



A Bird's-Eye View of the Field of Neuromodulation Technology:

A bibliographic network analysis on transcranial direct
current stimulation (tDCS) research studies

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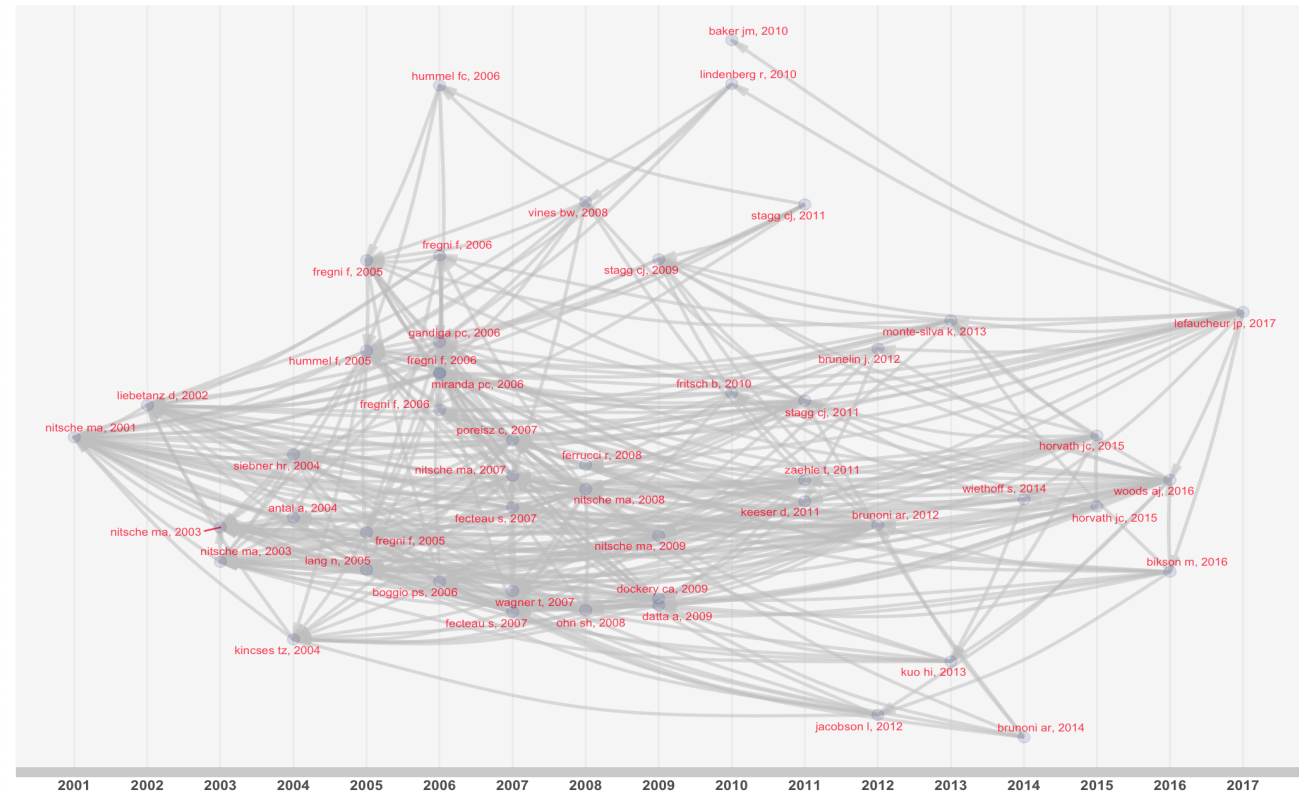
Stanford University

Aims of the Study

- This study applies bibliographic network analysis methods to:
 - (1) assess the level of maturity of the field of a neuromodulation technology and
 - (2) investigate the prevalence and diffusion of ethical concerns, such as uncertainty around the efficacy of neuromodulation technology, within the field.
- Transcranial direct current stimulation (tDCS) as a case study

