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# Dr. Markus Dahlem

## Personal information

Date of birth 30. March 1968  
Place of birth Moers, Germany  
Nationality German  
Marital status Married, one child

## Present affiliation

Institut für Theoretische Physik  
Technische Universität Berlin  
Hardenbergstr. 36  
10623 Berlin, Germany

## Education

- Oct 03 – Sep 04 **Entrepreneurship**, 1-year course, Otto-von-Guericke University Magdeburg, Germany.  
Focus on technology transfer between basic research and industry (Prof. Dr. Matthias Raith).
- May 95 – May 00 **Physics**, *Dr. rer. nat. (summa cum laude) Faculty award for outstanding dissertation*, Otto-von-Guericke University Magdeburg, Germany.  
Thesis title: *Modellierung Gesichtsfeldbezogener Phänomene bei der Migräne-Aura auf der Grundlage von Erregungswellen in der primären Sehrinde*. Thesis adviser: Prof. S. C. Müller (final examination in May 2001).  
· Development of a mathematical framework based on cortical feature maps and nonlinear wave dynamics explaining pattern forming visual hallucinations as neurological symptoms.
- Jan 95 – Mar 95 **Mathematical Biology**, *visiting graduate student*, University of Utah, USA.  
Winter quarter for the Special Year in Mathematical Biology, Modeling in Physiology and Cell Biology (<http://www.math.utah.edu/~dallon/winter.html>).
- Oct 89 – Oct 94 **Physics**, *Diplom*, Georg-August University Göttingen, Germany.  
Thesis title: *Untersuchung der Dynamik von Spiralzentren in retinaler Spreading Depression*.  
· Imaging intrinsic optical signals of rotating spiral wave patterns in retinal spreading depression. (Field: Biomedical engineering)
- Oct 88 – Sep 89 **Physics**, *Vordiplom*, RWTH Aachen, Germany.

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## Research

- since Jan 07 **Research associate**, *Nonlinear Dynamics and Control in Neural Systems*, Institut für Theoretische Physik (Prof. E. Schöll), Technische Universität Berlin, Germany.  
Main research field:  
Design of novel therapeutic approaches based on chaos control for migraine, stroke, and epilepsy.
- Oct 02 – Dec 06 **Research associate**, *Laboratory of Computational Neurology*, Clinic for Neurology II, 4 years 3 months  
Medical Faculty, Otto-von-Guericke University (OvGU) Magdeburg,  
Co-affiliation: Leibniz Institute for Neurobiology (IfN), Member of Special Lab: *Non-Invasive Brain Imaging*, Magdeburg, Germany.  
Main research field: Modeling migraine with aura.
- Sep 00 – Sep 02 **Research associate**, *Computational Neuroscience (Prof. F. Wörgötter)*, Department of Psychology, Stirling University, Scotland, UK. 2 years 1 month  
Main research field: Robotics & bio-inspired algorithms: Depth cues from optic flow.
- May 97 – Aug 00 **Research assistant & Graduate fellowship**, *Biophysics (Prof. S. C. Müller)*, Otto- 3 years 1 month  
von-Guericke University Magdeburg, Germany.  
Main research on doctoral thesis: Pattern forming visual hallucinations during migraine with aura.
- intermittent* **Research assistant**, *Visual development and plasticity (PD Dr. S. Löwel)*, Leibniz 3 months  
Apr 99 – Jun 99 Institute for Neurobiology, Magdeburg, Germany.  
Main research task: Data analysis of optical imaging of cortical maps in area 17 of cats.
- Nov 96 – Apr 97 **Visiting scholar**, *Department of Biomedical Engineering (Prof. V. M. de Lima)*, Uni- 6 months  
versity UNICAMP, Campinas, Brazil.  
Main research task: Recording intrinsic optical signals in retinal spreading depression.
- Apr 92 – Jul 96 **Student assistant & Research assistant**, *Pattern Formation in Chemical Systems (PD 4 years 1 month*  
*Dr. S. C. Müller)*, Max Planck Institute for Molecular Physiology, Dortmund, Germany.  
Main research field: Pattern formation in retinal spreading depression.
- intermittent* **Visiting scholar**, *Department of Biomedical Engineering (Prof. V. M. de Lima)*, Uni- 3 months  
Feb 95 – Apr 95 versity UNICAMP, Campinas, Brazil.  
Main research task: Build experimental set-up to image intrinsic optical signals in brain tissue.
- Oct 91 – Mar 92 **Student assistant**, *Neurobiology (Prof. O. D. Creutzfeldt)*, Max Planck Institute for 6 months  
Biophysical Chemistry, Göttingen, Germany.  
Main research task: Modeling and data analysis of cortical spreading depression waves with PD Dr. K. Kaufmann.

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## Collaboration

### Berlin

- Prof. Dr. Jens Dreier (*Neurology, Charité, Berlin*)  
Prof. Dr. Harald Engel (*ITP, TU Berlin, Berlin*)  
Prof. Dr. Jürgen Kurths (*Department of theoretical Physics, HU Berlin*)  
Prof. Dr. Niko Busch (*Medical Psychology, Berlin School of Mind and Brain*)

### National

- Prof. Dr. Rudolf Graf (*MPI for Neurological Research, Köln*)

Dr. med. Klaus Podoll (*Clinic for Psychiatry und Psychotherapy, University Hospital Aachen*)  
Prof. Dr. Wolfgang Hanke (*Physiology, University Hohenheim*)

#### International

Prof. Anthony Strong MD (*Kings College Hospital, London, UK*)  
Prof. Nouchine Hadjikhani MD (*Harvard Medical School, USA and EPFL, Swiss*)  
Prof. Steve J. Schiff PhD, MD (*Penn State Center for Neural Engineering, USA*)  
Prof. Nathalia Peixoto PhD (*Neural Engineering Lab, George Mason University, USA*)  
Prof. Vera M. Fernandes de Lima MD (*UFSJ Divinopolis, Brazil*)  
Prof. José W. M. Bassan PhD (*Department of Biomedical Engineering, UNICAMP, Campinas, Brazil*)

