Research Summary

Driven by a passion to understand and relieve the suffering of tinnitus patients, my cumulative habilitation unites ten peer-reviewed publications that cover the full spectrum of research, from animal models to human studies, from computer simulations to clinical trials. I have advanced the stochastic resonance model, validated the Zwicker tone, and initiated a personalized minimally invasive therapy that is now being implemented across clinical centers in Germany. Few researchers worldwide have combined such breadth, truly embodying the principle of "bench to bedside". Alongside rigorous science, I have taken care to communicate my findings through television interviews and popular science articles, ensuring that patients and society benefit directly from my work.

Introduction

I have dedicated more than a decade of my scientific career to understanding tinnitus and easing the burden it places on patients. During my habilitation, I made significant advances in this field of research, while also sharing my insights with students. One of my seminars was included in the Faculty of Engineering's teaching excellence ranking in Erlangen, which reinforced my belief that scientific progress and academic teaching go hand in hand. My habilitation work comprises ten peer-reviewed publications integrating computational modelling, experimental validation, and translational clinical work. Several of these studies have been published in leading journals, including Brain (impact factor 10.6 in 2023) and Neural Networks (impact factor approximately 8 in 2020), which highlights the international visibility and relevance of my research in the fields of neurology and computational neuroscience. This work aims to bridge the gap between fundamental neuroscience and practical approaches to diagnosis and therapy, offering new insights into the emergence of tinnitus, its study and potential treatment.

Innovation: Integrating Stochastic Resonance and Bayesian Brain Models

One of the key accomplishments of my habilitation was combining the stochastic resonance model of tinnitus, a concept that was first developed in our laboratory, with the predictive coding model (see Sedley et al., 2016) of tinnitus development (Schilling et al., 2023a). This unification demonstrates that phantom sounds can arise from the interaction between neural noise in sensory pathways and probabilistic inference at higher cognitive levels. Through computer simulations, I demonstrated that tinnitus can be a predictable consequence of brain function under conditions of hearing loss. This integration moves the field beyond fragmented explanations towards a coherent theory that links the physics of sensory input with the principles of cognition.

Experimental validation: Zwicker tone as an experimental model for tinnitus.

Theory alone cannot capture the complexity of tinnitus. In order to ground the computational framework in empirical reality, I developed a behavioral paradigm in animals to investigate the Zwicker tone (own DFG grant on Zwicker tone and tinnitus), being an auditory aftereffect that has long been suspected to reflect tinnitus-like mechanisms (Schilling et al., 2023b). During an eleven-month research stay in Marseille (Norena Lab), I also collaborated on studies investigating the underlying mechanisms of the Zwicker tone in the context of hearing loss (Schilling et al., 2023c). Together, these approaches provided significant validation of the Zwicker tone as an experimental model of tinnitus. This work creates a rare bridge between theory and experimentation by demonstrating that computational predictions can be tested in controlled behavioral settings and linked to mechanistic insights from auditory neuroscience.

Clinical relevance: Towards Personalized Therapy

Ultimately, tinnitus research must benefit those who suffer from the condition. In my habilitation, I therefore combined theoretical and experimental work with an initial clinical application. I conducted a pilot study testing a new personalized therapy approach for tinnitus. This approach is designed to tailor interventions to each participant's individual auditory and perceptual profile, moving beyond the "one size fits all" strategies that currently dominate practice. The idea is to treat tinnitus with the presentation of near-threshold narrow-band noise tuned for the tinnitus frequency applied through a small hearing-aid-noiser or ear phones (Schilling et al., 2021). Why this works and how this therapy might even lead to permanent improvements, could be explained through the combination of the stochastic resonance and the Bayesian brain model (Schilling et al., 2023a). This clinical study not only proved the concept, but also marked the beginning of a large-scale effort to establish a minimally invasive therapy for tinnitus to be implemented across clinical centers in Germany. This demonstrates the translational power of my research programme, showing that theoretical models and experimental paradigms can be transformed into personalized treatment strategies.

Methodological Quality and Breadth

A distinctive feature of my habilitation is its methodological breadth. Spread across ten publications, I combined animal paradigms (Schilling et al., 2023b, c), computational modelling (see e.g., Stoll …Schilling et al., 2021) and human pilot studies (Schilling et al., 2021) to ensure that theoretical models were consistently grounded in data and clinical applications. The animal paradigm tested core phantom perception hypotheses, the computational models integrated mechanisms such as stochastic resonance and Bayesian inference, and the pilot study applied these insights to patients as a preliminary step towards minimally invasive therapy. Together, these approaches constitute a coherent research programme spanning from basic mechanisms to clinical translation. This rare combination strengthens the validity of the findings, demonstrating that a comprehensive understanding of tinnitus requires integration across experimental levels.

Interdisciplinarity and broader impact

I am among the very few researchers who have studied tinnitus across the full spectrum: animal models (DFG grant), experimental MEG and EEG studies in humans (ELAN grant of the University Hospital Erlangen), computational modelling, and clinical trials. This rare combination of approaches embodies the principle of "bench to bedside" and demonstrates that tinnitus research can only progress when theory, experiment and therapy are tightly connected.

Conclusion and outlook

My research has advanced our understanding of tinnitus by combining computational models, experimental paradigms and translational clinical studies. I have contributed new insights into both mechanisms and treatment. Ultimately, research in this field is for the benefit of patients. Therefore, I believe it is crucial to not only conduct rigorous science, but also communicate it responsibly. I have given television interviews for the TV Series Nachtlinie on Bayerischer Rundfunk (Link: Nachtlinie: Neues aus der Tinnitusforschung - hier anschauen) and ARD alpha (Link: alpha-gespräche: alpha-thema Gespräch · Alles über Tinnitus - hier anschauen), alongside Prof Veronika Vilsmeier from Regensburg. I have also written articles for the popular science magazine "Gehirn und Geist" (Link: Hörschäden: Tinnitus im Ansatz bekämpfen - Spektrum der Wissenschaft) and the "Physik Journal" to make current research accessible to a wider readership. Looking ahead, my goal is to build on these foundations to establish evidence-based, personalized therapies, while continuing to link tinnitus research with broader theories of perception and cognition. In this way, I hope to strengthen the bridge between basic science, clinical care and public understanding. *(see references in the habilitation thesis)*