

2 Projects and Results

2.1 Theory and Data Analysis

The main research activities of the Department of Theory and Data Analysis are the analysis and interpretation of the empirical body of knowledge referring to psychophysical relations and extraordinary states of consciousness. In particular, this refers to:

1. Development of theoretical concepts for an integration of empirical results into the body of knowledge of the involved scientific disciplines.
2. Elaboration and application of new techniques of data analysis as well as proposals for future studies.

Until 2009, the research areas in TDA had been structured according to the contributing scientific disciplines: statistics and data analysis, theoretical physics, cognitive neuroscience, and philosophy of science. The increasingly interdisciplinary character of the projects and corresponding scientific approaches entails that such a structure is no longer appropriate. The resulting reorganization of our research areas led to four focal areas, defined by the following topics: 1. Concepts of Mind-Matter Relations, 2. Generalized Quantum Theory, 3. Multistability and Acategoryality, 4. Conceptual and Methodological Issues.

Among these areas, number (4) includes topics whose clarification or elaboration is necessary to move forward in the other areas of research. As a rule, this concerns mostly questions of the philosophy of science or mathematical techniques for the solution of specific problems. The focal areas (1) to (3) are interlocked in such a way that they overlap or complement one another at particular central and critical points.

Our work places an essential accent on sustainability. The focal areas are concerned with topics that require lasting commitment and cannot be carried out on otherwise usual project timescales of two or three years. These areas form the framework of our research for more than ten years and have produced numerous successful subprojects with innovative and convincing results. Many of our publications receive citations over long periods, presentations of key topics of our research are permanently in demand, and we have established long-term national and international collaborations.

The special funding situation at IGPP due to the Holler Foundation provides us with an independence necessary to address “big questions” in our focal areas – questions that play background roles at best at many other research institutions. We are in the lucky situation that we can abstain from rampant funding pressure, excessive publish-or-perish behavior, or inappropriate political considerations with their devastating influence upon science. A scientific advisory board, consisting of outstanding experts and regularly accompanies our work with criticism and suggestions, assesses its value primarily by the substance of the insights gained and their visibility and impact on the scientific environment in which they are embedded. The most recent board meeting took place in December 2011.

2.1.1 Concepts of Mind-Matter Relations

Even though most research in contemporary cognitive neuroscience assumes that mental states “basically are” neural states, this assumption floats in space essentially without solid theoretical or empirical evidence. The uncontroversial fact that mental and neural states are correlated has not yielded a clear picture of the nature of these correlations so far. A pertinent paper by Anderson (“Neural Reuse”, *Brain and Behavioral Sciences*, September 2010) gives a good impression of how inscrutable the current state of the art presents itself.

Alternatives to simplistic reductive approaches, which presumably do not represent the complexity of the situation properly, are therefore of great interest. In recent years we have been involved with two such alternatives that we could develop as far as toward realistic and empirical applications and proposals. One of these projects aims at a version of emergence, which is more flexible than plain reduction on the one hand, where a fundamental description is assumed to “fix everything”, and, on the other hand, not as arbitrary as a radical emergence where “anything goes”. The other project arises from an analysis of the speculative ideas of W. Pauli and C.G. Jung around the middle of the last century. It considers mental and material domains as dual aspects of one underlying, psychophysically neutral reality.

Contextual Emergence

Contextual emergence characterizes a specific kind of relationship between different levels of scientific descriptions of particular phenomena. It was developed and refined in collaborations within and outside the department, essentially since 2000. Contextual emergence utilizes lower-level features as necessary (but not sufficient) conditions for the description of higher-level features. It can be viably combined with the idea of multiple realization, a key issue in supervenience, posing sufficient (but not necessary) conditions.

In scientific areas such as physics, contextual emergence has been demonstrated as a formally precise and straightforwardly applicable interlevel relation. The situation becomes more challenging for less rigorously formalized fields of research. This is the case in the areas of cognitive neuroscience or consciousness studies, focusing at relations between neural and mental states. A review under the title “contextual emergence” at *scholarpedia* has recently been updated.