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## Teaching

- SS 07,08 **Lecturer**, *Nonlinear Dynamics in Neural Systems*, elective course, Technische Universität Berlin, Germany.  
Part of graduate program Physics in cooperation with Prof. E. Schöll.
- WS 03–05 **Lecturer**, *Neuromodeling and Neural Networks*, elective course, Otto-von-Guericke University Magdeburg, Germany.  
Part of graduate program Neurobiology, Neurosciences, and Physics in cooperation with PD Dr. R. König.
- SS 03–06 **Teaching assistant**, *Developing Bioinformatics Computer Skills*, practical course (2-double period lessons per semester of multi-instructor lecture), Otto-von-Guericke University Magdeburg, Germany.  
Part of graduate program Neurobiology and Neurosciences.
- SS 03–05 **Teaching assistant**, *Headache Pain & Visual Hallucinations*, Biological Psychology II (1-double period lesson per semester), Otto-von-Guericke University Magdeburg, Germany.  
Part of undergraduate program “Psychology” in cooperation with Prof. C. S. Herrmann.
- SS 97–99 **Teaching assistant**, *Biophysics*, elective course, Otto-von-Guericke University Magdeburg, Germany.  
Part of graduate program Physics.

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## Mentoring

### **Mentoring undergraduate students.**

*Computer Science*: Jan Tusch (Diplom) OvGU Magdeburg, 2004  
*Biological Psychology*: Kathrin Ohla (Diplom) OvGU Magdeburg, 2004  
*Physics*: Felix Schneider, Mathias Kehrt, Gerald Hiller, Hannelore Frank, Sebastian Brandstetter, Judith Lehnert, Fredericke Kerr (Diplom) TU Berlin, 2007-ongoing

### **Mentoring graduate students.**

*Biology*: Yuliya Ismailova (Dr rer nat) OvGU Magdeburg, 1998-2000  
*Physics*: Philipp Hövel (Dr rer nat) TU Berlin 2007-2009  
*Biomedical Engineering*: Gerson Florence (PhD), UNICAMP, Brazil, 2007-2008  
*Mathematics*: Jan-Philipp Pade (Dr rer nat) TU Berlin/Charité, 2008-ongoing

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## Service

### Editorial positions

- Since Apr 09 **Associate Editor**, *The Journal of Nano Systems and Technology (JNST)*.  
Since Aug 00 **Co-Editor-in-Chief**, *Migraine Aura Foundation*.  
Web site with over 380 pages, including:  
Over 230 case reports on migraine with aura.  
Over 300 images and animations of migraine aura.  
Jul 02 – Oct 04 **Editor**, *Open Directory Project*, Topic: Migraine.

### Referee for journals

Experimental Brain Research, Chaos, International Journal of Bifurcation and Chaos, The Journal Clinical Neurophysiology, Nature Medicine, International Journal of Computer Mathematics, PLoS ONE, Vision Research, European Journal of Neuroscience, Journal of Biomedical Engineering, Biological Cybernetics, Journal of Cerebral Blood Flow & Metabolism, Journal of Biological Systems, Brain, New Journal of Physics, Journal of Theoretical Biology, The International Journal of Neuroscience.

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## Conference organization

- 20-23 Sep 2010 **Scientific co-organizer**, *International Migraine Symposium*, Bari, Italy, together with Prof. M. de Tommaso and Dr. S. Stramaglia, University of Bari, Italy.  
18-23 Jul 2009 **Scientific organizer**, *Modeling Migraine: From Nonlinear Dynamics to Clinical Neurology*, CNS workshop at the 18<sup>th</sup> Annual Computational Neuroscience Meeting, CNS 2009, Berlin, together with Dr. S. Stramaglia, University of Bari, Italy.  
9 Jan 09 **Scientific organizer**, *Non-local neuronal connectivity, wave control and migraine modelling*, Workshop of Mathematical Neuroscience Network: MNN, UK, together with Prof. S. Coombes.  
9-11 June 08 **Programme committee**, *Net-Works, 2<sup>nd</sup> Meeting on topics in complex networks in cooperation with the Society for Industrial and Applied Mathematics (SIAM)*, Pamplona.  
9-11 Sep 07 **Programme committee**, *Net-Works, Meeting on topics in complex networks in cooperation with the Society for Industrial and Applied Mathematics (SIAM)*, Madrid.

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## Memberships

Neurowissenschaftliche Gesellschaft NWG  
Deutsche Physikalische Gesellschaft DPG  
Deutscher Hochschulverband DHV

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## Honors and awards

- 2009 **Paper selection**, *American Institute of Physics and the American Physical Society*.  
"Schneider et al.: *Control of traveling waves in excitable media by nonlocal coupling and time-delayed feedback.*" *Chaos* **19**, 015110 (2009).
- 2008 **Paper selection**, *American Institute of Physics and the American Physical Society*.  
"Dahlem et al.: *Failure of feedback as a putative common mechanism of spreading depolarizations in migraine and stroke*" *Chaos* **18**, 026110 (2008).
- 2005 **Nomination**, *international media art award for science and art*, together with Dr. med. Klaus Podoll, University Hospital Aachen.  
"Mental images. From the pictures of our imagination to brain research" jointly organised by Südwestrundfunk Baden-Baden (SWR) and ZKM | Center for Art and Media Karlsruhe in cooperation with the Swiss television station SF, DRS and ARTE.
- 2001 **Faculty award**, *Faculty of Natural Sciences, OVGU Magdeburg*, for outstanding dissertation.
- 2001 **Silver medal of honor**, *Gesellschaft der Freunde und Förderer der Otto-von-Guericke University*.

