

Willy Østreng, editor

Convergence

Interdisciplinary
Communications
2004/2005

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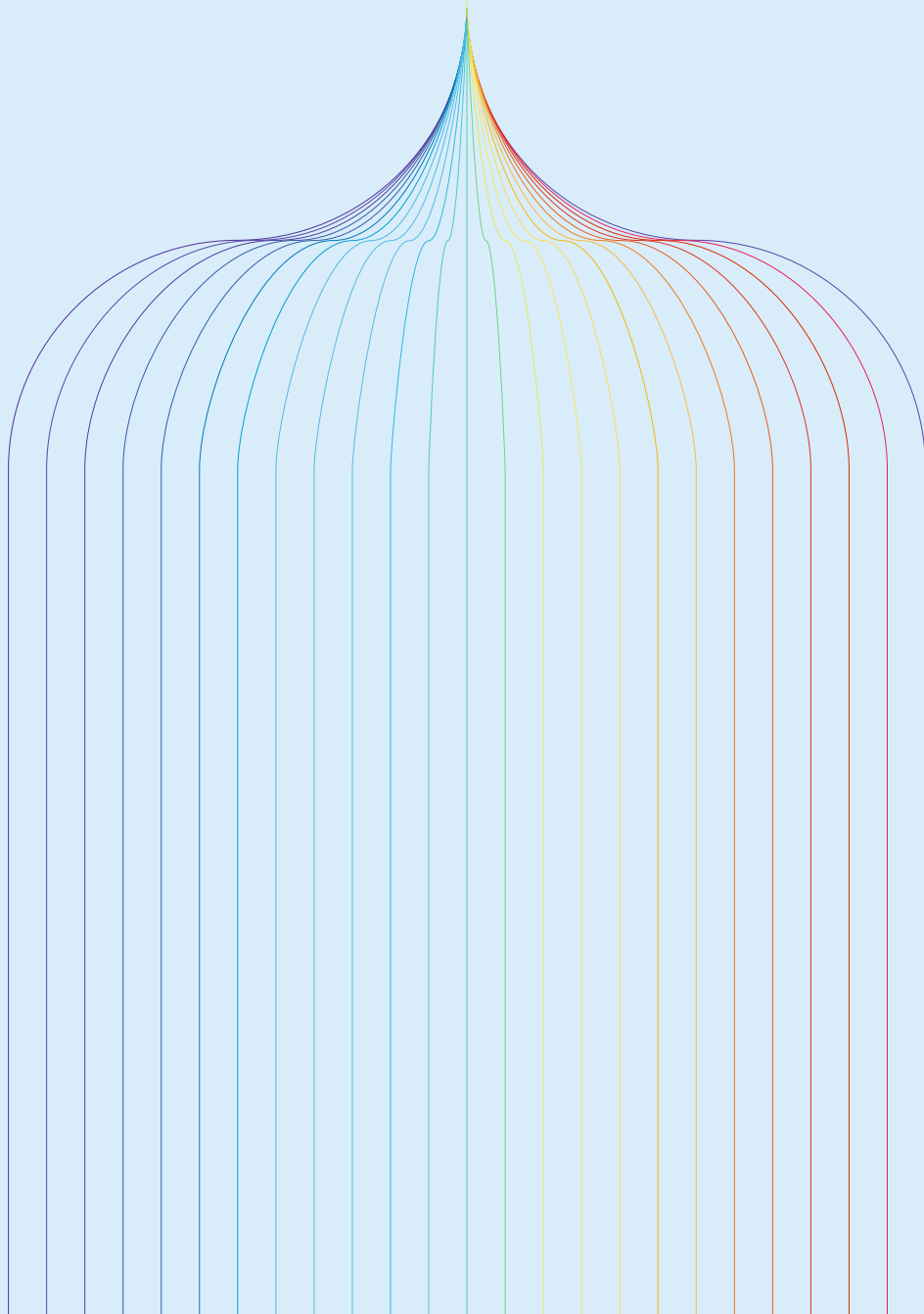


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Centre for Advanced Study in Oslo

The Centre for Advanced Study (CAS) is an independent private foundation. The Centre was established by the Norwegian Academy of Science and Letters in 1989, but its activities did not commence in full until the autumn of 1992. Its purpose is to promote basic research and interdisciplinary theoretical research on the highest international academic level within the humanities/theology, the social sciences/law and the natural sciences/medicine/mathematics. The Centre's academic activity is of a long-term nature and is to be permanent and academically independent vis-à-vis political and economic influences and the influence of research policy.

