HIGHLIGHTS

ERWIN L. HAHN INSTITUTE FOR MAGNETIC RESONANCE IMAGING

2024

ERWIN L. HAHN INSTITUTE FOR MAGNETIC RESONANCE IMAGING

Erwin L. Hahn Institute for Magnetic Resonance Imaging

HIGHLIGHTS 2024

Annual Report

ERWIN L. HAHN INSTITUTE FOR MAGNETIC RESONANCE IMAGING


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Preface

In 2024 the Erwin L. Hahn Institute for MRI (ELH) and its principal investigators (PIs) were actively involved in two 14-Tesla initiatives on both sides of the Dutch/German border. While the Dutch 14T DYNAMIC project headed by ELH PI David Norris, building the world's first 14T human MRI magnet, now has priority, the German 14T initiative also regained traction in 2024. On behalf of the German UHF network (GUFI) a 14-Tesla project proposal has been submitted to the BMBF in 2024, which, at the time of this writing, is under review. A status update from PIs Quick and Ladd is included in this annual report.

In this 2024 annual report you will find contributions and exciting updates of each of our PI groups working at the ELH with 7-Tesla UHF MRI, reflecting a broad spectrum of Brain and Body UHF MRI activities. Starting with body MRI, Tom Scheenen reports on a method enabling free-breathing high-resolution respiratory-gated radial stack-of-stars MRI of the upper abdomen at 7 Tesla (7T). The ELH PIs with focus on brain UHF MRI also have been very productive in 2024. Dagmar Timmann describes a project on the role of the cerebellum in "Treatment Expectations" (in TRR289). Ulrike Bingel continues to investigate the interaction between pain and cognitive processes. Nikolai Axmacher uses the increased sensitivity of 7T for laminar fMRI in the human hippocampus. Onur Güntürkün with his contribution takes us on an MRI-based odyssey through the brains of chicks, dolphins and humans. Matthias Brand is spokesperson of FOR2974 "Affective and Cognitive Mechanisms of Specific Internet-use Disorders (ACSID)" and in this annual report he provides an update on the successful application for the 2nd funding period. A true highlight for Matthias and all of us at the ELH in 2024 was the news that Matthias Brand by Clarivate™ has been named among the "Highly Cited Researchers 2024" and is ranked among the Top 1% of the world's most influential scientists across all disciplines. Congratulations to Matthias for this truly fantastic achievement!

On November 13, we held our annual "Erwin L. Hahn Lecture" and associated scientific workshop entitled "Brain & Spine – The Next Frontier" in the Oktogon on the grounds of Zeche Zollverein. The event in this very special location was again well attended on-site and online. Virginie Callot from University of Marseille gave a very inspiring lecture entitled: "Spinal Cord MRI at Ultra-High Field: Where are we now" which was very well received and lively discussed by the auditorium.

The 2025 ELH Lecture will take place on October 29th again in the neighbourhood of the ELH on the grounds of Zeche Zollverein - and we are planning a very special event celebrating the 20th birthday of the ELH. So, please mark your calendars!

I hope that you find the content of our annual report 2024 enjoyable, and look forward to another year's exciting research at the Erwin L. Hahn Institute.

Harald H. Quick
Essen, March 2025

Ivo Maatman, Jennifer Schulz, Sjoerd Ypma, Tobias Block, Sebastian Schmitter, John Hermans, Ewoud Smit, Marnix Maas and Tom Scheenen

Towards a novel technique for imaging of the upper abdomen at 7T

The research group of Tom Scheenen focuses on the development and implementation of novel in vivo magnetic resonance imaging (MRI) and spectroscopy (MRS) methods aimed towards therapy guidance and intervention in oncology. This year, they introduced a novel MRI technique for high-resolution imaging of the upper abdomen at 7T, addressing the challenges of motion and radiofrequeny transmit inhomogeneities in the body. The method aims to produce clear images of the liver, the kidneys and surrounding small structures without requiring patients to hold their breath, using the sensitivity of 7T to attain a high spatial resolution. The research team used a custom-made 8-channel coil array from an ongoing EU project for these measurements [1].

The core innovation lies in the combination of several techniques. We used a Radial Stack-of-Stars acquisition to sample data in a radial pattern, making it less sensitive to motion artifacts. It acquires data as stacks of intersecting radial projections, which provides a cylindrical k-space coverage. The technique uses free induction decay (FID) navigator signals to monitor the patient's breathing. This allows for retrospective respiratory gating, meaning the data is sorted into different respiratory phases to reconstruct images with minimal motion blur.

To address the issue of uneven signal distribution at 7T, the Time-Interleaved Acquisition of Modes (TIAMO) technique is used with personalized pairs of B1 shims to homogenize signal excitation. TIAMO acquires each k-space line two times with alternating B1 phase shim settings, creating a more uniform excitation. The use of a frequency-selective pulse (a 1ms block pulse) excites only water signals, enhancing the

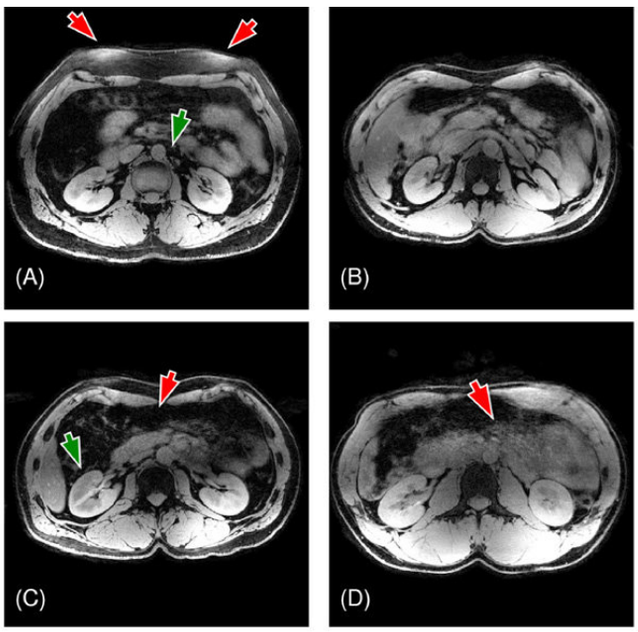

Figure 1. Axially reconstructed MRI images of the kidneys from four volunteers with the new method. The images clearly show blood vessels, lymph nodes (green arrow in A), as well as details within the kidneys (green arrow in C). Some residual signal from fat (red arrows in A), some signal loss in the intestines (red arrow in C), and few streaking artifacts remain (red arrow in D). (Figure from [2])

clarity of the images by avoiding off-resonance blurring from lipid signals.

We tested this method on 7 healthy volunteers, scanning the liver and kidney regions during free breathing, and showed that the TIAMO technique indeed provided high signal homogeneity, reducing signal dropouts typical at 7T. This is demonstrated in the images where the signal is uniform with minimal shading and little fat signals (Figs. 1 and 2). The technique allows clear visualization of small anatomical details of the kidney, clearly depicting renal vessels and small structures like lymph nodes (Fig. 1). The spatial resolution of 0.8x0.8x1.0 mm^3 allowed excellent depiction of structures such as the adrenal glands, the proximal ureter, the diaphragm and small blood vessels.

Within the liver, blood vessels were visible without the use of contrast agents, because of differences in T1 and T2* relaxation times of blood vs. liver tissue at 7T (Fig. 2). It also shows a sharp delineation of the diaphragm. Despite these successes, some streaking artifacts persisted, particularly in liver images due to residual motion and susceptibility differences. These artifacts were deemed more problematic for liver than for kidney images.

Altogether we demonstrated the feasibility of high-resolution, free-breathing abdominal MRI at 7T. The improved image quality and increased SNR has the potential to enhance diagnostic capabilities of MRI of the upper abdomen. Specifically, the ability to visualize small structures, such as lymph nodes, adrenal glands, small blood vessels, vessels within the liver without contrast agents might help in the early detection and staging of cancers in this region of the body.

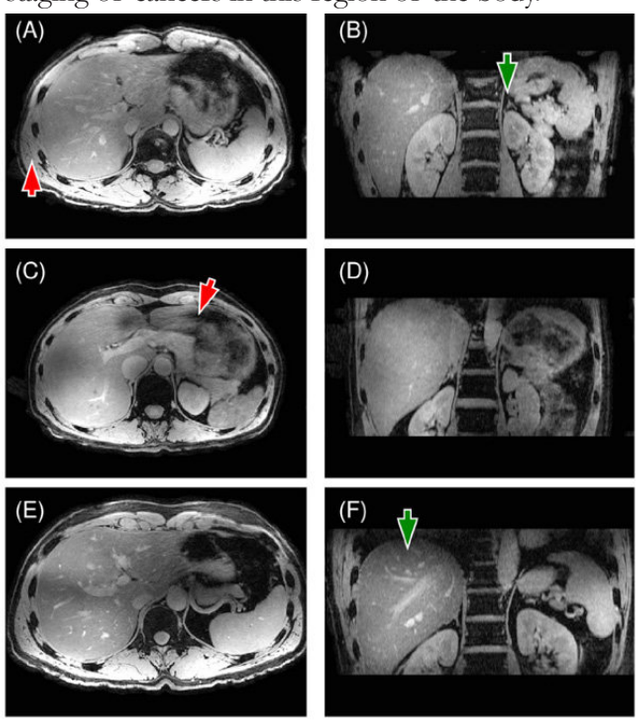

Figure 2. Axial and coronal reconstructions of the liver from three volunteers, showing clear visualization of blood vessels (arrow in F) and adrenal glands (arrow in B). Only minor variations in signal strength in the liver (arrow in A) and some streaking artifacts remained (arrow in C). (Figure from [2])

This method is a step towards expanding the clinical application of 7T MRI in abdominal imaging.