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## Funding

- Jul 10 – Jun 14 **BMBF (German Federal Ministry of Education and Research)**, *Teilprojekt (B2) Bernstein Centre for Computational Neuroscience, Spreading Depolarizations in Stroke, Migraine, and Epilepsy: Theory and Experiment*, (270 000 Euro for four years).  
PIs: M. A. Dahlem, J.P. Dreier, E. Schöll
- Jan 10 – Dec 11 **DAAD, Personnel Exchange Programme (Programme des Projektbezogenen Personenaustauschs, PPP)**, "*Direct current-feedback control of spreading depolarizations in horizontal slices of occipital cortex.*", (6 000 Euro travel grants for two years).  
PIs: M. A. Dahlem, E. Schöll, S. Schiff (Penn State Center for Neural Engineering, USA)
- Oct 09 – Sep 12 **Research Training Group 1558, German Research Foundation (DFG)**, *Nonequilibrium Collective Dynamics in Condensed Matter and Biological Systems*, Project: "Non-linear excitation waves in neural systems", One PhD position for three years. (25 000 Euro/year).  
PIs: H. Engel, E. Schöll, M. A. Dahlem
- Jul 04 – Mar 09 **Individual Research Grant (Sachbeihilfe)**, *German Research Foundation (DFG)*.  
Two research positions (total of 60 000 Euro/year) for two years.  
20 800 Euro for scientific instrumentation, consumables, travel, and miscellaneous.
- Jan 99 – Aug 00 **Graduate fellowship**, *Saxony-Anhalt (Promotionsstipendium der Graduiertenförderung des Landes Sachsen-Anhalt)*.
- Apr 99 **Travel scholarship**, *German Neuroscience Society*.
- Feb 95 – Apr 95 **DAAD/CAPES scholarship**, *Travel research grant for doctoral candidates*, Brazil.

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## Scholarly activity

### Peer reviewed articles

- [25] S. Brandstetter, **M. A. Dahlem**, and E. Schöll: Interplay of time-delayed feedback control and temporally correlated noise in excitable systems, *Phil. Trans. Roy. Soc. London*, *in press* (2009)
- [24] **M. A. Dahlem**, R. Graf, A. J. Strong, J. P. Dreier, Y. A. Dahlem, M. Sieber, W. Hanke, K. Podoll, and E. Schöll: Two-dimensional wave patterns of spreading depolarization: retracting, re-entrant, and stationary waves, *Physica D*, *in press* (2009).
- [23] P. Hövel, **M. A. Dahlem**, and E. Schöll: Control of synchronisation in coupled neural systems by time-delayed feedback: *Int. J. Bifur. Chaos*, *in press* (2009).
- [22] **M. A. Dahlem** and N. Hadjikhani: Migraine aura: retracting particle-like waves in weakly susceptible cortex: *PLoS ONE* **4**, e5007 (2009).
- [21] F. M. Schneider, E. Schöll, and **M. A. Dahlem**: Control of traveling waves in excitable media by nonlocal coupling and time-delayed feedback. *Chaos* **19**, 015110 (2009). APS/AIP selected paper *Virtual Journal of Biological Physics Research* March 2009. (IF 2.188)
- [20] G. Florence, **M. A. Dahlem**, A. G. Almeida, J. W. M. Bassani, J. Kurths, The role of extracellular potassium dynamics in the different stages of ictal bursting and spreading depression: a computational study: *J. Theo. Biol.* **258** 219-228, (2009). (IF 2.323)
- [19] M. Kehrt, P Hövel, V Flunkert, **M. A. Dahlem**, P. Rodin, and E. Schöll: Stabilization of complex spatio-temporal dynamics near a subcritical Hopf bifurcation by time-delayed feedback, *Eur. Phys. J. B* **68**, 557-565 (2009).
- [18] E. Schöll, G. Hiller, P. Hövel, and **M. A. Dahlem**: Time-delayed feedback in neurosystems, *Phil. Trans. Roy. Soc. London* **367**, 1079 (2009). (IF 1.520)
- [17] **M. A. Dahlem**, G. Hiller, A. Panchuk, and E. Schöll: Dynamics of delay-coupled excitable neural systems, *Int. J. Bifur. Chaos* **19** 745-753 (2009). (IF 0.910)
- [16] **M. A. Dahlem**, F. M. Schneider, and E. Schöll: Failure of feedback as a putative common mechanism of spreading depolarizations in migraine and stroke, *Chaos* **18**, 026110 (2008). APS/AIP selected paper *Virtual Journal of Biological Physics Research* July 2008 (IF 2.188)
- [15] **M. A. Dahlem**, F. M. Schneider, and E. Schöll: Efficient control of transient wave forms to prevent spreading depolarizations, *J. Theo. Biol.* **251**, 202 (2008). (IF 2.323)
- [14] P. Hövel, **M. A. Dahlem**, and E. Schöll: Synchronization of noise-induced oscillations by time-delayed feedback, *Noise and Fluctuations* **922**, 595-598, (2007).
- [13] K. Ohla, N. A. Busch, **M. A. Dahlem**, and C. S. Herrmann: Circles are different: the perception of Glass patterns modulates early event-related potentials, *Vision Res.* **45**, 2668 (2005). (IF 2.027)

- [12] **M. A. Dahlem** and S. C. Müller: Reaction-diffusion waves in neuronal tissue and the window of cortical excitability, *Ann. Phys.* **13**, 442 (2004). (IF 3.006)
- [11] **M. A. Dahlem** and E. P. Chronicle: A computational perspective on migraine aura, *Prog. Neurobiol.* **74**, 351 (2004). (IF 11.933)
- [10] Y. A. Dahlem, **M. A. Dahlem**, T. Mair, K. Braun, and S. C. Müller: Extra-cellular potassium alters frequency and profile of retinal spreading depression waves, *Exp. Brain Res.* **152**, 221 (2003). (IF 2.302)
- [9] **M. A. Dahlem** and S. C. Müller: Migraine aura dynamics after reverse retinotopic mapping of weak excitation waves in the primary visual cortex, *Biol. Cybern.* **88**, 419 (2003). (IF 1.933)
- [8] **M. A. Dahlem** and F. Wörgötter: *Rotation-invariant optical flow by gaze-dependent retino-cortical mapping*, *Lect. Notes Comput. Sc.* **2525**, 137 (2002).
- [7] Y. A. Ismailova, **M. A. Dahlem**, T. Mair: Effect of potassium ions on spontaneous spreading depression waves characteristics, *J. Mol. Med.* **78**, 7 (2000). (IF 4.820)
- [6] **M. A. Dahlem** and S. C. Müller: Image processing techniques applied to excitation waves in the chicken retina, *Methods* **21**, 317 (2000). (IF 3.622)
- [5] **M. A. Dahlem**, R. Engelmann, S. Löwel, and S. C. Müller: Does the migraine aura reflect cortical organization, *Eur. J. Neurosci.* **12**, 767 (2000). (IF 3.872)
- [4] **M. A. Dahlem** and S. C. Müller: Image processing techniques to analyse traveling waves, *Forma* **13**, 375 (1999).
- [3] **M. A. Dahlem** and S. C. Müller: Self-induced splitting of spiral-shaped spreading depression waves in chicken retina, *Exp. Brain Res.* **115**, 319 (1997). (IF 2.302)
- [2] S. Brand, **M. A. Dahlem**, V. M. F. de Lima, S. C. Müller, and W. Hanke: Dispersion relation of spreading depression waves in the chicken retina, *Int. J. Bifurc. Chaos* **7**, 1359 (1997). (IF 1.014)
- [1] M. K. Ram Reddy, **M. A. Dahlem**, V. S. Zykov, and S. C. Müller: The effect of an illumination jump on wave propagation in the Ru-catalysed Belousov-Zhabotinsky reaction., *Chem. Phys. Lett.* **236**, 111 (1995). (IF 2.438)