Mental States from Neurodynamics

The basic idea of contextual emergence is that, starting at a particular neural level L of description, a two-step procedure can be carried out that leads (1) from an individual neural description L_i to a statistical neural description L_s and (2) from L_s to an individual mental description H_i . The essential goal of step (1) is to identify a partition consisting of equivalence classes of individual neural states, representing the multiple realizability of statistical neural states in L_s . The essential goal of step (2) is to assign individual mental states at level H to statistical neural states at level L . This is impossible without a context at H defining the

set of observables at level H that is to be constructed from L_s . This context can be implemented as a stability criterion at level L .

It has been demonstrated how this procedure works for experimental data from cognitive neuroscience. For this purpose we used data from the EEG of subjects with sporadic epileptic seizures. The analytic procedure starts with the construction of a (Markov) transition matrix reflecting the EEG dynamics in the neural state space. The eigenvalues of this matrix yield time scales defining partitions of increasing refinement that can be used for the assignment of mental states. The result of the partitioning can be inspected in the originally recorded time series. This comparison of obtained mental states with corresponding episodes in the EEG dynamics showed perfect agreement between the distinction of normal and epileptic states and the bipartition resulting from the spectral analysis of the neural transition matrix.

Atmanspacher; together with Allefeld, beim Graben, Wackermann

Publication: Atmanspacher (2011)

Invariant Subspaces

The mentioned partitioning of the state space is essentially based on the identification of invariant subspaces and their assignment to symbols. Methods of symbolic dynamics thus allow us to map the neural dynamics onto a discrete string of symbols characterizing mental states. There is an intriguing parallel of this approach with the, purely mathematical to begin with, concept of a shift invariant subspace (SISS) of a Hardy space. Starting from the complete analytical characterization of all SISS in the spectral domain (Beurling-Lax theorem), we developed a method for calculating projections on arbitrary such subspaces. It remains to be investigated whether and how this approach can be translated into the language of symbolic dynamics, and thus be utilized for the determination of proper partitions.

Atmanspacher, Ehm

Publication: Ehm (2010)

Mental Causation

In the philosophy of mind, the argument of overdetermination is often used against the causal efficacy of mental states on neural states. If neural states are described as effects of previous neural states, then an additional mental influence (mental causation) “overdetermines” the neural states. This can lead to severe inconsistencies. In a series of influential publications, Kim has argued (with his “supervenience argument”) that the reducibility of mental states to neural states is the easiest way out of this dilemma.

However, Kim’s dilemma evaporates if mental states are defined by proper partitions of the neural state space in the sense of contextual emergence. For mental states to be causally efficacious at all, they must be robust in their temporal evolution. This central point is guaranteed by their construction from stable statistical neural states. The corresponding kinds of dynamics are then topologically equivalent and, as a consequence, compatible. Such a correlative

balance of mental and neural states has been proposed by Yablo in 1991. We could for the first time show how it can be realistically implemented in detail.

Atmanspacher; together with Harbecke

Publication: Harbecke, Atmanspacher (in press)

Dual-Aspect Monism

Correlations between mental and material states are an intrinsic feature of mind-matter models which consider such states as dual aspects of an underlying reality that itself is neither mental nor material. An early version of such a model is due to Spinoza, and since then variants thereof have recurrently been formulated, mostly outside philosophical mainstream directions. Well-known names in the modern philosophical history of dual-aspect monism are Strawson, Nagel, and Chalmers. From the perspective of philosophically interested scientists, Wolfgang Pauli and C.G. Jung are to be mentioned (subsequently, e.g., Bohm and d’Espagnat).

In a series of publications, partly with a history-of-science flavor, we could systematically reconstruct the most significant characteristics of the ideas of Pauli and Jung. For this purpose, the comprehensive correspondence of Pauli, edited in eight volumes by Karl von Meyenn, was enormously helpful. We worked out how the apparently related position of neutral monism (Mach, James, Russell) deviates from the conception of Pauli and Jung. A key difference is that the psychophysically neutral reality in the Pauli-Jung scheme is empirically accessible only in an *indirect* fashion, through its aspects.