Outstanding researchers from Norway and abroad are nominated for one-year stays to engage in research in the Centre's premises in the Norwegian Academy of Science and Letters' mansion in Oslo. The activities are organized in three groups – one in the humanities, one in the social sciences and one in the natural sciences - each with from six to ten members whose affiliation is long-term. In addition come numerous researchers who spend shorter periods conducting research, altogether some 40–45 researchers of 10 to 15 nationalities a year. Each group is planned and organized around a unifying theme and headed by one or more outstanding researchers. The groups have no other obligations than their own research. They receive administrative and financial support from the Centre in formalized cooperation with six Norwegian universities and one high-level research college, i.e. the University of Oslo, the University of Stavanger, the University of Bergen, the University of Tromsø, the Norwegian University of Science and Technology in Trondheim, the Norwegian University of Life Sciences in Ås and Norwegian School of Economics and Business Administration in Bergen. The Centre has a Board appointed by the Norwegian Academy of Science and Letters, the Norwegian Association of Higher Education Institutions and the Research Council of Norway. The administration is taken care of by a staff of four full-time and two part-time employees and headed by a Scientific director.

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Project groups 2004/2005

Turbulence in Plasmas and Fluids

Group leaders:

Professor Hans L. Pécseli and Professor Jan Trulsen, University of Oslo

Turbulence in fluids and plasmas is one of the least understood topics in classical continuum physics. The problem addresses randomly varying flows, where individual realizations are too complicated to be comprehensible, but which can be described and analysed by statistical methods. In spite of significant progress in the studies of neutral flows (in water etc.), there are still several basic problems, which are not fully understood. As far as plasmas are concerned (i.e. gases composed of charged particles) the situation is even more unfavourable.

In this case the sensitivity of the gas to electric and magnetic fields adds to the complexity, and progress has only been made by significant simplifications, which are not always justifiable. It is however quite important that we improve our understanding of turbulent plasmas, since most of the matter on astrophysical and heliospheric scales is in the plasma state, and is often found to be strongly turbulent.

One of the most important properties of turbulent fluctuations in gases and fluids is their ability to disperse particles at an anomalously large rate. This implies that boundaries in space are maintained only to the extent allowed by turbulent transport. Similarly, it is found that the electrical conductivity of a plasma is often controlled by turbulence. This latter problem is studied even less than turbulent transport, but it is expected to be central for the understanding of the large scale current systems associated with the Earth's magnetosphere. The research group addressed selected central questions concerning turbulent transport, with emphasis on applications in nature.

Linguistic Theory and Grammatical Change

Group leader:

Professor Jan Terje Faarlund, University of Oslo

The goal of the project was to establish new theories of language internal conditions for grammatical change over time. This was done on the basis of empirical data from a variety of languages, and recent linguistic theory. The project concentrated on identifying principles and mechanisms which underlie grammatical change.

In all languages we can observe change over time. Such changes may have identifiable external causes, but those usually explain only why a process of change started at some point. In order to explain why the outcome of the change is as it is we need theories of grammar and internal linguistic structure. This project dealt with the relationship between internal linguistic structure and grammatical change. The relationship between language acquisition and change has become a hot topic

in modern linguistics, and precise hypotheses have been formulated about how the grammar of a language may change in the process of first language acquisition.

In a project like this, material from various languages and language families are of crucial importance. The participants included experts on older Germanic languages, Slavic languages, Latin and Romance, Finno-Ugric languages, Caucasian languages, and native American languages. Some of the participants work within various versions of formal generative grammar, others have their theoretical basis on more functional and typological theories.