Data

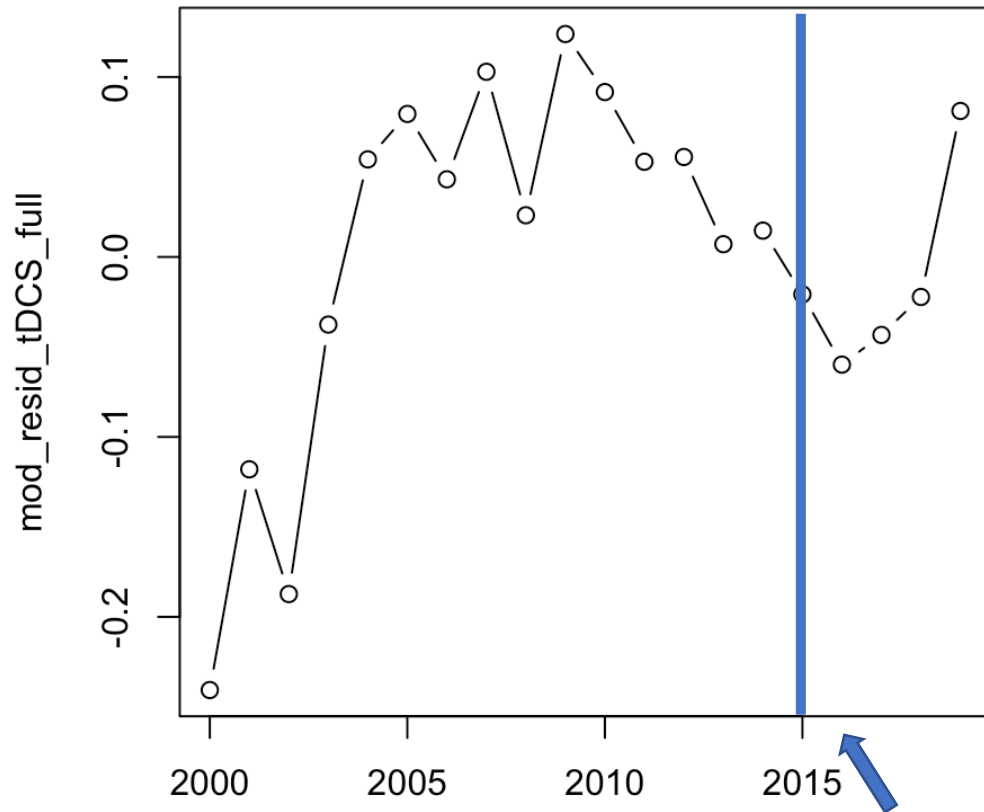
- Web of Science search with the term “transcranial direct current stimulation” (4,225 articles)
 - for comparison, also collected “transcranial magnetic stimulation (22,000 articles) and “deep brain stimulation” (20,000 articles)
- Citation network analysis with R (bibliometrix & igraph package)



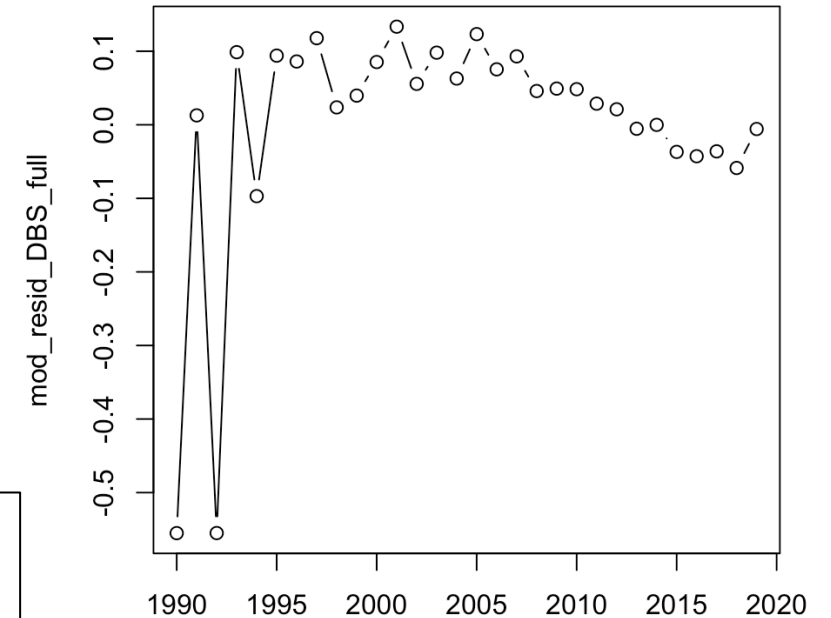
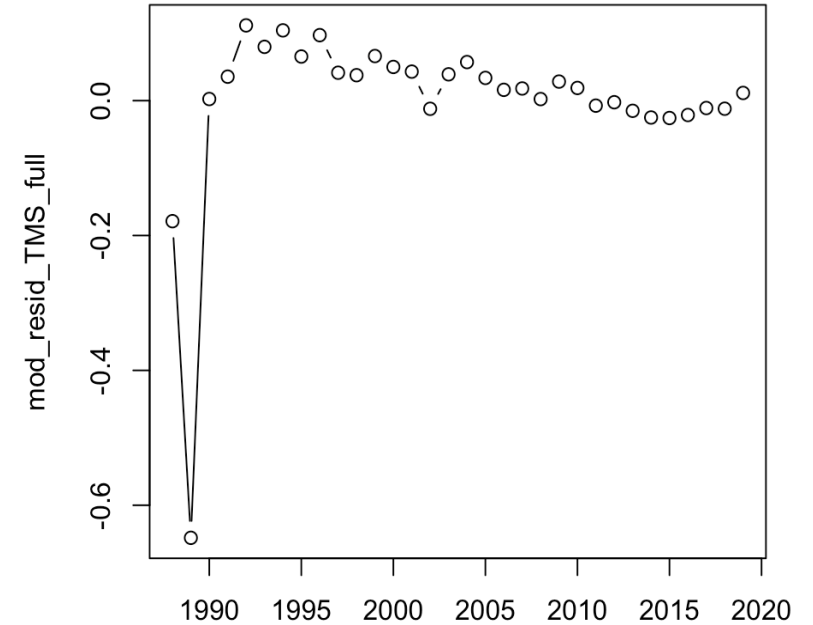
Part I: Modularity as an index of maturity in the field