#### Book chapters

- E. Schöll, P. Hövel, and **M. A. Dahlem**: Time-delayed feedback control - from nano to neuro, in *Complex Time-Delay Systems*, edited by F. M. Atay (in press) (Springer, 2009).
- M. A. Dahlem**, T. Mair, and S. C. Müller: Spatio-temporal aspects of a dynamical disease: Waves of spreading depression. In: Deutsch, A.; Falcke, M.; Howard, J.; Zimmermann W. (eds.) *Function and Regulation of Cellular Systems: Experiments and Models*. Birkhäuser, Basel. 2002

## Selected proceedings (out of 26)

P. Hövel, S. A. Shah, **M. A. Dahlem**, and E. Schöll: Feedback-dependent control of stochastic synchronization in coupled neural systems, *World Scientific conference proceedings, in press* (2009).

A. Panchuk, **M. A. Dahlem**, and E. Schöll: *Regular spiking in FitzHugh-Nagumo systems coupled through linear delay*, Proc. NDES 09 177 (2009).

**M. A. Dahlem**, F. M. Schneider, A. Panchuk, G. Hiller, and E. Schöll: *Control of sub-excitable waves in neural networks by nonlocal coupling*, Proceedings of the Workshop Net-Works 2007, Aranjuez, 10–11 September, p. 39-54, 2007 (arXiv:0707.4619).

**M. A. Dahlem**, J. Tusch: What is the geometric structure of probability density models of canonical training sets for curved Kohonen layers?, Proceedings of the Second International Symposium on Information Geometry and its Applications, p. 208-214, 2005.

**M. A. Dahlem**, and F. Wörgötter: Dynamic retino-cortical mapping. In Würtz, R. and Lappe, M. (eds) *Dynamic Perception*, Workshop of GI section 1.0.4. “Image Understanding” and the European Networks MUHCI and Ecovision, IOS Press, p. 41-46, 2002

**M. A. Dahlem**, and E. P. Chronicle: Migraine aura: New insights from computational neuroscience. In: *Headache and migraine*, Proceedings of the Anglo-Dutch Migraine Association, Utrecht, p. 21-33 2001.

J. Tusch and **M. A. Dahlem**: Retino-cortical magnification on naturally curved human cortical surfaces, in Proceedings of the 6th Göttingen Conference of the German Neuroscience Society (2005), p. 457.

J. Tusch and **M. A. Dahlem**: What is the geometric structure of probability density models of canonical training sets for curved kohonen layers?, in Proceedings of the 2nd International Symposium on Information Geometry and its Applications (2005), pp. 208–214.

## Books

**M. A. Dahlem** (Editor): *Modeling Migraine: From Nonlinear Dynamics to Clinical Neurology*, reviewed by Neuroscience Springer (under contract)

**M. A. Dahlem**, Heinz G. Schuster, Eckehard Schöll (Eds): *Chaos Control und Neurology*, proposal for Reviews of Nonlinear Dynamics and Complexity, Wiley-VCH, Berlin (proposal)

## Under review or invited

**M. A. Dahlem**: Models of Spreading Depression. *Scholarpedia* (invited by Dr. Eugene M. Izhikevich, Editor-in-Chief of Scholarpedia, the peer-reviewed open-access encyclopedia)

**M. A. Dahlem** and J. Tusch: *Cortical magnification tensor: A quantitative measure of the significance of sulcal landmarks for functional entities*: PLoS Computational Biology (under revision).



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## Selected talks (last three years)

- 24 Mar 10 **Fachverband Dynamik und Statistische Physik, DPG-Fruehjahrstagung**, invited topical talk, Prof. Holger Kantz, Sprecher des Fachverbandes.  
*The Physics of Migraine*
- 18 Dec 09 **Central Institute for Medical Engineering, Technical University of Munich**, invited talk, Selection Committee for Chair in "Minimal-invasive therapeutische Implantate" .  
*Control of pathological pattern in the cortex*
- 15 Dec 09 **Seminar in Theoretical Physics, University of Münster**, invited colloquium, Prof. Rudolf Friedrich.  
*Transient traveling wave segments of characteristic size*
- 04 Dec 09 **Seminar at the Institute of Neuroinformatics, University of Zurich & ETH Zurich**, invited colloquium, Prof. Daniel C. Kiper.  
*Modeling migraine: From nonlinear dynamics to clinical neurology*
- 16 Oct 09 **Symposium, Chicago, USA**, invited talk, SfN Satellite Symposium: Dynamical Neuroscience XVII: Dynamical Disease, Prof. Dennis Glanzman, NIH.  
*Migraine: A dynamical disease*
- 05 Oct 09 **Delayed Complex Systems, Dresden, Germany**, invited Talk on international workshop, Prof. Wolfram Just, London, UK.  
*Delayed feedback in reaction-diffusion systems*
- 17 Sep 09 **Dynamics in Systems Biology, Aberdeen, UK**, invited talk on international conference, Prof. Dr. C. Grebogi, Aberdeen, UK.  
*Migraine: A dynamical disease*
- 08 Sep 09 **Workshop on Delay Differential Equations: From Theory to Applications, Bristol, UK**, invited talk on international workshop, Dr. Yuliya Kyrychko, Bristol, UK.  
*Delayed feedback in reaction-diffusion systems*
- 02 Sep 09 **Dynamics Days Europe 2009, Göttingen, Germany**, invited talk on international workshop, Prof. Dr. Eberhard Bodenschatz.  
*Two-dimensional waves in migraine and stroke*
- 23 Jul 09 **Modeling Migraine, Berlin, Germany**, international workshop on CNS\*09 meeting.  
*Spreading depression wave patterns in two spatial dimensions: A new paradigm*
- 09 Jun 09 **Oberseminar Nonlinear Dynamics, Berlin, Germany**, invited colloquium at Free University Berlin, Prof. Bernold Fiedler.  
*Neurons don't get migraines (neither do Cyborgs)*
- 25 Mar 09 **DPG Spring Meeting, Dresden, Germany**, contributed talk Dynamics and Statistical Physics Division, Session: Reaction-diffusion systems.  
*Controlling the onset of traveling pulses in reaction-diffusion systems by nonlocal feedback*
- 27 Feb 09 **Harz-Seminar, Hahnenklee, Germany**, invited talk at 13<sup>th</sup> seminar "Strukturbildung in Chemie und Biophysik", Prof. E. Bodenschatz, Prof. M. Hauser, Prof. R. Imbühl, Prof. A. S. Mikhailov.  
*Two-dimensional wave patterns of cortical spreading depression: retracting, re-entrant, and standing waves*