Atmanspacher

Publication: Atmanspacher (in press)

Classes of Psychophysical Correlations

Breaking the symmetry of the psychophysically neutral domain into mental and material aspects implies correlations between the two, which follow directly from the structure of the model and should be permanent and reproducible. Correlations between mental and neural states or psychosomatic correlations would be obvious examples. But Pauli and Jung also speculated that, in front of this structural correlative background, additional psychophysical correlations (“synchronistic events”) can be induced which are highly contextual and essentially irreproducible.

Situations that are conducive for such induced correlations are characterized by the fact that the experiencing subject ascribes meaning to them that does not follow from the objectively given situation alone. The psychophysical model by Pauli and Jung allows us to derive a classification of induced correlations which can be compared with empirical material. Corresponding work has been started together with the counseling department at IGPP. First factor analytical results from about 1500 documented cases show perfect agreement with the Pauli-Jung conjecture.

Atmanspacher, Fach

Publications: Atmanspacher (in press), Fach (2011)

Riemann's Philosophical Speculations

Little known speculations of the mathematician Riemann concerning the philosophy of nature witness his attempts to develop a universal world view encompassing the physical as well as the mental domain. In this speculative work, he heavily drew on ideas of the philosopher Herbart. We demonstrated in particular that Riemann sought to connect the mental and the physical by means of an "agens" wherein the concepts of state and change are integrated. Riemann's adaptation of Herbart's ideas is a showcase for the influence of philosophy on the development of science in the 19th century. It points to a dual-aspect conception that attempts to unite substance and process oriented approaches.

Ehm

Publication: Ehm (2010)

Journal "Mind and Matter"

The journal "Mind and Matter" was established in 2003 and has received increasing visibility as a medium for questions of mind-matter research since then. The journal appears semi-annually, and the contents of all issues published so far can be found at www.mindmatter.de. The number of submissions grows continuously, the current acceptance rate is about 35%. Since 2005 the journal has been produced and distributed by Imprint Academic, Exeter (UK); the editorial office has remained in the hands of the IGPP theory group. The themes of the 2010 and 2011 issues were "Between Intent and Intentionality", "Experience: Elusive or Conclusive?" and "C.G. Jung and Wolfgang Pauli".

Atmanspacher, Moos

Publications: Atmanspacher, ed., Mind and Matter 8(1), 8(2), 9(1)

2.1.2 Generalized Quantum Theory

Quantum theory contains two key concepts, complementarity and entanglement, that are often metaphorically applied to situations beyond physics. In 2002 we proposed an axiomatically formalized, generalized quantum theory to make such applications more rigorous. The crucial formal criterion leading to complementarity and entanglement is the non-commutativity of particular observables of the system considered. The ordinary Hilbert space quantum mechanics can be recovered by stepwise adding the necessary features.

Meanwhile, a number of international groups utilize tightly related approaches for questions and problems of psychology, for instance decision processes, multistable perception, associative semantic networks, etc. Since 2007 there are regular conferences for this novel field of research, and in 2012 we will organize a workshop with leading scientists to discuss (common and different) foundations and future applications.

Our own work in the field refers to non-commutative effects in bistable perception, order effects in surveys, and learning processes. In addition to pertinent publications concerning these topics, we also published a comprehensive review article ("Quantum Approaches to Consciousness", updated

2011, Stanford Encyclopedia of Philosophy) and popular presentations of the basic ideas.

Publications: Atmanspacher (2010, 2011), Filk, von Müller (2010)

Temporal Nonlocality of Mental States

The concept of temporal nonlocality has been discussed in physics for 25 years (Leggett and Garg, Physical Review Letters 1985), but could not be experimentally realized for physical systems so far. It refers to states of a system that are not sharply localized in time but extend over a time interval of non-zero duration. We investigated the question whether, and how, such a temporal nonlocality can occur in mental processes.

For this purpose we exploited the empirically supported Necker-Zeno model for bistable perception, which is based on non-commuting operations implying an option for non-local states. We derived so-called temporal Bell inequalities and demonstrated under which conditions they can be violated in this model, indicating temporal nonlocality. Although the empirical proof of such a violation is difficult, we pursue it intensely because it would have significant consequences for our understanding of mental processes.