1. Klomp D, Scheenen T, Quick HH, et al. EU MITI. Non-ionizing Metabolic Imaging for predicting the effect of and guiding Therapeutic Interventions (MITI). 2022 - 2024, EU HORIZON-EIC-2021, Project Number 101058229
2. Maatman IT, Schulz J, Ypma S, Block KT, Schmitter S, Hermans JJ, Smit EJ, Maas MC, Scheenen TWJ. Free-breathing high-resolution Free-breathing high-resolution respiratory-gated radial stack-of-stars magnetic resonance imaging of the upper abdomen at 7T. NMR Biomed. 2024 Oct;37(10):e5180. doi: 10.1002/nbm.5180. Epub 2024 May 22.PMID: 38775032

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On the way to 14 Tesla ...

In last year's ELH "Highlights" brochure, we described the plans of the GUFI community to pursue a 14 Tesla human whole-body system in Germany. In 2024, we responded to a call from the German Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung, BMBF) to submit projects to develop new national scientific infrastructures. In a proposal coordinated by the Friedrich-Alexander University Erlangen and the German National Metrology Institute (Physikalisch-Technische Bundesanstalt) in Berlin, GUFI formulated a comprehensive plan to establish a 14 Tesla system in Erlangen in close vicinity to the University Hospital as well as Siemens Healthineers.

The evaluation of the submitted projects is ongoing, and it is expected that a short list of projects particularly suitable for maintaining and expanding the leading position of the German science system in international competition will be published by the end of the summer 2025.

As part of the ongoing developments toward this goal, Harald Quick and Mark Ladd together with Klaus Scheffler of the MPI in Tübingen and Oliver Speck from the University of Magdeburg co-authored a review article summarizing the design requirements of ultra-high-field (UHF) magnets for human MRI [1]. In the article, we present the essential considerations for developing such magnets.

We emphasize the importance of achieving a homogeneous magnetic field, as inhomogeneities can lead to image artifacts and reduce diagnostic accuracy. We also highlight the need for a spacious bore diameter to accommodate various patient sizes comfortably, which is crucial for patient compliance, and to enable whole-body imaging. Additionally, the article addresses the challenges associated with the increased specific absorption rate (SAR) at higher field strengths and the need for careful management of radiofrequency power deposition.

We advocate for collaborative efforts between MRI

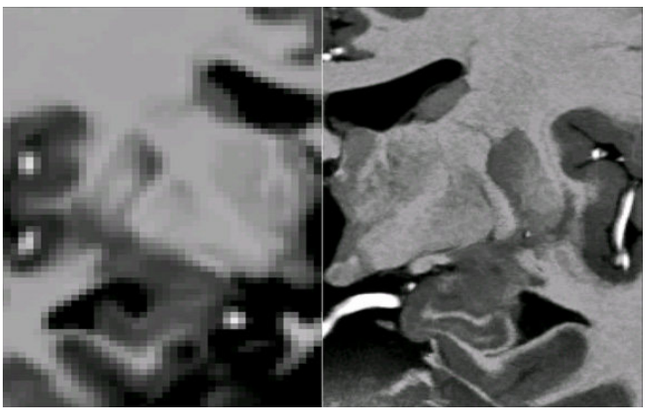

Figure 1. T1-weighted MRI at 7 Tesla with 1 mm isotropic resolution of the deep grey matter and medial temporal lobe region including hippocampus (left) compared to a very high-resolution in vivo acquisition with 250 µm. (Figure from [2]).

scientists and magnet designers to ensure that UHF magnets effectively meet clinical and research requirements. Figure 1 from our article [1] illustrates only one of the many motivations to pursue the development of 14 Tesla MRI. While at 7 Tesla the acquisition of this brain MRI at unprecedented 250 µm isotropic resolution took several hours, it is expected to be feasible at 14 Tesla at less than 1/9th the acquisition time.

Networking Activities

International German Ultra-High-Field Imaging (GUFI) Meeting at ISMRM 2024 in Singapore

At the ISMRM 2024 meeting in Singapore in June, Harald Quick (ELH, Essen), Mark Ladd (DKFZ, Heidelberg), and Oliver Speck (OVGU, Magdeburg) organized an on-site GUFI meeting "GUFI@ISMRM", with invited national and international UHF MRI partners (Fig. 2). With >30 participants, the meeting was well attended. The focus of this international GUFI meeting was again to give an update on UHF MRI beyond 7 Tesla field strength.

Nicolas Boulant from NeuroSpin, France, gave a presentation on the first human brain images acquired on the 11.7 Tesla MRI system at CEA, Paris [2]. This highlight marks an important milestone after more than 20 years of development of the 11.7 Tesla human MRI system at CEA. This presentation was followed by an update on the planned 14 Tesla human system of the DYNAMIC consortium in the Netherlands.

Dennis Klomp presented an overview of the current and planned steps for realization of the world's strongest human MRI system. Funding from the NWO (NL) is secured, and magnet development (Neoscan Solutions, Magdeburg, Germany) is underway. Robin Heidemann provided an update on UHF developments at Siemens Healthineers, and the meeting ended with an invitation from Aaron Hess (University of Oxford) to the Glasgow pTx workshop to be held in June 2024. Today (2025) we know that this workshop was a huge success for the UK 7T network and partners like GUFI.

Figure 2. Participants at the 2024 GUFI & Friends Meeting at the ISMRM 2024 in Singapore – looking forward to the 2025 meeting in Honolulu, Hawaii. Aloha!

1. Ladd ME, Quick HH, Scheffler K, Speck O. Design requirements for human UHF magnets from the perspective of MRI scientists. Superconductor Science and Technology. 2024 37:113001. https://doi.org/10.1088/1361-6668/ad7d3f
2. Lüsebrink F, Mattern H, Yakupov R, Acosta-Cabronero J, Ashtarayeh M, Oeltze-Jafra S, Speck O. Comprehensive ultrahigh resolution whole brain in vivo MRI dataset as a human phantom. Sci Data. 2021 May 25;8(1):138. doi: 10.1038/s41597-021-00923-w
3. Boulant N, Mauconduit F, Gras V, Amadon A, Le Ster C, Luong M, Massire A, Pallier C, Sabatier L, Bottlaender M, Vignaud A, Le Bihan D. In vivo imaging of the human brain with the Iseult 11.7-T MRI scanner. Nature Methods. 2024 21:2013-2016. https://doi.org/10.1038/s41592-024-02472-7

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UHF MRI Sites

2024: The (success) story continues

For the group around PI Brand, the defining event of this year actually happened in December of 2023: Months of planning and practicing were put to the test, when a review group consisting of national and international researchers and review board members from the German Research Foundation (DFG) gathered at the Zollverein UNESCO World Heritage Site to evaluate the plans for a second funding period of the research unit FOR2974 "Affective and Cognitive Mechanisms of Specific Internet-use Disorders" (ACSID) (Spokesperson Matthias Brand).

The preparation paid off, as in March 2024 the DFG announced the extension of the research unit ACSID funding all nine proposed research projects (plus the coordination project) for another three years with a volume of around five million euros. This transregional research unit, involving researchers from the Universities of Duisburg-Essen, Bochum, Bamberg, Giessen, Mainz, Lübeck and Hannover Medical School, investigates addictive online behaviors, including excessive gaming, shopping, pornography consumption, and social network use. Two research projects (RP4 and RP10) will mainly be carried out at the ELH, and others (like RP11) plan exploratory MRI parts. RP4, led by Stephanie Antons together with Martin Diers and Oliver Wolf (Bochum), continues to investigate neural responses towards video game- or pornography-related stimuli in individuals with disordered gaming or pornography use.

New to the second funding period will be a focus on neural correlates of stress, habit formation and the use of MR spectroscopy to measure the concentration of specific neurotransmitters in certain regions of interest. Similarly, RP10, headed by Matthias Brand together with Rudolf Stark (Giessen) and Nicole Krämer (Duisburg-Essen), investigates neural correlates of cue-reactivity in disordered buying-shopping and social network use.

The use of similar methods, without stress in-

duction, but also including MR spectroscopy, will allow for systematic comparisons across behaviors. Additionally, inviting female participants from RP11 enables more systematic gender comparisons.

In June, the Kick-off/Farewell Workshop marked the start of the second as well as the completion of the first funding period of the FOR2974, which was a great success. Data collection finished in September 2024 with a total of almost 1200 participants who completed extensive laboratory test-sessions - a treasure trove of data from which we can draw for a long time.