- 09 Jan 09 **UK Mathematical Neuroscience Network**, *Nottingham, UK*, Non-local neuronal connectivity, wave control and migraine modelling, Co-organized with Prof. Steve Coombes.  
*Combining volume and synaptic transmission: a mathematical framework to investigate spreading depolarizations*
- 05 Jan 09 **Seminar Statistical Physics and Nonlinear Dynamics**, *Berlin, Germany*, invited colloquium at Humboldt-University, Prof. Lutz Schimansky-Geier.  
*Traveling wave segments in migraine*
- 31 Oct 08 **Seminar at the Centre for Vision Research**, *Toronto, Canada*, invited colloquium at York University, Prof. F. Wilkinson and Prof. H. R. Wilson.  
*Pattern formation in migraine with aura, from mechanism to control*
- 23 Oct 08 **Seminar in the Penn State Center for Neural Engineering**, *State College, USA*, invited colloquium, Prof. S. Schiff.  
*Control of spreading depolarizations in migraine, seizures, and stroke*
- 16 Oct 08 **Seminar in the Neural Engineering Lab**, *Washington, USA*, invited colloquium at the George Mason University, Prof. N. Peixoto.  
*Control of spreading depolarizations waves occurring in migraine and stroke*
- 09 Oct 08 **28<sup>th</sup> Dynamics Days Berlin-Brandenburg**, *Postdam, Germany*, invited talk at international conference, session organizer: Prof. J. Kurths.  
*Control of traveling waves close to the excitation limit*
- 27 Aug 08 **28<sup>th</sup> Dynamics Days Europe**, *Delft, Netherlands*, contributed talk at annual international conference, session: Formation and Dynamics of Patterns, session organizer: Prof. U. Ebert.  
*Time-delayed feedback control of traveling waves close to the excitation limit*
- 17 Jul 08 **Mathematical Modeling in Neuroscience**, *Kiev, Ukraine*, invited talk at bilateral German-Ukrainian workshop: National Scientific Centre for Medical and Biotechnical Research & Research Center Jülich, Prof. V. Maistrenko, Prof. Y. Maistrenko, Prof. P. A. Tass.  
*Modeling reaction diffusion waves during migraine and stroke*
- 17 Jul 08 **DFG-Forschungszentrum MATHEON**, *Berlin, Germany*, invited seminar Dynamics of Coupled Systems and Applications to Neurodynamics, Dr. S. Yanchuk.  
*Modeling reaction diffusion waves during migraine and stroke*
- 03 Mar 08 **Harz-Seminar**, *Hahnenklee, Germany*, invited talk at 12<sup>th</sup> seminar "Strukturbildung in Chemie und Biophysik", Prof. E. Bodenschatz, Prof. M. Hauser, Prof. R. Imbihl, Prof. A. S. Mikhailov.  
*Feedback control of travelling waves close to the excitation limit*
- 21 Jan 08 **Complex Systems**, *Lavin, Switzerland*, invited talk at international winter workshop on Statistical Physics and Nonlinear Dynamics of Complex Systems, Prof. R. Stoop.  
*Failure of feedback control as a putative common mechanism of spreading depolarizations*
- 20 Nov 07 **Seminar in the Institute of Theoretical Physics and Astrophysics**, *Kiel, Germany*, invited colloquium at the Christian-Albrechts-Universität, Prof. H. G. Schuster.  
*Control of cortical reaction-diffusion patterns during migraine*
- 22 Nov 07 **8<sup>th</sup> Meeting of COSBID**, *Köln, Germany*, invited guest talk at internal COSBID meeting (Cooperative Study on Brain Injury Depolarisations), Prof. R. Graf.  
*Modeling propagation of depolarisations*

- 10 Sep 07 **Net-Works, Madrid, Spain**, invited talk at meeting on topics in Complex Networks in co-operation with the Society for Industrial and Applied Mathematics (SIAM), Prof. R. Criado.  
*Modulation of weakly excitable waves in neural networks*
- 10 Jul 07 **27<sup>th</sup> Dynamics Days Europe, Loughborough, UK**, invited talk at annual international conferences, session: Complex systems in biology, session organizer: Prof. S. Coombes.  
*Suppression of migraine waves by long-range coupling*
- 05 Jun 07 **From Complex Systems Theory to Clinical Neurology, Dresden, Germany**, contributed talk at international workshop, Prof. H. A. Braun, Prof. E. Mosekilde, Prof. F. Moss.  
*Efficient control of transient wave forms to prevent spreading depolarizations*
- 28 Feb 07 **Workshop Membrane Physiology, Augsburg, Germany**, invited talk, Dr. T. Franke.  
*Migraine and Spreading Depression*
- 12 Feb 07 **Harz-Seminar, Hahnenklee, Germany**, invited talk at 11<sup>th</sup> seminar "Strukturbildung in Chemie und Biophysik", Prof. E. Bodenschatz, Prof. M. Hauser, Prof. R. Imbihl, Prof. A. S. Mikhailov.  
*Efficient Neuromodulation of Hyperexcitability to Prevent the Spread of Seizure or Seizure-like Activity*

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## Scientific outreach

**Gray Matters** Blog in SciLogs – The daily storyline of science, developed by Spektrum der Wissenschaft Verlagsgesellschaft mbH, Heidelberg, Germany.