Atmanspacher, Filk

Publications: Atmanspacher, Filk (2010, 2011a, 2011b, in press)

Violation of Temporal Bell Inequalities

In order to provide empirical evidence for the violation of temporal Bell inequalities, one needs two successive states, the first of which must be measured as non-invasively as possible. For this purpose, perceptual states could be useful in which visual information has already been processed to some degree, but which have not yet transgressed the threshold to becoming conscious.

In this spirit we developed an experimental paradigm, which first determines the temporal perception threshold as the minimal duration of presentation of a disambiguated Necker cube that is necessary to identify its orientation of (about 90ms). Then we presented non-ambiguous and ambiguous cubes in randomized sequence, such that the first cube was either below or above threshold. The subsequent duration of presentation was varied between values for which the Necker-Zeno model predicts a maximal violation of the Bell inequalities.

Since the first state has to be determined as non-invasively as possible, subjects only had to report whether or not the state changed without having to specify the states they perceived. This way the measurement of two separate states to be correlated was replaced by one direct correlation measurement, thus enhancing the likelihood for significant results. Data assessment has been completed, and their analysis will start soon.

Atmanspacher, Filk, Kornmeier

Complementarity of Mental Descriptions

Descriptions of mental states and their dynamics are incompatible, or even complementary, if they are based on

an improper partition of the underlying neural state space. Compatible psychological descriptions, which are consistent with the underlying neurodynamics, emerge only if the mental states defined at the psychological level are dynamically stable. Such stable states can be constructed, in the sense of contextual emergence, by so-called generating (or Markov) partitions. As a consequence, we argue that the program of a unified science of psychology, with mutually compatible domains of description, depends on a proper choice of partitions of the neural state space.

On the other hand, there are interesting ramifications of *non-generating* partitions as well. Because they lead to non-commuting, incompatible observables and descriptions, they might be the basis for (epistemically) entangled mental states, to be interpreted analogous to quantum theoretical superposition states. It is conceivable that such entanglement correlations extend over time, so that temporally nonlocal mental states arise.

Atmanspacher, Filk; together with beim Graben

Publication: Atmanspacher, Filk, beim Graben (2011)

Order Effects in Surveys

The non-commutativity of observables plays an important role in numerous psychological situations, in which the result of successive operations depends on their sequence. This applies in particularly obvious ways to so-called order effects (or context effects) for responses to survey questions. Such effects are well-known and have been addressed using classical statistical techniques so far.

We analyzed such order effects on the basis of non-commuting operators (questions), leading to a framework for a quantitative treatment of response distributions in terms of non-classical probabilities. This reproduces all order effects known from literature, which are basically expressed as shifts of expectation values. A recent paper by Busemeyer and Wang shows that such effects can be quantitatively explained within a non-classical Hilbert-space model. We predicted additional variance effects resembling the Heisenberg relations of quantum theory.

Atmanspacher, Römer

Publication: Atmanspacher, Römer (in press)

Learning in Networks

We studied supervised learning operations in small recurrent networks, leading from a given set of input conditions to predetermined outputs. Networks that have optimized their output are asymptotically stable and can be characterized by attractors. As the mapping from a series of inputs onto a series of such attractors generally depends on the sequence of inputs, this process is non-commutative.

Surprisingly, the size of the set of attractors, indicating the complexity of learning, was found to behave non-monotonically as learning proceeds. This behavior can be reproduced with alternative complexity measures, but at present we are unable to correlate this result with other network features. Moreover, recent results showed that constraints on the network complexity during learning reduces its learning success in ways that depend on the nature of the applied limitation.

A key question in this work is which structural properties distinguish good “learners” from random networks. This led us to consider so-called “small-world” properties of networks, focusing at a generalization of their cluster coefficient which consists of the distribution of particular motifs (special sub-networks). We compared the motif distribution of learners to those of random networks and found that particular motifs do indeed increase distinctly during learning. Corresponding differences can be found in the eigenvalue distributions of the adjacency matrices of the networks, which correspond formally to the abundance of motifs.

Atmanspacher, Filk, Kleiner, Scheingraber

Publication: Atmanspacher, Filk, Finke, Gruber (2010)

2.1.3 Multistability and Acategoriality

In this third focal area of research we are interested in the behavior of mental systems under the influence of instabilities. This includes all kinds of transient behavior, bifurcations, spontaneous transitions etc. Psychological examples are decision processes at all levels, from controlled rational decisions (in uncertain or conflicting situations) to almost unconscious mechanisms in the perception of ambiguous stimuli or in binocular rivalry.