Attention-Deficit/Hyperactivity Disorder (ADHD) from Genes to Therapy

Group leader:

Professor Terje Sagvolden, University of Oslo

The primary aim of the ADHD group was to take advantage of the strong Norwegian neuroscience research community in bridging the present gap between basic and clinical research on Attention-Deficit/Hyperactivity Disorder (ADHD). Prior to the ADHD group at the Norwegian CAS, broad interdisciplinary collaboration between clinical researchers and basic neuroscientists on this disorder was largely non-existent even on an international level. It was the first time that an international interdisciplinary group had been gathered for trying to reach a comprehensive theory of ADHD.

It was expected that such a theory will form the basis, not only for future diagnosis and treatment of ADHD, but also for the design of future studies on animal and mathematical models that will be helpful in advancing the understanding of ADHD.

CAS' annual book series on multi- and interdisciplinarity

In the academic year of 2003/2004 CAS commenced the publication of a long-term series of books on multi- and interdisciplinary research and communication. The books are based on weekly luncheon seminars in which the Fellows of the Centre are invited to make presentations of their scientific specialities to a mixed bag of humanists, social scientists and natural scientists. In this multidisciplinary setting unexpected results have emerged.

As part of the dispersion policy of CAS, the books are distributed free of charge to a wide readership – nationally and internationally – extending far beyond the ranks of experts. The following books have been published and are available from CAS:

Willy Østreng (ed): *Synergies. Interdisciplinary Communications 2003/2004*, Centre for Advanced Study, Oslo, January 2005, 112 pages (A few copies are still available)

Willy Østreng (ed): *Convergence. Interdisciplinary Communications 2004/2005*, Centre for Advanced Study, Oslo, December 2005, 155 pages (Copies are still available)

Acknowledgement

This booklet involves the work of many individuals. Bjarne Røsjø, project leader at *Faktotum Informasjon A/S* has coordinated the work between the designer, CAS and the printer, whereas Ketill Berger at *dEDBsign* is responsible for the attractive design of the book. The language editing has been competently done by Dr. Patrick Nigel Chaffey and Hilary Chaffey. Maria Sætre has taken all the nice looking portraits and has together with Unn Hagen invested long hours in a most conscientious proof-editing process. Marit Finnemyhr Strøm has – as always – assisted where and when need be. To these individuals, the editor would like to express his appreciation.

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Foreword

The Centre for Advanced Study (CAS) in Oslo has two overriding long-term objectives. The first is to enhance the quality of Norwegian basic (fundamental) research to the highest international level and standard. Here the call is for specialization and penetration in depth – to benefit basic disciplinary science. The other is to promote the same quality and achieve the same level of excellence when it comes to interdisciplinary research. Here the call is for wholeness and integration in breadth as well as in depth – to benefit complex system science. The two objectives relate equally to the humanities, the social sciences and the natural sciences and both are supposed to find expression within and between the three fields of academe.

This book is the result of a series of weekly luncheon seminars in which the fellows of the Centre have made presentations of their respective specialties with the aim of fostering a multidisciplinary dialogue between the groups and across disciplinary delineations. Three scientific groups were in action throughout the academic year of 2004/2005. The humanists addressed the relationship between *Linguistic Theory and Grammatical Change*, the social scientists aimed at developing a more complex understanding of *Attention-Deficit/Hyperactivity Disorder (ADHD)* – *from Genes to Therapy*, whereas the group of natural scientists were concerned with *Turbulence in Plasmas and Fluids*. At the outset of the discussions, it seemed as if the humanists and the social scientists had a common denominator in their joint focus on language, whereas the physics group, on the face of it, had no obvious professional connection to the others. The former assumption proved right, the latter proved wrong. The *theory of turbulence* – the very essence of the work of the physics group – at an early stage caught the interest of some of the humanists and the social scientists who wanted to test if the theory of turbulence was discipline-straddling, providing a novel and supplementary approach to the study of language change in linguistics and information processing in the neurosciences. How these expectations turned out upon application is discussed in *Section II: The Theory of Turbulence in Physics, Linguistics and Psychology*. Thus, the luncheon seminar turned out – as it did in 2003/2004 – to be instrumental in creating a feeling of both social and professional community between the groups. At the same time, it produced a multidisciplinary atmosphere of utility for the clarification of interdisciplinary concepts in theory-building within and between the groups.