Our team was also well represented at national and international conferences, such as the Suchtkongress, the Lisbon Addictions or the ELH Lecture, where we presented first results from (preliminary) data and from related projects. One highlight was the International Conference on Behavioral Addictions (ICBA) in Gibraltar, where Matthias Brand held the keynote lecture and was honored with the "Great Achievement Award" for his work in the field of behavioral addictions. Also, Stephanie Antons was presented with the "Best Paper Award" announced in 2023.

Last but not least, the successes of the year were emphasized by Matthias Brand being awarded by Clarivate™ Highly Cited Researchers 2024 list as being among the top 1% of the world's most influential scientists across all disciplines. Team Brand is looking forward to continuing the research successes and a busy 2025 at the ELH.

Figure 1. Matthias Brand receiving the International Society for the Study of Behavioral Addictions Great Achievement Award.

Figure 2. FOR2974 PIs meet at the ELH in preparation of the 2nd funding period.

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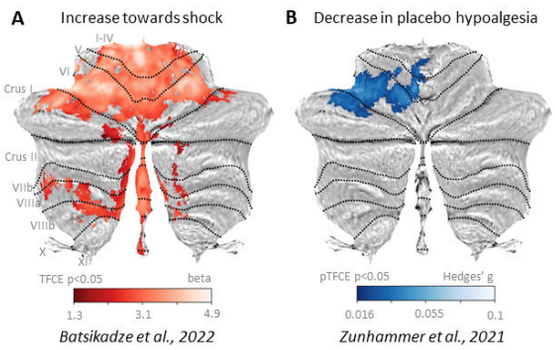
How does the cerebellum contribute to placebo hypoalgesia and nocebo hyperalgesia?

The Collaborative Research Center/Transregio TRR289 "Treatment Expectations" (speaker Ulrike Bingel) successfully applied for a second funding period in 2024. The group by Dagmar Timmann submitted a new project within the TRR289 addressing the contribution of the cerebellum to treatment expectations, which was granted funding. The project will be performed in close collaboration with Ulrike Bingel's group.

There is initial evidence that the cerebellum contributes to placebo hypoalgesia. For example, placebo hypoalgesia has been found to be reduced in patients with cerebellar stroke (Ruscheweyh et al., Pain, 2014). However, it is unknown which cerebellar areas are most critically involved. In the first part of their project, Timmann and colleagues wish to confirm findings of reduced placebo hypoalgesia in patients with pure cerebellar degeneration and extend findings to nocebo hyperalgesia. Based on structural and resting-state MRI, they will test the hypothesis that reduced placebo and nocebo effects are at least partly related to the degree of degeneration of the posterolateral cerebellar hemisphere (Crus I and II) due to known connections (via the thalamus) to the dorsolateral prefrontal cortex (dlPFC), an important part of the descending pain modulatory system.

In the second part of their project, Timmann and colleagues will perform the same placebo/nocebo experiment in combination with 7 Tesla fMRI, allowing them to measure brain activity at the level of the cerebellar nuclei and brainstem. Given that the cerebellum has direct connections with the periaqueductal gray (PAG), they will test the hypothesis that the cerebellum also contributes to placebo and nocebo effects via interactions with the PAG (with the cerebellum thus interacting with multiple levels



Flat maps of the cerebellum showing that shock-related increases (red) and placebo-related decreases (blue) of activations overlap during pain application. [Batsikadze et al. Neuroimage. 2022;253:119080.; Zunhammer et al., Nat Commun. 2021;12(1):1391. We like to thank Tamas Spisak for the preparation of the figure.]

of the descending pain modulatory system).

In the third part of their project, Timmann and colleagues aim to establish a more mechanistic understanding of how the cerebellum contributes to placebo hypoalgesia and nocebo hyperalgesia. Based on current ideas of cerebellar function, Timmann and colleagues will test the hypothesis that altered predictive output of the cerebellum explains reduced treatment expectation effects in patients with cerebellar disease. In the 1st funding period of TRR289, Michael Rose and Christian Büchel found expectation of pain to be related to characteristic electroencephalography (EEG) signatures (e.g., Strube et al., eLife 2021, Neuron 2023).

Based on these findings, Timmann and colleagues will perform EEG recordings in patients with pure cerebellar degeneration during the placebo/nocebo experiment and examine changes in EEG power and frequency bands related to the cue-related outcome expectation of a pain treatment. This will be done together with Michael Rose's group in Hamburg. Furthermore, in collaboration with Christian Büchel's group in Hamburg, computational modeling based on a Bayesian pain model will be used to understand how cerebellar dysfunction may result in reduced magnitude of placebo (and nocebo) effects.

In two comprehensive studies, this project will address the following research questions:

Key questions

• Are placebo and nocebo effects reduced in patients with pure cerebellar degeneration (i.e., diseases which are restricted to the cerebellum)?
• Does the cerebellum contribute to placebo and nocebo effects through interactions with both cortical (dlPFC) and subcortical (PAG) regions of the descending pain modulatory system?
• Are reduced treatment expectation effects in patients with pure cerebellar degeneration related to altered predictive output of the cerebellum?

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The interaction between pain and cognitive processes

Ulrike Bingel and her research group focus on the interaction between pain and cognitive processes. They have a longstanding expertise in investigating the CNS mechanisms underlying nociception, pain, and pain modulation in health and disease. In their research, they use behavioural paradigms, pharmacological modulations, as well as functional and structural brain imaging. Being particularly intrigued by the reciprocal effects of pain and cognition, they have a strong focus on translational questions such as the role of expectations and prior experiences on analgesic treatment outcomes. Their interdisciplinary research group comprises neurologists, neuroscientists, psychologists, biologists, and computer scientists and is based at the Department of Neurology at the University Medicine Essen.

A highlight in 2024 was the on-site review of the transregional TRR289 "Treatment Expectation" (www.treatment-expectation. de) that has been funded by the DFG since 2020. The team is excited and grateful that the DFG has approved the next funding period from 2024-2028. The consortium lead by Ulrike Bingel focuses on the mechanisms underlying expectations on health and treatment outcomes and explore how expectations can be systematically used to improve health care. The consortium involves many projects using brain imaging and the central scientific project Z03 co-lead by Tamas Spisak (https://pni-lab.github.io) has started to develop a unique research infrastructure for harmonizing and sharing brain imaging data across sites and projects.

This will provide a unique basis for pooled and meta-analytic approaches as will also benefit future collaborative engagement of the ELH. Such "mega-analyses" of several hundred datasets of the placebo imaging consortium (https://github.com/placebo-imaging-consortium) have already fostered novel discoveries regarding the mechanisms of

placebo analgesia, such as the contribution of the cerebellum, as published in Nature Communication in 2021 [1]. The cerebellum provides an ideal target to be followed up with high field neuroimaging in a joint endeavor with the group by Dagmar Timmann (see page 14), a world leading expert in this field. Bingel and her team are excited to have won Dagmar Timmann as a new PI in the TRR for the new project N17. In a joint endeavor with Dagmar Timmann, the scientists plan a 7T study on brainstem-thalamo-cortical pathways underlying expectation change in analgesia in project A01.

The research activities in the field of learning in project A11 of the CRC1280 Extinction Learning (https://sfb1280.ruhr-uni-bochum.de) were also continued. In this project Ulrike Bingel will continue to investigate the mechanisms underlying pain-related learning and how this might contribute to the development and maintenance of chronic pain. The members are glad to have attracted Jialin Li, a PhD from the prestigious Max Planck School of Cognition, as well as Jonas Zaman as a Humboldt Fellow to support and strengthen these lines of research. In the next months the proposal and onsite-review for the third funding period of this consortium, which will take place in July 2025, will be prepared.

Last but not least several exciting projects have been initiated or completed. Together with David Norris and colleagues, they will explore the contribution of resting state activity of the spinal cord for an individual's pain sensitivity in health and chronic pain states, a project that perfectly builds upon their previous work on cerebral resting state networks and pain sensitivity in healthy volunteers.

Another exciting upcoming project: The DFG has granted a joint research proposal with Matthias Brand and Dagmar Timmann to investigate the role of the cerebellum and its connections with the VTA in reinforcement learning which may have strong implications for pain-related learning. Additionally, a collaboration with the neuroimaging center at Sheeba Medical Center in Tel Aviv to investigate the role of cognitive and resting-state-network flexibility in chronic pain has been launched. The PI group's new PhD Jenya Lerer, supported by the Minerva Foundation, will link the two institutions.

1. Zunhammer M, Spisák T, Wager TD, Bingel U. Placebo Imaging Consortium. Meta-analysis of neural systems underlying placebo analgesia from individual participant fMRI data. Nat Commun. 2021. 12(1):1391. doi: 10.1038/s41467-021-21179-3

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MRI-based odysseys through the brains of chicks, dolphins, humans and other animals

Among other techniques, Onur Güntürkün uses (f)MRI to study learning-, memory-, and cognition-related BOLD responses in awake and actively participating birds like pigeons and chicks. However, he also studies the brains of other animals like humans and dolphins for graph-theoretical properties of the intrinsic functional networks of their brains.