- Shwed and Bearman (2010)
 - : Modularity is an index of internal division of a citation network that reflects the level of contestation in the field.
 - Modularity compares the odds of within-community ties with these odds after a random rewiring of the network (Newman, 2006)
 - Partitioning a network into communities by maximizing modularity

Part I: Preliminary results



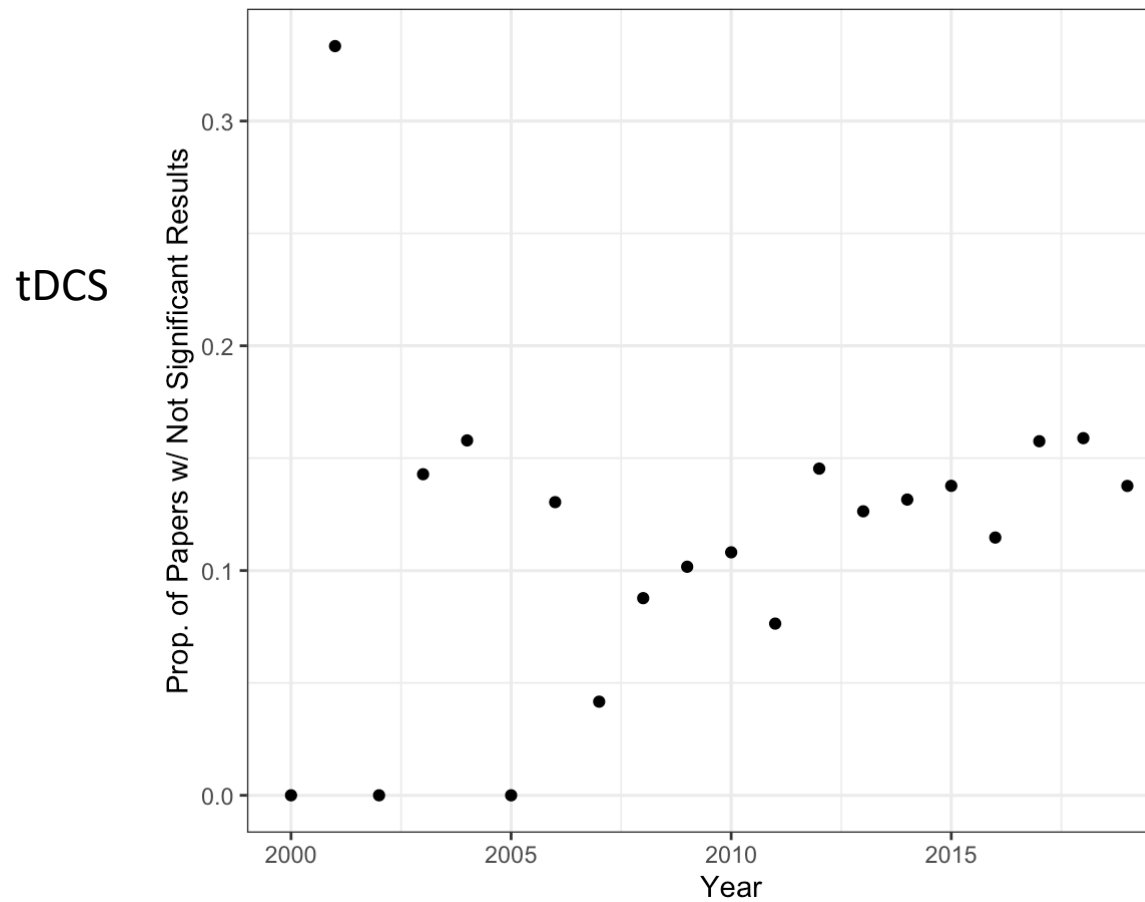
Critical review papers on the inconsistent findings among tDCS studies were published (Horvath et al, 2015a; Horvath et al, 2015b)