To provide an overall integrative perspective to the book, and in particular to *Section II*, the editor has contributed an article on *Complex System Science and Discipline-Straddling Theories*, suggesting, among other things, that the rich stock of discipline-based theories may unleash some unrealized interdisciplinary potential through wider applications. *Section II* deals with that.

We have two hopes for the book. First, to extend the internal multi- and interdisciplinary discussions of the CAS to a wider readership – nationally as well as internationally – and to ease communication between readers and authors by providing the relevant e-mail addresses. Second, and closely related to the first point, we want to break down the alleged “ivory tower of basic fundamental research” by dispersion of a book that we hope will appeal to readers beyond the realm of pure experts.

Happy Reading!

Oslo, November 2005

Willy Østreng,
Scientific director and Editor

Section I:

Interacting Specialities

Complex System Science and Discipline-Straddling Theories

When something is complex, it is composed of interconnected parts. Thus, in complex system science, researchers are supposed to address all relevant variables of a particular system or problem by fusion of unrelated but relevant disciplines. This kind of science holds the vision that fundamentally new phenomena may rise from the collective interactions of large numbers of factors that cannot be adequately studied by disciplinary measures in confinement. Complex systems come in many shapes, designs and sizes. They range from the smallest of systems like cell biology and the functioning of the human brain to the largest of systems like climate formation, biodiversity and ecology.



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In their book *Frontiers of Complexity*, Peter Coveney and Roger Highfield define complex system science as a new way of thinking about the collective behaviour of many basic and interacting units that lead to coherent collective phenomena existing at higher levels than those of the individual units, and *where the whole is more*

than the sum of its components. Steven Weinberg, in looking at nature at levels of greater and greater complexity, sees phenomena emerging that have no counterparts at the simple levels, least of all at levels of the elementary particles: He sees nothing like intelligence on the level of individual living cells, and nothing like life on the level of atoms and molecules.

The quest to understand the “extras” stemming from the dynamics of interconnected parts belongs to the biggest and most demanding challenges in modern science. To know the individual bits and pieces of complex systems is not the same as understanding how the “extras” of wholes form and emerge. In acknowledging the enormity of this task, my ambition in this article is one of extreme moderation, addressing, in the form of a brief sketch, the ability of discipline-straddling theories to pick up and integrate bits and pieces of complex systems across disciplinary delineations.

Discipline-Straddling Theories.

Scientific theories, defined as a consistent set of ideas and/or variables about how a phenomenon works, are often diffused through and across disciplinary boundaries. They possess integrative power, i.e. the ability to piece perspectives, knowledge, ideas, concepts and data together into a whole. The integrative potential of theories makes them to a large, if not absolute, extent *discipline-neutral*. Even theories developed within the confines of a particular discipline have been adopted by other disciplines, helping the “borrowing” discipline to conceive of phenomena in new and

broader ways. This is how discipline-based theories become discipline-neutral or discipline-straddling. In the last section of this book, *turbulence theory* – developed within the field of physics – has been applied to selected topics of linguistics and psychology to illustrate the unleashed integrative potential of discipline-based theories, the overall assumption being that there may be a flora of discipline-based theories in the inventory of the sciences that go far beyond the integrative confines of their mother-discipline.

In principle, one can distinguish between three interrelated and partly overlapping categories of discipline-straddling theories: *Synthetic theories*, *Interfield theories* and *Seminal theories*.

Synthetic theories

In the early 1970s, Jean Piaget made the case that a theory of interdisciplinarity should be based on common structures to be developed from the holistic perspective of systems theory concerned with patterns and interrelations of wholes. Piaget acknowledged that, when it comes to building blocks, a system in the social sciences is, in principle, no different from a system in the natural sciences, or for that matter between natural science disciplines.