Using chicks, Güntürkün and his team could for the first time ever, uncover the neural network of filial imprinting for the mother hen in chicks (Behroozi et al., 2024). Filial imprinting represents a one-short learning paradigm that has lifelong effects. To study this in chicks, the research team developed an fMRI technique for awake, newly hatched chicks, capturing BOLD signal changes during imprinting experiments. The scientists could not only identify the long-term storage of imprinting memories, but also the partly different activated system during retrieval of this memory. It turns out that not only the hippocampal formation and the prefrontal-like nidopallium caudolaterale play key roles, but also action- and habit-related structures (Fig. 1). Thus, one-shot learning activates beneath well-known memory-related systems also the whole executive system that leads from decisions via actions up to habit-based responses.

Dolphins are to some extent a mystery. They belong to the order of Cetacea in which animals with the largest brains of our planet are congregated. Since understandably, invasive studies are not permitted for any of these endangered species, the researchers applied a state-of-the-art algorithm of diffusion-weighted imaging called Constrained Spherical Deconvolution on diffusion data of three fixed brains of bottlenose dolphins (Gerussi et al., 2024). Their findings indicate that in order to maintain the

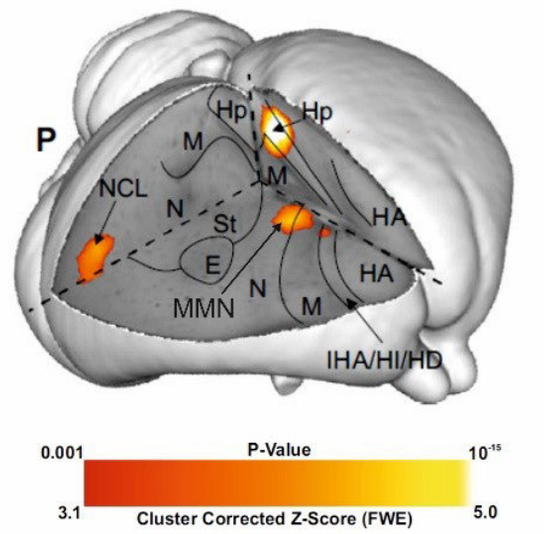

Figure 1. BOLD response pattern during imprinting memory retrieval in young chicks. The high-resolution 3D depiction of the chick brain shows BOLD responses in the prefrontal NCL, the hippocampus (Hp) and the higher-order motor area MMN. [Behroozi et al. 2024]

structural integrity of the tissue, short-term post-mortem fixation is necessary. Furthermore, preprocessing steps are essential to remove the classical diffusion-weighted imaging artifacts from images. However, the algorithm is still able to resolve fiber tracking in regions with various signal intensities. The described imaging technique reveals complex fiber patterns in cetacean brains that have been preserved in formalin for extended periods of time and thus opens a completely new window into the understanding of cetacean neuroanatomy. The research

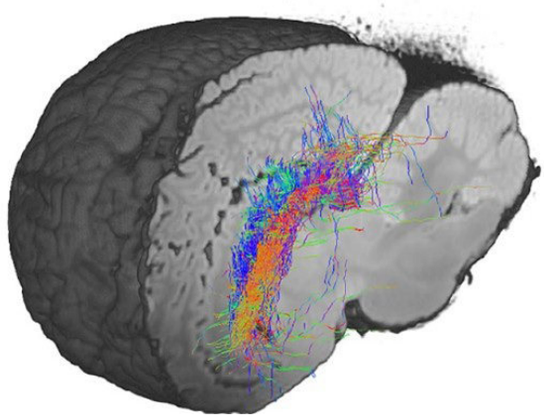

Figure 2. Regional tractogram of the corpus callosum (cc) of a male bottlenose dolphin. The colors of the corpus callosum reflect the direction along the MRI scanner; x, latero-lateral; y, dorso-ventral and z, cranio-caudal. Color codes: red: latero-lateral; blue: dorso-ventral; and green: cranio-caudal. [Gerussi et al. (2024]

team's approach visualizes for the time the inter-hemispheric axonal system of dolphins (Fig. 2) and can even clarify the long-term dispute if dolphins have a prefrontal cortex. Indeed, they have one, but it is shifted sideways and sits lateral to the motor cortex.

1. Behroozi M, Lorenzi E, Tabrik S, Tegenthoff M, Gozzi A, Güntürkün O, Vallortigara G. Functional MRI of imprinting memory in awake newborn domestic chicks. Commun Biol. 2024 Oct 15;7(1):1326. doi: 10.1038/s42003-024-06991-z
2. Gerussi T, Graïc JM, Cozzi B, Schlaffke L, Güntürkün O, Behroozi M. Constrained spherical deconvolution on diffusion-weighted images of dolphin brains. Magn Reson Imaging. 2024 May;108:104-110. doi: 10.1016/j.mri.2024.02.002

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Antoine Bouyeure, Viktor Pfaffenrot, David Norris and Nikolai Axmacher

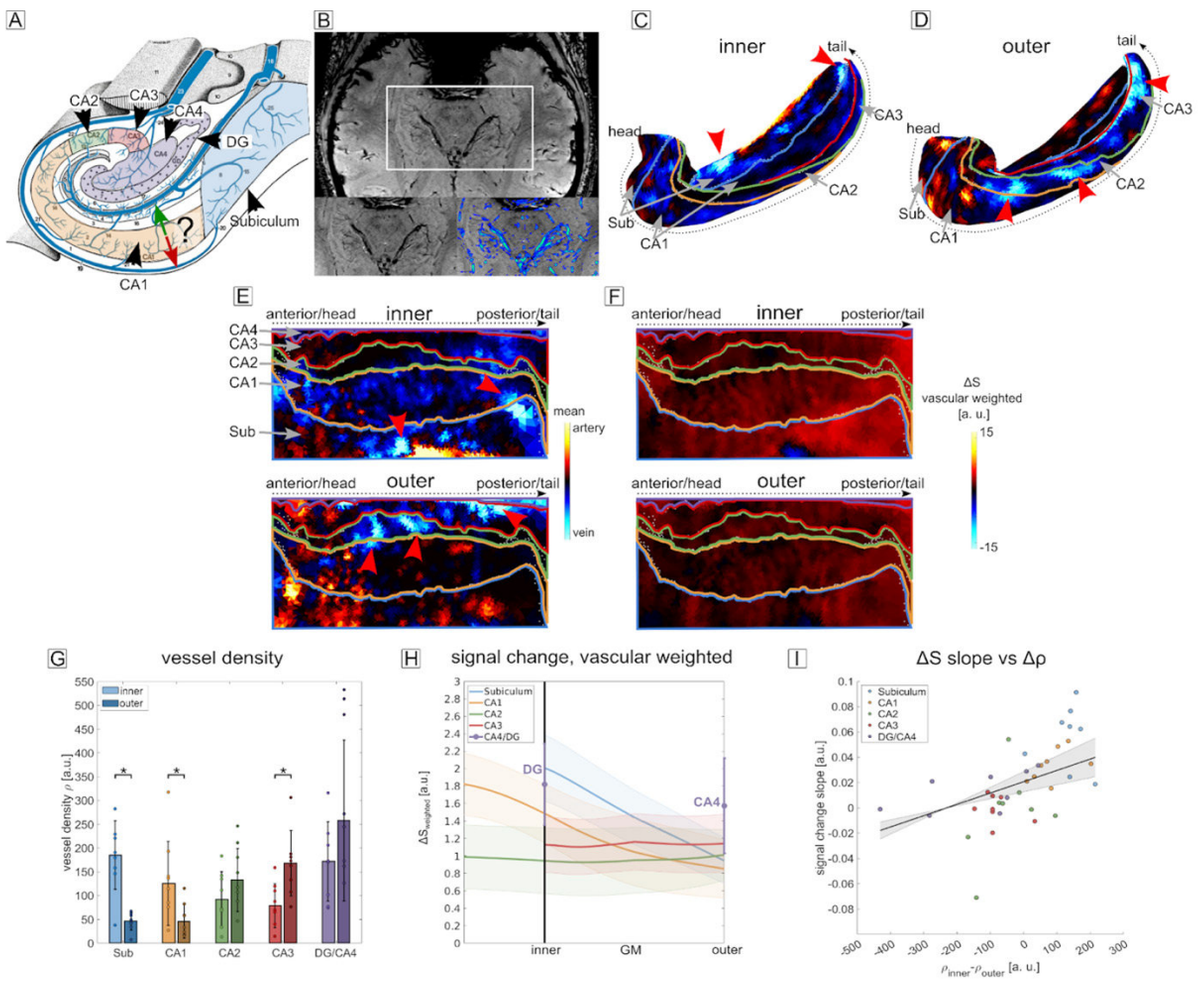
Characterizing BOLD activation patterns in the human hippocampus with laminar fMRI

Cortical gray matter is, at the mesoscale, composed of distinct tangential cellular layers. These cellular layers have a characteristic distribution of different neurons and distinct connections with other cortical and subcortical regions. Therefore, understanding how brain activity is modulated at the mesoscale (i.e., at the level of layers) is currently one of the great challenges of functional magnetic resonance imaging (fMRI) in humans.