This last area refers to the keyword of multistability or its special case of bistability. Considerable part of our work in this field, both psychophysically and psychophysiologically oriented, is devoted to the investigation of the switching behavior between the two representations of an ambiguous stimulus. A related issue refers to a suitable characterization of the *unstable* state between representations. Such in-between states are elementary parts of every perceptual switch, but are usually not consciously experienced – because they are highly unstable and decay rapidly.

Jean Gebser (1949) has coined the term “acategoriality” for such states, and speculated about their significance for different modes of consciousness. In particular, acategorial states à la Gebser are to be expected in exceptional mental experiences as they are reported in spiritual traditions. We investigate essential features of acategoriality with scientific approaches and try to relate them to contemporary topics in the philosophy of mind.

EEG-Traces of Elementary and Complex Processes

The discontinuous presentation of an ambiguous stimulus synchronizes the instant of a perceptual change with the stimulus onset and enables us to identify endogenous events with high temporal resolution (± 30 ms). Using this “onset paradigm”, a chain of event-related potentials (ERPs) has been observed during perceptual changes of a Necker cube, starting with an early positivity at 100 ms (P100) and a subsequent occipital positivity (“reversal positivity”, RP) at 130 ms.

In agreement with previous reports, we found a monotonic increase of the P100-amplitude with increasing stimulus size and a general dominance of the central occipital electrode. However, the RP amplitude saturates with increasing stimulus size, with no significant difference between

electrodes. Our results indicate an independence of the elementary visual processing of stimulus size (P100) from the complex processing steps underlying a perceptual change (RP), although the two take place in close temporal and spatial neighborhood.

Kornmeier; together with Bach, Pfäffle; funded by DFG

Publication: Kornmeier, Pfäffle, Bach (2011)

Attentional and Adaptive Effects

Small variations of ambiguous stimuli entail their stable perception and release a strong ERP signature around 400 ms (P400), which is missing for ambiguous stimuli or with shifted attention. Using an adaptation paradigm we studied the question of whether attention is a necessary condition for the processing of stimulus information.

It turned out that stimulus-directed attention leads to a P400 for disambiguated stimuli and to a strong adaptation effect for ambiguous stimuli. For ambiguous stimuli and shifted attention this P400 disappeared as expected, the adaptive effect remained though. This result points to an independence of elementary stimulus processing and P400. The high latency of the P400 suggests processes significantly delayed after elementary stimulus processing.

Kornmeier; together with Bach, Hassberg

Publication: Dissertation Hassberg (2010)

Stability and Ambiguity of Stimuli

The representation of a visual stimulus can be described as an attractor in a mental state space, where the attractor depth reflects the stability of the representation which should decrease with increasing ambiguity. In order to test this hypothesis, we used a Necker lattice with gradually disambiguated lattice variants. In a second experiment we applied stroboscopic alternative motion (SAM) of two diagonally located dots as an ambiguous motion stimulus. The critical parameter for ambiguity in this case is the ratio of horizontal and vertical dot distance.

Both experiments yielded a sigmoidal curve for the relative frequency of ambiguous perception as a function of the critical stimulus parameter. Moreover, we found that the Necker lattice is preferably perceived under the perspective from above. Both visual stimuli provided optimal control over the stability of visual perception. In a current EEG experiment we now test the hypothesis of a correlation of the P400 amplitude with varying critical parameter.

Kornmeier; together with Wörner, Bach

Distribution of Dwell Times

Numerous studies of perceptual changes of ambiguous visual stimuli presuppose implicitly that the observed distribution, e.g. of dwell times, is statistically stationary. On the other hand, it is well known that physiological time series are often highly non-stationary. Therefore we investigated the stationarity of dwell-time distributions and their moments with respect to time and stimulus size. We compared two parametric fits and one non-parametric fit of the measured dwell times to a gamma distribution.

