuring and experimenting, but also in its ways of communicating. In the pursuit of my doctoral degree, it became more and more clear to me that scientists' methods of knowledge dissemination are no longer fully focused on peer-reviewed publications and on-site conferences. Perhaps accelerated by the ongoing pandemic, scientists seem to be looking for more flexible ways of communicating their findings and establishing collaborations, such as online/hybrid meetings and conferences, sharing preprints, sharing data and analysis code, and making use of social media. These changes are in line with ongoing initiatives such as the movement towards open ("*FAIR*") science, and the Dutch "*Recognition & Rewards*" program. I believe that this paradigm shift may be especially beneficial for early career researchers on fixed-term contracts that are trying to find a new academic position and/or obtain their own funding. Since the peer-review cycle can easily take one year for a single publication, there must be ways to evaluate progress and impact before the final product is published. Besides this, I also believe that we must find better ways to quantify the actual visibility and impact of our work, rather than clinging to the impact factor (IF) of the journal that it is published in. We already know that the IF provides limited information about individual articles (Bollen et al., 2009; Paulus et al., 2018), and that impact in different research fields cannot be easily compared (Radicchi et al., 2008). In any case, I hope to play my part in the movement away from the “high IF journal”-centered mentality in academia, towards a more diverse and inclusive approach. In line with these developments, I (we) shared several preprints, datasets, and user-friendly analysis code. To gain more visibility, I also shared my (our) work on my personal academic website and on social media such as *Twitter*, *LinkedIn*, and *ResearchGate*. This has led to fruitful discussions with researchers from different countries.

As scientists, we can have many roles besides “just doing science”. For instance, we can be educators, mentors, and role models. I taught students from several master programs about the possibilities and limitations of non-invasive brain stimulation. I taught students from a local high school about brain imaging and stimulation methods, and about the implications of my (our) work. Multimodal brain research as described in this doctoral thesis requires advanced technical skills, and my hope is to inspire and encourage young females to dive into such technical topics. I told the “non-official” story behind our simultaneous TMS-EEG-fMRI set-up to PhD candidates at the *Ghent Doctoral Schools*. I furthermore shared my experiences during several phases of the research projects on *Twitter*. I also wrote a blog for *EDLAB* (the Maastricht University institute for education innovation), explaining how unforeseen circumstances in research can lead to novel insights (https://edlab.nl/dealing-unforeseen-circumstances/). Sharing this kind of background information can help others gain a deeper understanding of the challenges and accomplishments that happen behind the scenes before the end-result is published. Such information may be of special importance for early-career researchers, first-generation students/researchers, or researchers aiming to switch fields. By not only sharing the published manuscript, but by also taking the time to teach others about potential difficulties that may happen along the way, others may obtain a more realistic view on what constitutes “success” in academia.

If we take a closer look at the different projects presented in this doctoral thesis, what can we take away from them? The “attention adaptation” paradigm described in **Chapter 2** shows the theoretical potential of neuronal adaptation for studying cognitive processes and for targeting specific neuronal sub-systems within the human brain. I hope that this may inspire others to think outside the box and apply established paradigms to new contexts. In our case, across three experiments, results were statistically significant and expected, statistically significant and unexpected, and statistically non-significant. Clearly, behavioral findings can differ strongly across studies, even if the experimental procedures are (nearly) identical. This chapter thus highlights the importance of replication studies in science, even if results are statistically strongly significant and in line with expectations.

TMS effects can also show considerable variability. **Chapter 3** proposed that the within- and between-subject variability in TMS effects may in part be explained by spontaneous fluctuations in the oscillatory brain state. It also compared two technical solutions for considering the oscillatory brain state during TMS. This information is relevant for fundamental and clinical applications of TMS, since it may help better predict and control the effects of TMS. Especially during TMS treatment, the goal is often to modulate specific functional brain pathways, so we should maximize our chances of targeting the desired pathway. Related to this, in **Chapter 4** we assessed how TMS signal propagation across the brain may depend on the oscillatory and/or the neurocognitive brain state during TMS. It shows the feasibility and theoretical utility of simultaneous TMS-EEG-fMRI in cognitive networks. It also provides concrete recommendations for future multimodal TMS studies, to increase the likelihood of visualizing brain-state-dependent TMS effects.

A central theme in this doctoral thesis is that NIBS protocols should be individually calibrated to enhance their consistency. With tACS, this often takes the form of individualizing the stimulation frequency based on the peak within a particular oscillatory frequency band. Typically, such a peak frequency is based on a single short resting-state M/EEG measurement. TACS is then often applied at that peak frequency during a different neurocognitive state (i.e., task performance) across different sessions. **Chapter 5** showed that individual peak alpha frequencies ("IAF") are reliable both within and between sessions, and during resting state and task performance. It also showed that individualizing the stimulation frequency based on EEG was more accurate than using a standard frequency for everyone, and that rest-EEG data provided better results than task-EEG data. This provides empirical evidence for the commonly used approach of individualizing tACS frequencies based on rest-EEG data. We also found that a "Gaussian fit" procedure led to better (more reliable) IAF values compared to the traditional "maximum" method. To help other researchers implement this improved peak frequency detection technique, I created a user-friendly code that is shared along with the data on *DataverseNL*. In this code, I implemented an automatic peak rejection algorithm to help researchers determine objectively whether a peak is present in the power spectrum or not. This can be especially helpful in cases where many power spectra must be assessed regarding the presence or absence of an oscillatory peak. For comparison, the code then also calculates the peak frequency based on the traditional maximum method and the improved Gaussian method. This code can be of use to any researcher or clinician wanting to calibrate the rhythmic (tACS, TMS, or even sensory) stimulation frequency to an individual peak frequency within a defined oscillatory frequency band – or, more generally, to anyone interested in peak oscillatory frequencies.

Chapter 6 goes one step further in terms of trying to increase the consistency of tACS effects. We developed and tested a broadband-alpha-tACS protocol that was based on individual resting-state EEG data. Though this study was only the first step, it shows that there is much more for us to explore in the domain of calibrating NIBS to individual oscillatory information. There are numerous brain-based disorders that show abnormal oscillatory activity, including Alzheimer's disease, schizophrenia, and bipolar disorder (Başar et al., 2015). When it comes to clinical applications, tACS is an especially attractive method given its (relatively) low price and portability. We should therefore keep on pushing the boundaries towards more advanced and efficacious tACS protocols.

Finally, **Chapter 7** investigated whether processing of face trustworthiness relies on the early visual cortex (EVC) or not. We found a distinction between objective and subjective processing, in the sense that subjective processing was impaired by TMS to EVC, while objective processing was not. This teaches us that the processing of complex facial features can bypass EVC, similar to other evolutionarily relevant (but more basic) facial features such as emotions. This study also provides an example of how Bayesian statistics can help us draw conclusions regarding the absence of effects. Finally, it once again demonstrates the versatility of TMS as a research tool.

In sum, this doctoral thesis shows that behavioral, TMS, and tACS effects can show large variability, underlining the importance of replication studies and further methodological advancements. It encourages individual calibration of NIBS protocols for increasing their consistency, and outlines the promises and challenges of multimodal brain research.

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