The hippocampus, a region critical for memory, has been extensively studied at the macroscale using fMRI, but the underlying microcircuits at the mesoscale remain largely uninvestigated in humans. Indeed, such an investigation is confronted with unique challenges: the most widely used contrast for laminar fMRI is the gradient echo (GRE) blood oxygenation level dependent (BOLD) contrast due to its high sensitivity.

However, GRE-BOLD responses at the laminar level are weighted toward large venous vessels, the well-known draining vein bias. While VASO, the main alternative to GRE-BOLD, can measure laminar responses with reduced venous contamination in the neocortex, it suffers from an intrinsically low temporal efficiency and reduced sensitivity to cerebral blood volume changes in inferior brain structures, which renders it currently unviable in the hippocampus.

This project targeted two questions fundamental to hippocampal laminar fMRI: How does the venous bias affect the interpretation of hippocampal laminar responses, and is it possible to establish a benchmark laminar fMRI experiment which robustly elicits single-subject hippocampal activation utilizing the most widely applied BOLD contrast? A custom pipeline was built to extract layer profiles for each



Vascular distribution and breath-hold induced signal change. **A** Schematic of the venous vessel distribution in the human hippocampus. **B** High-resolution SWI image filtered for veins (blue structures in zoomed section). **C-D** Subject-averaged vascular distribution of large vessels at the inner (C) and outer (D) surface (veins and arteries in blue and red, respectively) shown on the folded hippocampus. Colored borders represent the demarcation between subfields. The venous density exhibits a clear subfield-specific differentiation between the inner and outer surface. **E** Same data as in C, D plotted on the unfolded hippocampal surfaces. **F** Breath-hold induced signal change with vascular weighting. **G** Venous vessel density ϱ for the inner and outer layer of each subfield, averaged over hemispheres. **H** Vascular-weighted, subject- and echo-averaged signal change during breath-hold as a function of cortical depth for each subfield. **I** Relationship between the slope of the signal change curves in H and the difference in vessel density $\Delta\varrho$ in G.

hippocampal subfield (i.e., hippocampal subregions) corresponding to laminar activity during memory retrieval.

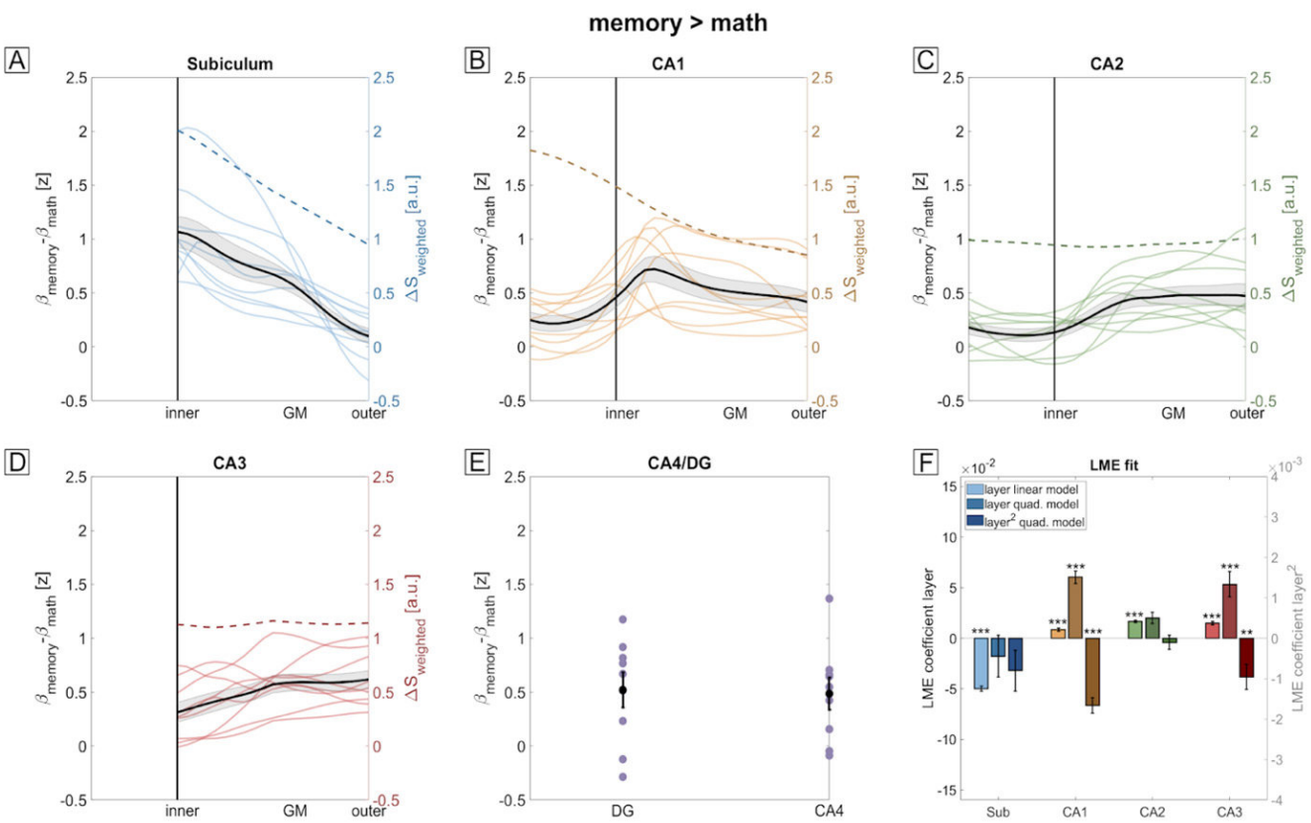
Results showed that the vascular architecture differs between subfields, leading to subfield-specific laminar biases of GRE-BOLD responses. Moreover, in the CA1 and Subiculum subfields, the results indicate a difference in BOLD activity at the layer level that suggests a more pronounced trisynaptic path input rather than dominant direct inputs from entorhinal cortex during autobiographical memory retrieval.

Finally, the patterns of BOLD activity at the layer level did not systematically correlate with the laminar biases of the GRE-BOLD responses, showing the feasibility of performing layer-fMRI of the human hippocampus with the GRE-BOLD contrast.

The scientists' study provides unique insights into the hippocampus at the mesoscale level and will help interpret hippocampal laminar fMRI responses and

allow researchers to test mechanistic hypotheses of hippocampal function.

This project was a collaboration between Viktor Pfaffenrot and David Norris (ELH, University of Duisburg-Essen) and Antoine Bouyeure and Nikolai Axmacher (ELH, Ruhr-University Bochum). A manuscript describing the results is currently under revision. Results were also presented at the ISMRM 2024 and OHBM 2024 conferences.



Laminar fMRI profiles of autobiographical memory. **A-E** Laminar fMRI responses for all subfields during the memory › math contrast. Subject-averaged profiles are shown as black overlays (shaded area corresponds to SEM). The vascular-weighted signal change during breath-hold is plotted as dashed line. In case of CA4 and the DG, only two bins were defined since layers are less clearly defined. **F** LME model comparisons using approximated F-tests show a significant effect of depth for all subfields. Here, 'layer quad. model' and 'layer² quad. model' refer to the linear and quadratic term in the second-order LME model, respectively. In CA1 and CA3, a quadratic model fitted the data significantly better than a linear model.

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Prof. Dr. Ulrike Bingel
Prof. Dr. Onur Güntürkün
Prof. Dr. Mark E. Ladd
Prof. Dr. Tom W.J. Scheenen
Prof. Dr. Dagmar Timmann

Administrative Director
Dr. Franziska Günther

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Radiographer
Daniel Osenberg

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Dr. Antoine Bouyeure
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MSc. Alice Doubliez
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Dr. Thomas Ernst
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MSc. Tobias Spronk
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Paula Klose
Matthias Mälzer
Denis Mai
Maya Metzger
Lara-Minou Nasution
Patrick Pais Pereira
Jost Scheufen
Carolin Stevens
Jakob Stührk
Annika Verheyen
Leon Voß
Luca Wessing

2024 IN SHORT

The rectorates from Radboud University in Nijmegen and the University of Duisburg-Essen visit the ELH.

Launch of the lunch talk sessions and ELH workshops, which quickly become an ELH staple.

The DFG grants second funding periods for TRR289 "Treatment Expectation" and FOR2974 "Affective and cognitive mechanisms of specific Internet-use disorders (ACSID)".

Launch of "Sex & Gender in the Life Sciences" lecture series in an joint initiative with the Center of Medical Biotechnology and the Essen College of Gender Research.

The Erwin L. Hahn Lecture & Workshop reaches a new record number in online participants from all over the world.

ISMRM Participation 2024 in Singapore

Ahmadi K, Stawarczyk D, Pfaffenrot V, Gomez CA, Patai Z, Norris DG, and Axmacher N: Laminar profile of hippocampal subregions during spatial navigation. *Session: Mesoscale fMRI,* Oral.