Our results show deviations of the dwell-time distribution of individual subjects from stationarity with respect to time, which disappear in the ensemble of all subjects. The moments of the distribution are even individually stationary. With respect to stimulus size, we found a linear correlation of the two gamma parameters which is not completely understood so far. We also found a significant preference of cube perception under the perspective from above, not only for the initial percept, but also as a stable effect prevailing for the complete duration of the experiment.

Atmanspacher, Kornmeier; together with Wernery, Folkers, Candia

Effects of Surround Color

There are indications that surround color may influence the performance of subjects on cognitive tasks. Since cognitive factors also play a role in the perception of ambiguous stimuli, effects of surround color are to be expected in bistable perception as well. We investigated this possibility with Necker cubes and Rubin's vase/face stimulus.

For the Necker cube we found an initial-percept preference for the perspective from above (89%), which prevailed persistently for subsequent dwell times. For the vase/face stimulus there was an initial-percept preference in favor of the face (75%), but no difference for subsequent dwell times. Blue (as opposed to red) surround color depleted the dwell-time preference for the Necker cube and the initial-percept preference for the vase/face stimulus.

Kornmeier; together with Bach, Heinrich, Wiedner

Gamma Oscillations and Feature Binding

Synchronous oscillations of neural assemblies in the gamma frequency band (30-80 Hz) are discussed as the solution of the binding problem ("binding hypothesis") and even as the correlate of consciousness. We tested the binding hypothesis via perceptual alternations of the Necker lattice: EEG correlates of the decay and build-up of neuronal binding can be measured unperturbed by a changing stimulus. The onset paradigm using discontinuous stimulus presentation guarantees a high temporal resolution for studying the endogenous perceptual alternations.

We found enhanced gamma activity 150 ms after stimulus onset for exogenous, and about 100 ms later for endogenous perceptual alternations. Two aspects are speaking against the gamma binding hypothesis: (1) The duration of the observed gamma modulation is shorter than the duration of a stable conscious percept. (2) The gamma modulation occurs too late: according to current knowledge about the dynamics of visual processing, binding processes should be accomplished way before 200 ms after stimulus onset. Moreover, all gamma modulations vanished after a pre-onset baseline correction.

Ehm, Kornmeier; together with Bach; funded by DFG

Publication: Ehm, Bach, Kornmeier (2010, 2011)

Acategoryal States With Non-Conceptual Content

The concept of acategoryal mental states can be substantiated by approaches developed in cognitive neuroscience

and in the analytical philosophy of mind. Acategoriality characterizes a form of knowledge that presumes fully developed categorial mental representations, yet refers to non-conceptual contents (an important topic in current debate) of mental states beyond categories. It relies on a simultaneous experience of potential individual representations and their actual “representational ground”, an undifferentiated non-categorial state discussed, e.g., by Metzinger.

Such experience is possible if a mental state does not represent directly, but is located in between representations. Acategoriality can be formally described as an unstable state of a dynamical mental system. This provides a framework of understanding temporally nonlocal, entangled states as distinguished by an extended duration of the (nonlocal) present. *Atmanspacher; together with Feil*

Publication: Feil, Atmanspacher (2010, 2011), Filk, von Müller (2010)

Acategoriality in Exceptional Experiences

Numerous reports of exceptional experiences (EEs) range from apparitions and extrasensory perception to meaningful coincidences and mediumship. Typical conditions under which such experiences occur can be characterized psychosocially as attempts to stabilize unstable situations often described as stressful or unhealthy. On the other hand, EEs are also reported as occurring along with the spiritual development of individuals. Depending on cultural traditions, they are sometimes referred to as “epiphenomena”, and it is recommended more or less explicitly not to devote much attention to them in order to keep the process of development in flow.

For a proper evaluation of this discrepancy, it is important to identify the type of EEs accompanying spiritual development and distinguish it from other types. This is possible on the basis of the dissociation or integration of a subject’s models of self and world. It will be particularly interesting to see how different classes of EEs can be assigned to non-categorial, categorial or acategorial mental states of the subjects concerned. The classification developed on the basis of the Pauli-Jung scheme plays an important role in this collaborative project with Collegium Helveticum Zurich and the Psychiatric University Clinic Zurich.