Fifty years earlier, the Norwegian biologist, Johan Hjørt observed that the word *organization* is a biological expression for the same thing as is known in physics and chemistry as a *system*. On this account, he concluded that the two concepts, ‘organization’ and ‘system’ reveal to us “the unity in our mind from which they both arise.” Thus, system theory refers to a theory that is applicable to many systems – social as well as natural – and which is built on a set of interrelated concepts to be jointly used in system analysis in all sciences. These concepts, although varying in content between the fields, become operational for interdisciplinary undertakings through a process of mutual adjustment to each other. Julia Thompson Klein points out that these theories have been used to strengthen theory in one discipline, to unify a single discipline, to provide an integrative methodology or theory of cluster of disciplines, and even to function as a unified science by integrating all disciplines around a single transcendent paradigm.

Interfield theories

A distant relative of synthetic theories is interfield theories, which seek to identify relationships between phenomena in various *fields of inquiry*. A field of inquiry is defined by: *a central problem, facts related to a problem, techniques and methods applicable to a problem, and goals and factors providing clues as to how the problem is to be resolved*. The motivation to develop an interfield theory arises when researchers recognize that the phenomenon in which they are interested are connected to phenomena in other disciplines. The pooling of disciplines in cognitive science is an example of how interfield theories develop. Here the broadly based disciplines of psychology, artificial intelligence, linguistics, anthropology and philosophy are united by a common field of inquiry: *cognition*. Given that the goal of an interfield theory is to identify these relations, there is no need or demand to derive a theory of one field from that of another. An interfield theory opts to reveal relations between phenomena in different fields, for example to identify in one field the physical location of an entity or process discussed

in another, frequently revealing a part-whole relation between the entities studied in the two fields. It may also identify an entity characterized physically in one field with the same entity characterized functionally in another, or it may locate in one field the cause of an effect recognized in the other field. To succeed in building interfield theories, no attempts should be made to make the theory of one discipline work for another, but rather to draw useful connections between the investigations of all involved disciplines.

Seminal theories

Seminal theories are discipline-straddling in that they are basically defined at the junction between fields. For the sake of illustration, let us take the examples of game and regime theories. Game theory has been applied in economics and finance, psychology, biology, political science, law, military planning and strategy etc., whilst regime theory has been used in disciplines like sociology, economics, geography, political science, international law and biology. Since these theories are applicable to all these disciplines the probability is that they may also be used to pool the same disciplines together in a unified holistic perspective. Some of the bridging potential of regime theory has already been tested.

In 1989 Kenneth W. Abbott published an article in which he argued that regime theory holds a rich potential to close the gap between international relations theory and international law. He even went so far as to call for a 'joint discipline' between law and political science. In a follow-up article some years later, Anne-Marie Slaughter et al., concluded that international relations theory and international law have rediscovered each other and that a new generation of interdisciplinary scholars has emerged, acknowledging that the disciplines represent different faces of and perspectives on the same empirical and/or intersubject phenomena. On the basis of their analysis of the inventory around which international relations and international law scholars converge, the authors suggested the establishment of 'joint disciplines' between the two domains when it came to 'international governance', 'social construction' and 'liberal agency'. In addition, the focus on substantive themes cross-cutting established paradigms and self-defined disciplinary boundaries made the authors suggest six clusters of research questions on which collaborative interdisciplinary research agendas could be built. These clusters fall under the headings of *regime design*, *process design*, *discourse on the basis of shared norms*, *transformation of the constitutive structure of international affairs*, *government networks* and *embedded institutionalism*.

The Integrative Reach of Scientific Theories

These categories of theories all possess synthetic power. Synthetic theories are based on a common denominator, system, which is a feature of both the social and natural worlds. As such, synthetic theories may be applied to pick up the bits and pieces of complex systems spanning the human-natural divide, for example global climate change. Interfield theories also bridge this divide, but offer a supplement to the approach of synthetic theories in that the former have no pre-defined theoretical outlook or common denominator to start with. Theories built within a variety of fields of inquiry develop gradually as the empirical research process evolves and will differ between the fields. In this way, interfield theories

carry thematic flexibility and complementarity to the integrative potential of the other categories of theories. Seminal theories are thematically and problem-oriented, and since problems usually do not come in discipline-shaped forms, these theories are by definition established at the cross-section of disciplines – as a common property of fields. Problems know no disciplinary boundaries.