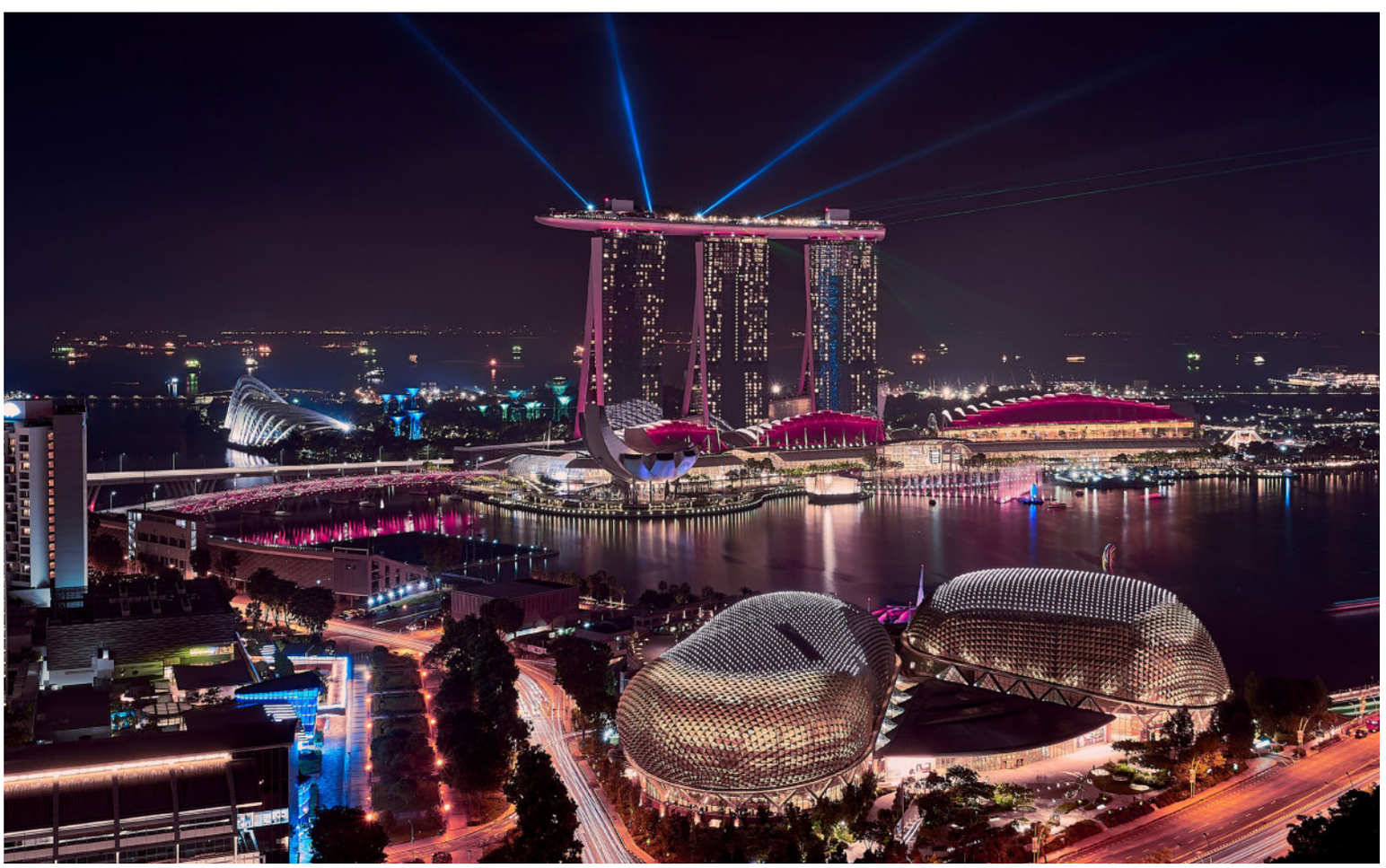
Grimm JA, Kraff O, May MW, Lutz M, Orzada S, Quick HH, Ladd ME, and Schmitter S: A comparison of various custom-built pTx RF arrays for body imaging at 7T with regard to their transmit effciency. *Session: B0 & B1 Coils & Phantoms,* Traditional Poster.

Kraff O, Deuermeier N, May MW, Pfaffenrot V, Theisejans J, Theysohn JM, and Quick HH: Evaluation of metal-artifact reduction techniques at 7T: Hardware adaption, phantom study, and preliminary in vivo results. *Session: Hardware at the Extremes: Ultra-Low & -High Fields,* Digital Poster.

Mai D, Fiedler TM, Knöbel N, Wessing L, Kraff O, Lanz T, Quick HH, and May MW: Simulation of an 8-channel transmit meander stripline array for combined head and neck imaging at 7Tesla MRI. *Session: Unconventional Concepts in RF Coil Design,* Digital Poster.

Pfaffenrot V, Bouyeure A, Axmacher N, and Norris DG: Laminar fMRI of the human hippocampus: Accounting for physiological fluctuations and vasculature. *Session: Mesoscale fMRI,* Digital Poster.

Solomakha GA, May MW, Kraff O, Scheffer K, Quick HH, and Avdievich NI: Toward densely populated dipole arrays for human prostate imaging at7T: 8Tx16Rx coaxial-end dipole array. *Session: Ultra-Challenging Ultra-High Field Applications,* Oral.



Erwin L. Hahn Workshop & Lecture 2024

ELH director Harald Quick welcomes speakers and listeners to the Erwin L. Hahn Lecture & Workshop.

Aerial view of the Oktogon's stunning interor.

Keynote speaker Virginie Callot from the Center for Magnetic Resonance in Biology and Medicine at Aix-Marseille Université, who spoke about "Spinal Cord MRI at Ultra-High Field: Where are we now?"

Harald Quick presents the International Erwin L. Hahn Award to to Simon Schmidt from the University of Minnesota for his publication "Improved ^{1}H body imaging at 10.5 T: Validation and VOP-enabled imaging in vivo with a 16-channel transceiver dipole array".

Signe Johanna Vannesjö had by far the longest journey, travelling all the way from Trondheim in Norway for her talk "Levelling the field in spinal cord MRI: B0 homogeneity and stability".

A rare opportunity: With almost all ELH members present, it was high time for an updated group photo.

Girls' Day 2024 - Scientist for a Day

In 2024, as part of the Girls' Day, the ELH welcomed a dozen girls to learn about how MRI is used in science, especially in the field of psychology.

ELH member Annika Verheyen demonstrates how the scanner is used to conduct an fMRI study.

Stephanie Antons explains what the subject experiences during the study.

How does a study set-up work? How do you choose your test subjects? The Girls' Day participants not only get to discuss, but also to fill out a sample questionaire handed to potential study subjects.

Left to right: Annika Verheyen, Stefanie Zurek, Pia Musenrink, some of the girls who visited us on Girls' Day, and on the very right Stephanie Antons.

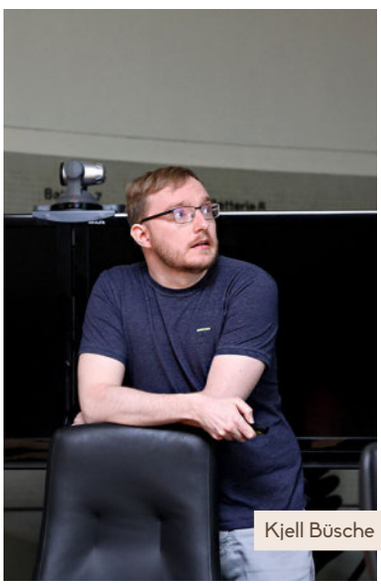
WIR MACHEN MIT!
Girls'Day
Mädchen-Zukunftstag
girls-day.de

Lunch Talks & ELH Workshops

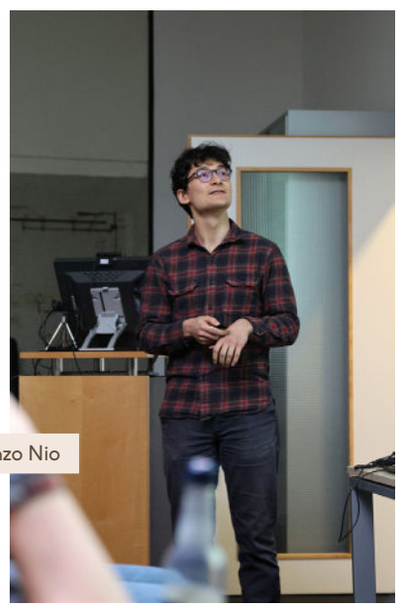
The ELH Lunch Talk series provides the perfect opportunity to learn more about the exciting research happening at the ELH. Every first Wednesday of the month, early- and mid-career scientists share insights into their ongoing research projects. After the presentation, an ELH-sponsored lunch provides a relaxed setting to continue the discussion, exchange ideas, and connect with other scientists.

In addition, the ELH also launched a workshop series where established scientists provide insights into topics across various research fields. These workshops create a valuable space for knowledge-sharing, skill development, and interdisciplinary exchange.