Atmanspacher, Fach; together with Folkers, Rössler, Wyss
Publication: Fach (2011)

2.1.4 Conceptual and Methodological Issues

As a complement to the three focal areas of research in TDA, we worked on conceptual and methodological questions presented subsequently. Primarily, this includes specific issues of the philosophy of science and, as far as empirical work is concerned, methods of data analysis. They elaborate background or side aspects of our key topics in such a way that these are solidly embedded in their scientific environment.

Causal Closure of the Physical

Many debates of mental influences on brain processes are based on the assumption of the “causal closure of the phys-

ical”. Briefly, this means that effects on physical states can only be caused by (previous) physical states. A detailed look at the notions involved shows that the causal closure assumption depends on time symmetries inherent in the fundamental physical equations of motion. Their solution always requires a specification of initial/boundary conditions and implies a breakdown of time symmetries due to the action of an experimenter or observer. This general objection against the causal closure of physical states is independent of the system considered.

Atmanspacher; together with Bishop

Publication: Bishop, Atmanspacher (2011)

Determinacy of Neuronal Processes

The determinacy (or determinism) of neuronal processes is another subject presenting deep problems that are often insufficiently considered. First of all, the question of determinacy versus stochasticity is a question of modeling: a deterministic *description* does not imply that the described system *behaves* deterministically. In addition, we showed in detail how sometimes deterministic and sometimes stochastic descriptions are pragmatically preferable at different levels of description (ion channels, individual neurons, neuronal assemblies). These and further issues suggest to consider bold statements as to the impossibility of mental causation or even free will because of the determinism of neuronal processes with utmost caution.

Atmanspacher; together with Rotter

Publication: Atmanspacher, Rotter (2011)

Assessing Statistical Predictions

Predictions of future events or measurements are not only uncertain but also imprecise. However, traditional pointwise predictions give no idea about their presumable inaccuracy. Substantially more informative are probabilistic predictions, e.g., predictive densities, which assign any possible realization a probability to materialize. An assessment of such predictions post hoc is possible with so-called scoring rules, which depend on the predictive density and the observation that materializes, and which have to satisfy certain criteria securing the validity of the assessment.

We studied a class of these “proper scoring rules” characterized by a locality property that combines practical with theoretical advantages. A complete characterization of the “local proper scoring rules” of order two could be given, which helped, e.g., finding robust alternatives to the only special case known so far (Hyvärinen score). Moreover, a surprising connection between the Hyvärinen score and Stein’s “unbiased risk estimation” was found which gave rise to a far-reaching generalization of this concept.

Ehm; together with Gneiting

Publication: Ehm (2011)

Multiple Testing for Time Series

Pinning down effects of interest in time series analysis usually requires carrying out many single tests sensitive to local deviations in, e.g., the time, space, and frequency domain. Depending on the size of the search space and the

desired resolution, the number of single tests can be huge. Moreover, unknown statistical interdependencies can make it difficult to control the alpha error. Such problems often are circumvented by defining regions of interest or reducing the resolution.

We developed a multiple testing procedure (“conquer and divide”, CAD) that operates by successively subdividing the time domain. CAD starts at the coarsest level and with liberal critical values and continues only where distinct effects are found. Monte Carlo simulations demonstrated CAD efficient in regard to specificity and sensitivity. For extensions to arbitrary search trees we proved that the procedure exactly controls the global error probability.

Ehm, Kornmeier, together with Heinrich; funded by DFG

Publication: Ehm, Kornmeier, Heinrich (2010)

Time Frequency Analysis

A characteristic feature of wavelets, a standard tool in the analysis of physiological time series, is the inverse proportionality between frequency and window width. It achieves a balance between time and frequency resolution that is advantageous for long time series with a broad spectrum, but not for short band-limited time series such as evoked potentials. Low frequencies then imply an insufficient time resolution and problems with boundary effects due to too large window widths, while at high frequencies the implied time resolution appears too sharp for noisy data and is paid for with low frequency resolution.

The window width should be thus be diminished at low and increased at high frequencies. While this is easily achieved by making the (usually constant) window width of the Gabor transform a monotone decreasing function of frequency, the resulting “flexlets” need not represent a genuine time-frequency transform. However, for a certain class of window functions including the Gaussian it could be shown that the transform is exactly invertible and achieves at least approximate conservation of energy.

Ehm