**Graue Substanz** Blog in Scilogs – Tagebücher der Wissenschaft, Blogportal der Spektrum der Wissenschaft Verlagsgesellschaft

**Migraine Aura Foundation web site:** Largest collection of migraine symptoms in the web, since 1999.

**Nonlinear Dynamics group** Founder, The NeuroNetwork, multidimensional professional networking site from Springer

**Preface** K. Podoll and M. A. Dahlem, Preface to: Migraine auras: when the visual world fails, by R. Grossinger Berkeley, Calif.: North Atlantic Books, 2006.

**Psychologie Heute** M. A. Dahlem, *In Hirngewittern*, August 2002, pp. 54-55.

**Video-Material** M. A. Dahlem, In Schuster H. and Gerhardt M. (eds.) *Simulationen des Lebens: Zelluläre Automaten als Modelle des Lebens*, Spektrum Videothek, Spektrum der Wissenschaft 1995, 31 Min.

Upcoming

**Gehirn und Geist** M. A. Dahlem, *Die Physik der Migräne*, invited popular science article (Spektrum Verlag)

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## Selected media resonance

### TV & radio

- 26 Jan 10 **ZDF drehscheibe Deutschland.**
- 12 Jan 10 **Nano 3Sat, Migräne Schwerpunktthema.**
- 12 Aug 09 **MDR Info, Gespräch mit Dr. Markus Dahlem.**
- 22 Jul 09 **SWR2 Impulse, Warum manche Migränekpatienten vor einer Migräneattacke seltsame Blitze und Zickzackmuster sehen. Ellinor Krogmann im Gespräch mit Dr. Markus Dahlem.**  
<http://tinyurl.com/mzqbby>
- 26 Mar 2008 **Deutsche Welle, Forschung, Physik gegen Migräne.**  
<http://tinyurl.com/lnpb7c>
- 29 Feb 2008 **Deutschlandfunk, Forschung Aktuell – Spezialbrille gegen Migräne? Physiker suchen nach den Ursachen der Kopfschmerz-Attacken.**  
<http://www.dradio.de/df/sendungen/forschak/747224/>
- 22 Oct 2005 **3Sat, Denkbilder: Die 50 Besten in 100 Minuten.**

### News papers, journals, and online

- 12 Aug 09 **Berliner Morgenpost, Wie Physiker die Migräne stoppen wollen.**  
<http://tinyurl.com/n4kaqg>
- 12 Aug 09 **Die Welt Kompakt, Lawine im Kopf.**
- 10 Aug 09 **Die Welt, Physiker stoppen fatale Migräne-Lawine im Kopf.**  
<http://tinyurl.com/m4cdoz>
- 7 Jul 09 **Neuro-online, Die Physik der Migräne - Chaostheorie, Genetik oder chemische Musterbildung.**  
<http://tinyurl.com/m9z4kc>
- 29 Mar 2008 **Kölner Stadt-Anzeiger, Zacken im Gehirn – Physiker simulieren die Aura von Migräne-Patienten (article).**
- 12 Mar 2008 **Tages-Anzeiger Zürich, Swiss, Eine spezielle Brille soll gegen Migräne helfen (article).**  
<http://sc.tagesanzeiger.ch/dyn/wissen/medizin/850548.html>
- Feb. 2008 **The New York Times, Migraine - Opinion (blog).**  
<http://migraine.blogs.nytimes.com/>
- 1 Oct 05 **Kunstaspekte, Von den Vorstellungsbildern bis zur Gehirnforschung, Internationaler Medienkunstpreis 2005.**  
<http://tinyurl.com/kpsfzp>

- 6 Mar 2002 **Frankfurter Allgemeine Zeitung**, *Wandernde Wellen bei Migräne (article)*.
- 7 Jan 2001 **Uni-Report**, *Physiker entwickelte mathematisches Modell zur Aura-Simulation Der Migräne-Aura auf der Spur (article)*.  
<http://www.uni-magdeburg.de/unirep/UR2001/januar2001/aura.html>
- 21 Aug 2000 **Magdeburger Volksstimme**, *Geisterbilder helfen bei Erforschung der Migräne*.
- 7 Aug 2000 **Die Welt**, *Wie im Gehirn Geisterbilder entstehen – Wissenschaftler klären Ursachen der Migräne-Aura auf*.  
<http://tinyurl.com/n8xcd5>

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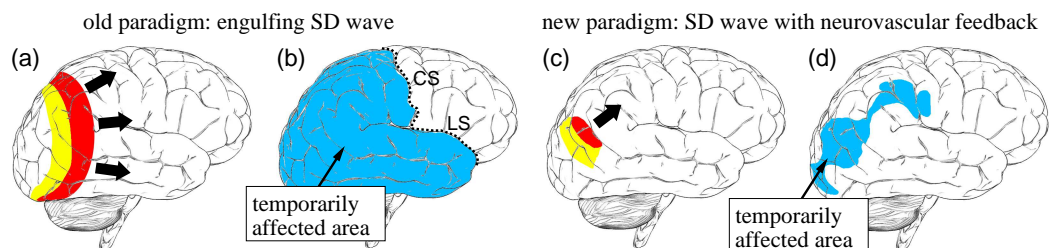
## My scientific achievements

### Main research areas: migraine and stroke

My work has significantly contributed to our understanding of migraine as a dynamical disease. In theoretical studies, I have predicted the generic mechanism of a self-propagating wave of neuronal depolarization causing migraine. In experimental and clinical studies, I have provided solid evidence for this mechanism. Moreover, in the field of stroke research, I investigated the emergence of re-entrant waves that increase the infarct core and thus worsen outcome. A particular focus is on an unifying picture explaining transitions from pathological waves related to migraine to those of stroke.