Viktor Pfaffenrot

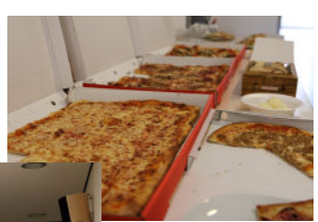


Luca Wessing

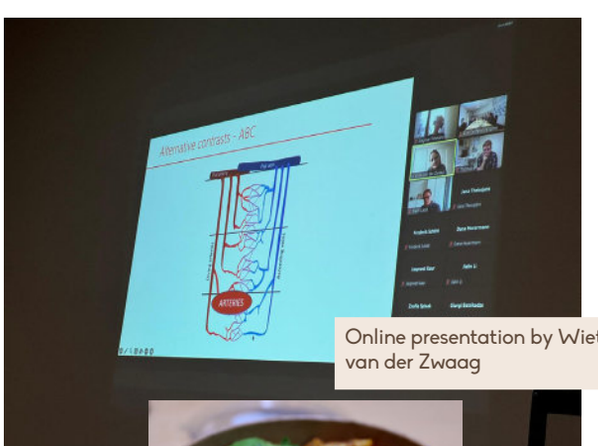


Enzo Nio

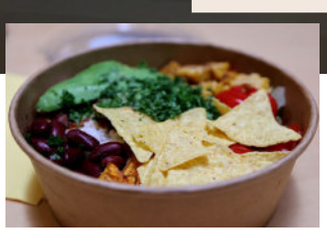
Kjell Büsche



David Norris and ELH members



Online presentation by Wietske van der Zwaag



Current Grants

DFG

N. Axmacher
CRC 1280 - A02: Neural mechanisms of context generalization (2021-2025)

N. Axmacher, D. Timmann, R. Kumsta
CRC 1280 - F02: Focus group neuroimaging and genetics (2021-2025)

N. Axmacher, E. Genç
CRC 1280 - A03: Functional role and dynamic change of extinction network connectivity (2021-2025)

U. Bingel
CRC 1280 - A11: Appetitive and aversive pain-related learning in health and chronic back pain (A11) (2021-2025)

U. Bingel
CRC/TRR 289: Treatment Expectation (2020-2028)

M. Brand
FOR 2974: Affective and cognitive mechanisms of specific Internet-use disorders (ACSID) (2020-2027)

H.H. Quick, N. Avdievich
F. Mauconduit (co-funded by ANR)
NeuroBOOST: Novel parallel-transmit head/neck RF coil arrays for ultra-high field MRI at 7T, 9.4T, and 11.7T (2024-2027)

D. Timmann
CRC/TRR 289 - A17: How does the cerebellum contribute to placebo hypoalgesia and nocebo hyperalgesia? (2024-2028)

D. Timmann, U. Bingel, M. Brand
Involvement of the human cerebellum in reinforcement learning via its connection with the ventral tegmental area (VTA) (2023-2026)

D. Timmann, H.H. Quick
CRC 1280 - A05: The contribution of the cerebellum to extinction: intrinsic mechanisms and cerebello-cerebral interactions (2021-2025)

EFRO/EU

N. Axmacher
Neural mechanisms, functional roles and pathophysiological relevance of human grid cell-like representations (2020-2025)

D. Klomp, H.H. Quick, T. Scheenen
Non-ionizing Metabolic Imaging for predicting the effect of and guiding Therapeutic Interventions (MITI) (2022-2024)

T. Scheenen, K. Herrmann
ILLUMINATE: Increasing Lutetium production, while leveraging metabolic imaging to enhance theranostics effectiveness (2024-2028)

D. Timmann
Marie-Skłodowska-Curie Innovative Training Network: Cerebellum and emotional networks (CEN) (2021-2025)

D. Timmann (Associated Partner)
Spinocerebellar ataxias: Advanced imaging with ultra-high field MRI (SCAIFIELD) (2021-2024)

MERCUR

N. Axmacher, D. Norris
Unlocking the function of the hippocampus with laminar fMRI (2022-2024)

O. Güntürkün, U. Bingel, M. Brand
ReThink (2022-2026)

NWO

R. Cools, D. Norris, W. Schellekens
Unravelling dopamine's role as gatekeeper of prefrontal cortex (2022-2027)

More information about the individual grants is available at the Erwin L. Hahn Institute website. (hahn-institute.de)

Selected Publications

Abbasi-Rad S, Norris DG. Adiabatic null passage for on-resonance magnetization transfer preparation. *Magn Reson Med.* DOI: 10.1002/mrm.29835

Bastgen T, Evers J, Oedekoven C, Weide C, Herzog L, Ashton N, Zetterberg H, Blennow K, Albus A, Vidovic N, Kraff O, Deuschl C, Dodel R, Ross JA. Repetitive head injuries in German American football players do not change blood-based biomarker candidates for CTE during a single season. *Neurol Res Pract.* DOI: 10.1186/s42466-024-00307-6

Batsikadze G, Pakusch J, Klein M, Ernst TM, Thieme A, Nicksirat SA, Steiner KM, Nio E, Genc E, Maderwald S, Deuschl C, Merz CJ, Quick HH, Mark MD, Timmann D. Mild Deficits in Fear Learning: Evidence from Humans and Mice with Cerebellar Cortical Degeneration. *eNeuro.* DOI: 10.1523/ENEURO.0365-23.2023

Brand M, Antons S, Bothe B, Demetrovics Z, Fineberg NA, Jimenez-Murcia S, King DL, Mestre-Bach G, Moretta T, Müller A, Wegmann E, Potenza MN. Current Advances in Behavioral Addictions: From Fundamental Research to Clinical Practice. *Am J Psychiatry.* DOI: 10.1176/appi.ajp.20240092

Brandtner A, Müller SM, Behrens S, Oelker A, Brand M. Permissive beliefs in the context of gaming, online shopping and alcohol drinking - Systematic development of a self-report measure. *Compr Psychiatry.* DOI: 10.1016/j.comppsych.2024.152507

Brunheim S, Gratz M, Johst S, Bitz AK, Fiedler TM, Ladd ME, Quick HH, Orzada S. Erratum to: Fast and accurate multi-channel B1+ mapping based on the TIAMO technique for 7 Tesla UHF body MRI. *Magn Reson Med.* DOI: 10.1002/mrm.29868

de Alba Alvarez I, Arbabi A, Khlebnikov V, Marques JP, Norris DG. Single-shot frequency offset measurement with HASTE using the selective parity approach. *Sci Rep.* DOI: 10.1038/s41598-024-60275-4

Fahr J, Kraff O, Deuschl C, Dodel R. Concussion in Female Athletes of Contact Sports: A Scoping Review. *Orthop J Sport Med.* DOI: 10.1177/23259671241276447

Fiedler TM, Ladd ME, Orzada S. Local and whole-body SAR in UHF body imaging: Implications for SAR matrix compression. *Magn Reson Med.* DOI: 10.1002/mrm.30306

Güntürkün O, Pusch R, Rose J. Why birds are smart. *Trends Cogn. Sci.* DOI: 10.1016/j.tics.2023.11.002

Kincses B, Forkmann K, Schlitt F, Jan Pawlik R, Schmidt K, Timmann D, Elsenbruch S, Wiech K, Bingel U, Spisak T. An externally validated resting-state brain connectivity signature of pain-related learning. *Commun Biol.* DOI: 10.1038/s42003-024-06574-y

Ladd ME, Quick HH, Scheffler K, Speck O. Design requirements for human UHF magnets from the perspective of MRI scientists. *Superconductor Science and Technology.* DOI: 10.1088/1361-6668/ad7d3f

Liebherr M, Brandter A, Brand M, Tang YY. Digital mindfulness training and cognitive functions: A preregistered systematic review of neuropsychological findings. *Ann N Y Acad Sci.* DOI: 10.1111/nyas.15095

Lindemann ME, Gratz M, Grafe H, Jannusch K, Umutlu L, Quick HH. Systematic evaluation of human soft tissue attenuation correction in whole-body PET/MR: Implications from PET/CT for optimization of MR-based AC in patients with normal lung tissue. *Med Phys.* DOI: 10.1002/mp.16863

Maatman IT, Schulz J, Ypma S, Block KT, Schmitter S, Hermans JJ, Smit EJ, Maas MC, Scheenen TWJ. Free-breathing high-resolution respiratory-gated radial stack-of-stars magnetic resonance imaging of the upper abdomen at 7 T. *NMR Biomed.* DOI: 10.1002/nbm.5180

Nio E, Pais Pereira P, Diekmann N, Petrenko M, Doubliez A, Ernst TM, Batsikadze G, Maderwald S, Deuschl C, Üngör M, Cheng A, Merz CJ, Quick HH, Timmann D. Human cerebellum and ventral tegmental area interact during extinction of learned fear. *bioRxiv.* DOI: 10.1101/2024.11.06.622063

Öz G, Cocozza S, Henry PG, Lenglet C, Deistung A, Faber J, Schwarz AJ, Timmann D, Van Dijk KRA, Harding IH; AGI Working Group on MRI Biomarkers. MR Imaging in Ataxias: Consensus Recommendations by the Ataxia Global Initiative Working Group on MRI Biomarkers. *Cerebellum.* DOI: 10.1007/s12311-023-01572-y