Although, theoretical approaches of this variety span the divide between the natural and social sciences, their integrative reach is still limited. Their thematic focus is restricted to specific issue areas, for instance systems and regimes, and to an endless variety of restricted fields of inquiry. They are synthetic within restricted scopes, covering only limited clusters of phenomena across fields. As such, they do not fulfil the ultimate dream of a final *theory of everything* – of total consilience between all sciences and disciplines. Such a task is itself beyond any one human mind, and inherently undoable due to the fact that knowledge expands faster than ways to categorize it. Ken Wilber sums it up nicely: “The holistic dream is an ever receding dream, a horizon that constantly retreats as we approach it, a pot of gold at the end of a rainbow that we will never reach. So why even attempt the impossible? Because, ..., a little bit of wholeness is better than none at all, and an integral vision offers considerably more wholeness than the slice-and-dice alternatives. We can be more whole or less whole; more fragmented, or less fragmented; more alienated, or less alienated – and an integrated vision invites us to be a little more whole, a little less fragmented, in our work ... (Wilber, p. xii).”

Complex system science does avail itself of multiple integrative measures in which both discipline-based, synthetic, interfield and seminal theories are part of the inventory. To gain more in-depth knowledge about the extras of wholes – some of which may never be fully understood – there is a need to increase the integrative power and scope of all available means of integration, theories included. The rich stock of discipline-based theories may unleash some unrealized interdisciplinary potential through wider applications (See last section of this book), whereas discipline-straddling theories may increase their collective integrative ability by combined applications to serve as complementary and supplementary means of convergence.

References

- Abbott, Kenneth W.: “Modern International Relations Theory: A Dual Agenda” in *Yale Journal of International Law*, vol. 14, 1989
- Bechtel, William: *Philosophy of Science: An Overview of Cognitive Science*, Lawrence Erlbaum Associates Publishers, Hillsdale, Hove and London, 1988
- Coveney, Peter and Highfield, Roger: *Frontiers of Complexity. The Search for Order in a Chaotic World*, Fawcett Columbine, New York, 1993
- Darden, L and Maull, N: “Interfield Theories” in *Philosophy of Science*, vol. 44, 1977
- Davies, Paul: *God and the New Physics*, A Touchstone Book, New York, London, Sydney, Tokyo, Singapore, 1984
- Hjort, Johan: *The Unity of Science*, Gyldendal, London, Copenhagen, Christiania, 1920
- Klein, Julia Thompson: *Interdisciplinarity. History, Theory and Practice*, Wayne State University Press, Detroit, 1990.
- Piaget, Jean: “The Epistemology of Interdisciplinary Relationships”, in *Interdisciplinarity: Problems of Teaching and Research in Universities*, OECD, Paris, 1972
- Slaughter, Anne-Marie, Tulemello, Andrew and Wood, Stephen: “International Law and International Relations Theory: A New Generation of Interdisciplinary Scholarship” in *The American Journal of International Law*, vol. 92, 1998.

Complex System Science and Discipline-Straddling Theories

- Weinberg, Steven: *Dreams of a Final Theory. The Scientist's Search for the Ultimate Laws of Nature*, Vintage Books, New York, 1993
- Wilber, Ken: *A Theory of Everything. An Integral Vision for Business, Politics, Science and Spirituality*, Shambhala, Boston 2000
- Wilson, Edward O.: *Consilience. The Unity of Knowledge*, Vintage Books, New York, 1999
- Østreng, Willy: *Science without Boundaries. Interdisciplinarity in Science and Politics*, forthcoming book, 2006

Greek Mind/Geek Mind

The roles of Χηαος (Chaos), Complementarity & Consciousness in ADHD

Advanced Study often requires a conceptual retreat to fundamental issues of epistemology to ensure that advances toward difficult issues are firmly grounded. *Attention Deficit and Hyperactivity Disorder* (ADHD) is a complex phenomenon, with neuroscientific, educational, parental, policy, and budgetary implications. Platonic and Aristotelian perspectives on knowing can provide solid ground from which investigators may redeploy the most modern equipment of genetic, neural and behavioral technologies.