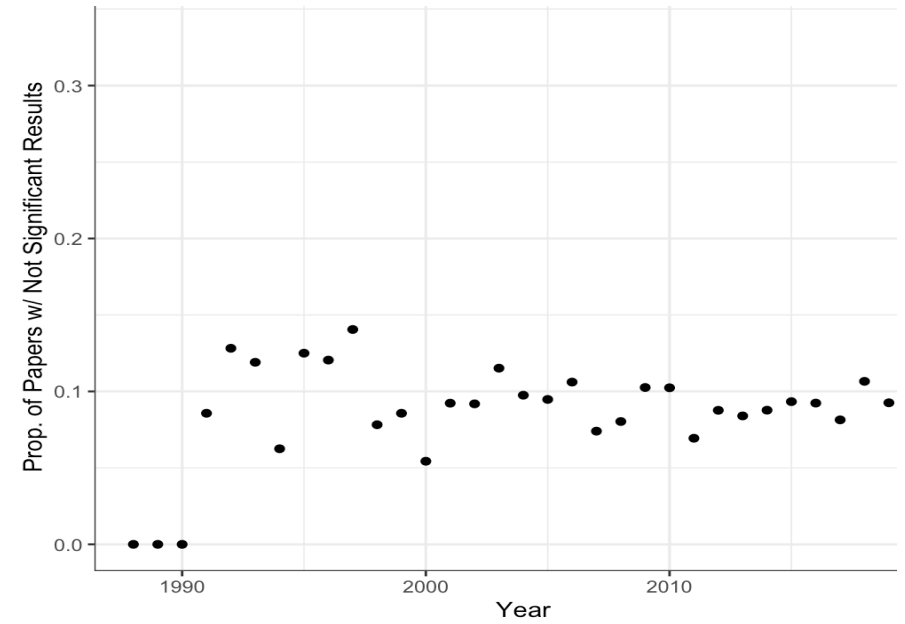
Part II: Emergence and diffusion of ethical concerns in the field

- Identified papers with abstracts that include
 - terms indicate results that are not statistically significant
: not significant, not statistically significant, insignificant, no effects ...

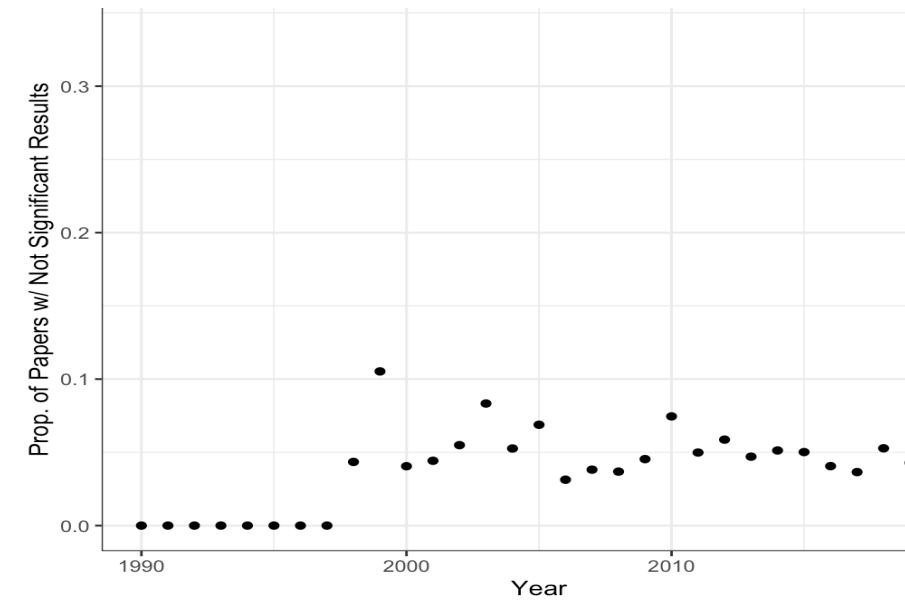
Part II: Preliminary results



TMS



DBS



Discussion

- The temporal changes of modularity in the citation network
 - decreasing trend until 2016 followed by a sharp increase
 - indicates that consensus has not yet formed
 - the future trajectory might follow cyclical pattern (“a case where consensus forms, is destroyed, and is rebuilt” without reaching the unification stage (Shwed & Bearman, 2010)).
- Increase of papers reported results that are not statistically significant
- The contestation around the efficacy of tDCS are still ongoing within the field
 - tDCS is not mature enough to reach the stage of normal science (Kuhn, 1962)
 - impetuous application of this technology, especially outside the clinical context, could lead to harmful consequences.