Orzada S, Fiedler TM, Ladd ME. Hybrid algorithms for SAR matrix compression and the impact of post-processing on SAR calculation complexity. *Magn Reson Med.* DOI: 10.1002/mrm.30235

Strunk D, Sinnecker T, Kleffner I, Doerr J, Ringelstein M, Gross CC, Deuschl C, Maderwald S, Quick HH, Yamac E, Wrede KH, Kraemer M. Central intra-lesional iron deposits as a possible novel imaging marker at 7 Tesla MRI in Susac Syndrome - an exploratory study. *BMC Med Imaging.* DOI: 10.1186/s12880-023-01171-7

Tenbergen CJA, Fortuin AS, van Asten JJA, Veltien A, Philips BWJ, Hambrock T, Orzada S, Quick HH, Barentsz JO, Maas MC, Scheenen TWJ. The potential of iron oxide nanoparticle-enhanced MRI at 7T compared with 3T for detecting small suspicious lymph nodes in patients with prostate cancer. *Invest Radiol.* DOI: 10.1097/RLI.0000000000001056

Thomas TA, Schmid AM, Kessling A, Wolf OT, Brand M, Steins-Loeber S, Müller A. Stress and compulsive buying-shopping disorder: A scoping review. *Compr Psychiatry.* DOI: 10.1016/j.comppsych.2024.152482

Hall of Fame

Dissertations/Masters & Bachelor Theses

Deuermeier, Niklas. Vergleich von Metallartefakt-Reduktionssequenzen in der Ultra-Hochfeld Magnetresonanztomographie bei 7 Tesla: Hardware-Adaption, Sicherheit und Bildqualitätsanalyse. (Masters Thesis)

Neil Knöbel. Comparison of I-MARS and MSL Antenna Designs for 7T MR. (Masters Thesis)

Mai, Denis. Simulation einer 8-Kanal Meander Stripline Sendespule zur kombinierten Kopf- und Nackenbildgebung bei 7 Tesla MR. (Masters Thesis)

Spronk, Tobias. Simulations and measurements of implant-induced artifacts in magnetic resonance imaging. (PhD Thesis)

Stevens, Carolin. Konstruktion und Charakterisierung der Sende- und Empfangseigenschaften eines Coaxial-End-Dipol Arrays für 7T MRT. (Bachelor Thesis)

Selected Awards

Ulrike Bingel. Focus Magazine Top Physicians

Ulrike Bingel. Stern Magazine Top Physicians

Matthias Brand. Highly Cited Researchers 2024. (Clarivate)

Matthias Brand. Great Achievement Award (Society for the Study of Behavioral Addictions)

Onur Güntürkün. Member of the scientific advisory board of the Hertie Foundation

Mark Ladd. Glocker Medal (German Society for Medical Physics)

Harald H. Quick. ISMRM Safety Committee

Dagmar Timman. DGKN's Großer Forschungspreis 2024 (Deutsche Gesellschaft für Klinische Neurophysiologie und Funktionelle Bildgebung)

Dagmar Timmann. Member of the DFG Fachkollegium 2.23 Neurowissenschaften

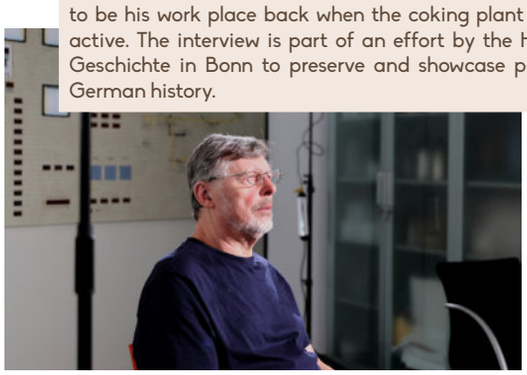
Glimpses of 2024

A lovely occasion: The rectorates of the Radboud University in Nijmegen and the University of Duisburg-Essen, as well as the administrative board of the ELH.

Sad goodbye: Viktor Pfaffenrot invites everyone to a barbecue on his last day at the ELH. The event includes a small exhibition of his bonsai collection. We wish you all the best, Viktor!

Kai Gehring and Mark Zietan visit the ELH.

Martin Ackermann remembers when the control room used to be his work place back when the coking plant was still active. The interview is part of an effort by the Haus der Geschichte in Bonn to preserve and showcase post-1945 German history.



In 2024, sheep can be seen grazing all over the grounds of the Heritage Site. This is due to an effort by the Stiftung Zollverein to manage the huge area more sustainably.

Girl Scouts! Initiated by Annika Verheyen, the ELH receives a visit by an inquisitive group of girl scouts.

Have yourself a merry little Christmas: The ELH Christmas party is a beloved and cozy tradition.

The 2024 company outing takes the ELH to karting.

Picture Credits

Title Page: "**Beyond Boundaries: 150 Years of ELH**" (Marcel Gratz)

"Embark on a journey into the future of MRI in 2156, shaped by 150 years of ELH innovation. The now accessible VertiFlex MRI revolutionizes the scanning encounter through its integrated platforms, elevating the scanning process to an unprecedented level of simplicity - effortlessly achieved with a step into the system." (ARTifact 2023 submission)

Bingellab
Page: 16

Marcel Gratz/ELH
Pages: 4, 17, 26, 35-37

Quincy van Houtum/ELH:
Page: 35

Stefanie Zurek/ELH
Pages: 26-29, 35

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Pages: 6, 8, 12, 14, 18, 20, 24, 25

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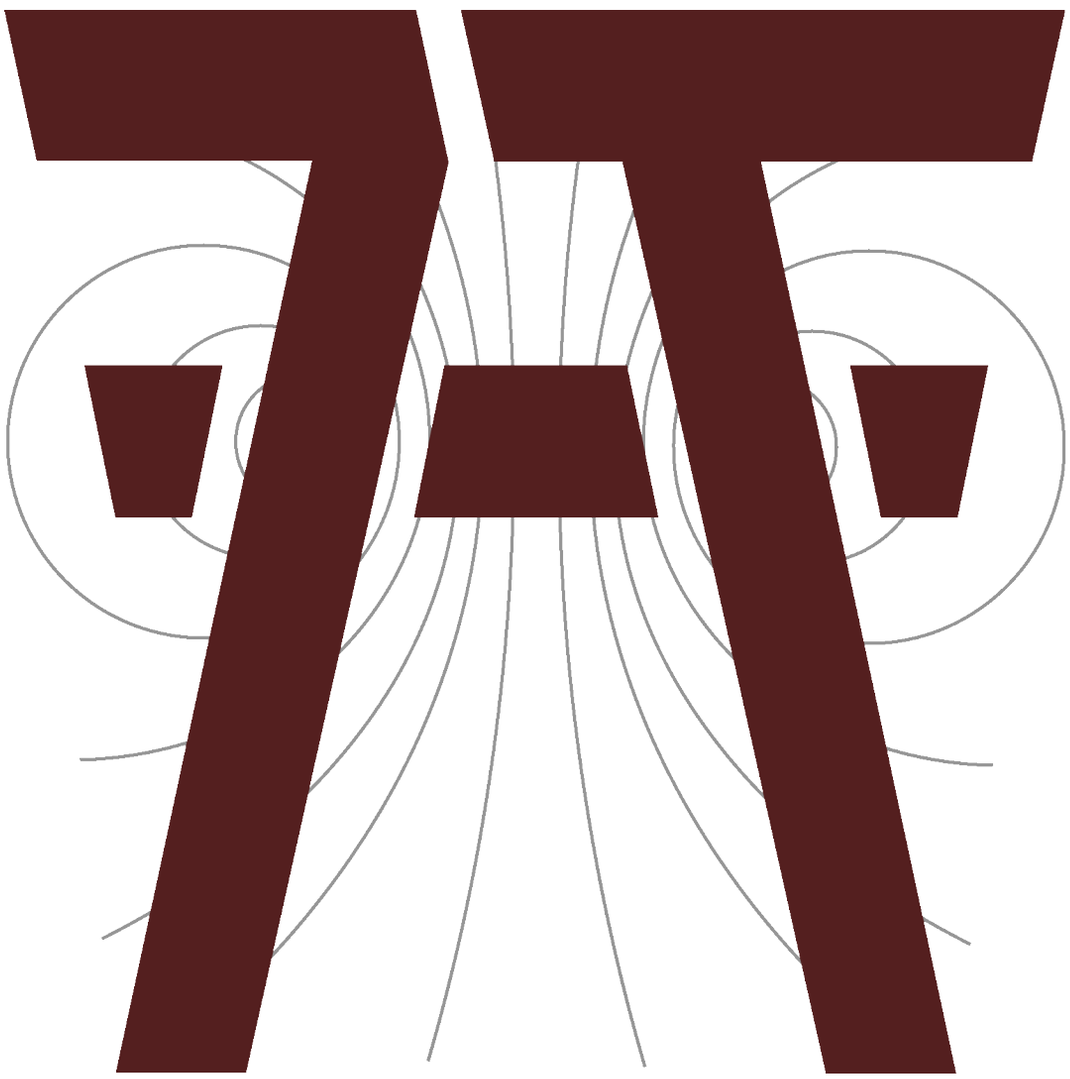

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