### Main result: Change in paradigm of full-scale migraine attack

The self-propagating wave is known in the medical literature under the name spreading depression or SD. It is a slowly traveling wave that invades human cortex at a pace of about 3 mm/min. It was long believed that SD can invade a whole cortical hemisphere in a full-scale migraine attack, except for the frontal lobe, i. e., roughly speaking 50% of one hemisphere. My work showed that the invaded regions are much more confined ( $\sim 5\%$ ) and, surprisingly, these regions are not predetermined by heterogeneities in the cellular composition of the cortex (cytoarchitectural borders), but determined by 3 factors: the ignition of SD, anatomical landmarks, and emerging universal patterns.



### Theoretical studies: Bifurcation analysis

I firstly predicted that cortical perturbations that ignite SD all collapse into the same characteristic shape of a particle-like wave independent of the initial localized perturbation. The collapse happens on a comparably fast time scale after which the emerged particle-like SD wave regularly propagates for a longer but again transient time. Eventually the wave vanishes covering at most about 5% of one cortical hemisphere. In the language of nonlinear dynamics, the identified mechanism is called a ghost of a saddle-node bifurcation, a metaphor describing a bottleneck configuration in state space that sucks in all sufficiently largely perturbed cortical states. While, as a consequence, recovery is slowed down, a pattern with universal space and time scales emerges.

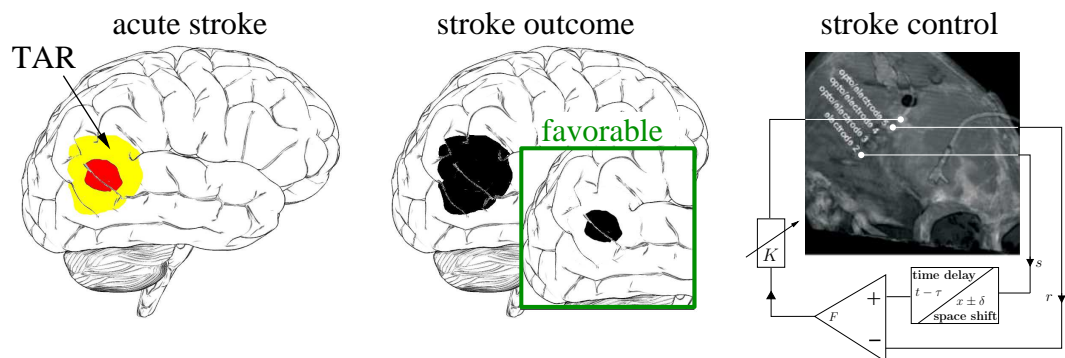
### Experimental verification: fMRI and intrinsic optical signals in retinal SD

I mimicked experimentally in retinal SD the characteristics of this pattern formation process. My next prediction was that the path of such an SD wave depends on cortical folding. The folding is partly individual, allowing us to test this prediction in a clinical study. It was the key in confirming my theory. Using functional magnetic resonance imaging (fMRI) in cooperation with Nouchine Hadjikhani (Harvard Medical School, USA), we measured the retinotopic map between visual cortex and the visual field in a migraine patient who suffered from typical visual field defects during migraine. We showed that his moving visual field defects matched SD propagation in the patient's cortex precisely the way the model predicted. We obtained a spatial resolution unmatched by direct SD measurements in human.

### Towards therapeutic approaches: Neural control

I believe that the proposed bifurcation structure will open up novel therapeutic approaches targeting migraines by changing the bottleneck passage time. Many of my colleagues share this view and encouraged me to continue my research in this particular direction, for example, when I presented my work, e.g., in an invited talk at the traditional NIH symposium *Dynamical Neuroscience XVII* in Chicago, in the group of Michael Moskowitz at Harvard Medical School, and at the international workshop *Modeling Migraine: From Nonlinear Dynamics to Clinical Neurology*, which I organized in Berlin.

I studied the translation towards therapeutic approaches in the last three years. Control methods, in particular time-delayed feedback control (chaos control), were investigated. Several studies resulted from this work, both related to SD propagation but also others considering for example semiconductor systems and coupled excitable neurons in networks with potential relevance to the emergence of seizure activity. The American Institute of Physics and the American Physical Society selected two of my papers on control of SD for the Virtual Journal of Biological Physics Research, and the Deutsche Physikalische Gesellschaft invited me to give on its Frühjahrstagung in 2010 a topical talk on neural control.



### Stroke research: Stimulation techniques to stabilize tissue at risk

In 2006, the first data of SD in humans during the acute phase of stroke was presented by the COSBID group (Cooperative Study on Brain Injury Depolarisations), and the hypothesis formulated that SD worsens stroke outcome. Together with three COSBID members, I began to investigate the emergence of re-entrant SD patterns that cycle around the infarct core. The infarct tissue provides an anatomical block for SD similar to the functional block that I investigated ten years earlier in spiral-shaped retinal SD waves. In a recent study, presented at the BBCI Workshop 2009 - Advances in Neurotechnologies, we proposed ECoG-based short-range recurrent stimulation techniques to stabilize tissue at risk (TAR) of progressive damage (see project **B**, p. 17.)

### A unifying concept: Pattern formation in migraine and stroke

A particular interest of mine is developing a unifying picture that explains transitions from SD wave patterns related to migraine to those of stroke. Over the last 6 years together with Klaus Podoll (UK Aachen), we build a data base of over 200 migraine patients with persistent visual field defects (> 1 year) but without evidence from non-invasive imaging of migrainous infarction. In a recent study done together with members of COSBID, we proposed an unifying mathematical framework of reaction-diffusion systems with nonlocal transmission capabilities for SD in migraine and stroke. With this framework, we investigated the emergence and transitions of patterns observed in clinical data and data from animal models of migraine and stroke.

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## Proposed research program

### **Nonlinear dynamics and control in neurology**

#### **Vision** *From bifurcation to bench and bedside*

My current and proposed research focuses on problems at the interface of applied non-linear science and clinical neurology. I want to understand neurological diseases, such as migraine, stroke, and epilepsies, as emergent transient states close to nonequilibrium phase transitions in the brain. My vision is to design control methods that prevent nucleation of such states and shorten their transient decay time.

#### **Summary**

Growing experimental evidence (cf. pages 14-15) links wave patterns in the human cortex, called cortical spreading depression (SD), to migraine. Similar waves of depolarizations cause the loss of potentially salvageable tissue in stroke. These spreading depolarizations resemble SD and were named "killer waves" in a recent *Nature Medicine*. This drastically highlights the clinical significance of such wave patterns.

For many research groups, SD is the key target in future therapeutic approaches in migraine and stroke. My unique approach to addressing this is that I converge the methodical and technological innovations that have been developed within the last few years in the fields of theoretical physics. These theoretical methods have high potential to contribute to better treatments of migraine and stroke. Having broad expertise in nonlinear science, but also in biomedical engineering, computational neuroscience, and neurology, I will further work on converging technologies in these fields to shape future directions in the area of such *dynamical diseases*.

#### **Short research program**

In Berlin, I have two projects funded and one under review for funding: in the Research Training Group 1558 (project C3) "Nonlinear excitation waves in neural systems"; in the Bernstein Center (project B2) "Depolarizations in Stroke, Migraine, and Epilepsy: Theory and Experiment"; and in a newly planned SFB. These projects will continue and can be partly transferred to my new position. The following projects are two additional ones that I would approach in a new position.

#### **Project A:** *Theoretical concepts of therapeutic rewiring: unlearning migraine*

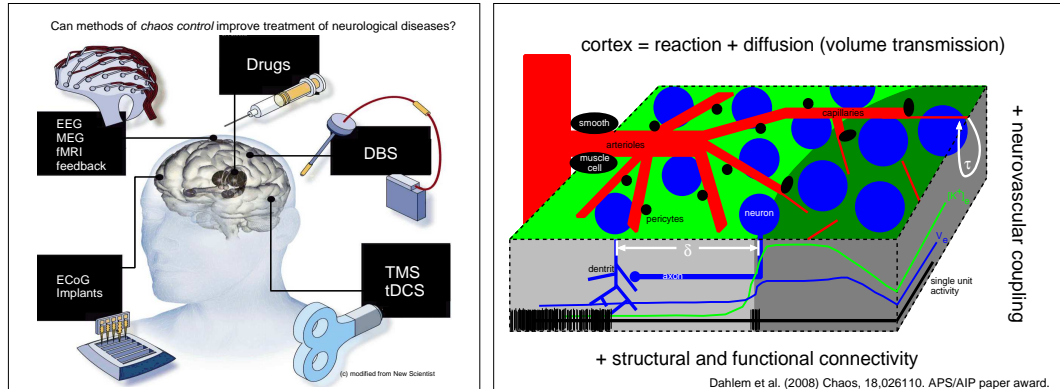
State of the art: Cortical excitability and susceptibility to SD is elevated in migraine patients. Animal data (e.g. Liebetanz et al. *Neurosci. Lett.* 398, 2006) suggests that anodal transcranial direct current stimulation (tDCS)—by increasing cortical excitability—increases the probability of migraine attacks even beyond the end of its application. Techniques adopted from chaos control predict by which means it is possible to reverse the effect and abort an attack using time-delayed feedback control. Moreover, synaptic connectivity can effectively be reshaped by an appropriate modulation of neuronal dynamics to persistently decrease susceptibility to SD (unlearning migraine). My previous work with Hadjikhani (page 14) provided important information for neuronavigation in therapeutic interventions. A theoretical basis of such concepts will now be formulated.

**Milestone 1:** Investigation of anatomical landmarks that are nucleation spots and areas with long decay times of SD propagation due to the curved geometry.

**Milestone 2:** Model-based analysis for transcranial stimulation techniques (rewiring) and prediction of desired coil position at subject's head using fMRI data.



**Clinical objective (long term):** Therapeutic rewiring stimulation in migraine. The application of intelligent transcranial stimulation may reduce frequency of migraine attacks. This can be tested in a randomized, double-blind, sham stimulation controlled investigation to assess the safety and to demonstrate that the method is effective as an add-on therapy in reducing susceptibility to SD.



**Project B:** *Intelligent software for ECoG-based BCI in acutely injured human*

State of the art: Clinical and biomedical engineering groups (see Collaboration) have collected data on SD on multiple time and space scales, from electrocorticography (ECoG) in acutely injured human to laser speckle imaging in animal models of stroke. Based on re-entrant blood flow pattern, it was shown that SD contributes to tissue damage, and we have suggested a mathematical framework for intelligent control strategies.

**Milestone 1:** Bifurcation analysis: adapting stimulation methodologies in Project A (transcranial stimulation) to brain computer interfaces (BCI). Focus on desynchronization of cortical spatio-temporal firing patterns with nonlocal and time-delayed couplings.

**Milestone 2:** Programming and testing a recurrent ECoG-based BCI device with on-demand feedback control.

**Experimental cooperation:** In cooperation with J. P. Dreier (Berlin): Data collection from rat hippocampal slice experiments. In cooperation with S. Schiff (Penn State): Implants with recurrent feedback loops in tangential slices of occipital rat cortex.

**Collaboration**

There are several ongoing collaborations to continue this research direction, including a cooperation with the COSBID (Cooperative Study on Brain Injury Depolarisations) members Jens Dreier (*Charité, Berlin*) and Rudolf Graf (*MPI for Neurological Research, Köln*), and Anthony Strong (Kings College Hospital, London UK). With Nouchine Hadjikhani (*Harvard Medical School and EPFL*), I collaborate to further improve fMRI studies in migraine. Together with Steve Schiff (*Penn State Center for Neural Engineering*) and Nathalia Peixoto (Neural Engineering Lab, George Mason University), I explore electrical stimulation to alter the cellular interactions that make up SD pattern formation in the cortex. Furthermore, together with Klaus Podoll (*University Hospital Aachen*), I manage the Migraine Aura Foundation with a current focus on persistent migraine aura without infarction aka visual snow. At last it should be noted that I will continue to closely collaborate with my current co-workers in Berlin, in particular Eckehard Schöll and Harald Engel (both TU Berlin) and Jürgen Kurths (HU Berlin) on the theoretical foundations of neural systems.