Plato likened our knowledge of the world to that of prisoners in a cave, chained to look only at a wall on which fell the shadows of real objects (Figure 1). In studying a phenomenon we must necessarily abstract certain dimensions for scrutiny: Any one characterization of an object is a projection into a lower dimensional space – the wall of our cave. The dimensions left behind might later be crucial for identifying features that matter. At the CAS we may stand back from the press of habit, talk to others who see the phenomenon from different perspectives, and invest the time necessary to develop the impli-

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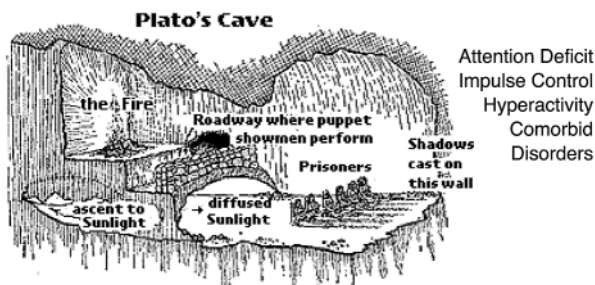


Figure 1. Plato's Cave. The Prisoners are scientists, trying to infer the nature of the objects held up by the showmen from the shadows they cast. Our shadows are the symptoms of ADHD. Are they cast by one real object, by three, or by many overlapping objects? Convergent information from alternate sources of light – alternate theoretical perspectives – can elucidate the object.

cations of a new formulation. The odds are against any one new formulation, but with time to come back at the phenomenon again and again, we turn the odds in our favor.

Our group seeks to understand *Attention*

Deficit and Hyperactivity Disorder (ADHD), characterized as a disorder of attention, of self control, of ability to settle into a task. These dimensions are measured by standard psychological instruments, carefully calibrated by expert statisticians. Yet what the parents or teacher wish to know –

whether the child is “normal” or has a psychological or biological problem – requires that the rich multidimensionality of every child first be abstracted into scores on 3 or 4 factors – and those factors further reduced to a binary decision of “ADHD” or “normal”. This Solomonic division of children is pragmatic; yet as scientists we look at the graded shadows on the wall of the cave, and ask whether they are thrown by the same object or by different objects – whether they really justify different names, and if so where to draw the category boundaries. Hyperactivity, inattention, and impulse control are meliorated by the same stimulant drugs, which supports the pragmatic lumping. Absent a solid theoretical taxonomy and pedagogic and biomedical protocols for dealing with the many varieties of ADHD that may exist, can we assume that the shadows on the wall are cast by an “ADHD disorder” and leave it at that? Our task at the Centre is

Aristotle's 4 beCauses (aition)

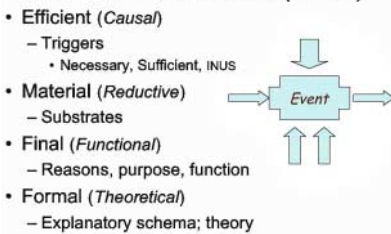


Figure 2. Aristotle identified four things (*aition*) we should know about an object to understand it. *Aition* was translated as ‘cause’, but a better translation might be “because”. A fifth “cause”, involving feedback was also identified by Aristotle

it (necessary causes). We must know what the object is made of: The material basis of a statue may be granite; of a man flesh and bones and neurons. The final cause of an object is what has brought it about. The final cause of a telephone is to communicate over a distance; of a heart to pump blood. The fourth thing we need to know about a phenomenon is its essential form: Remove all the arbitrary, “accidental” parts and what is left? We represent the essence of a phone with words, circuit diagrams, equations. Representation is a key activity of all science; scientists continually shuttle between the representation and the thing represented, adjusting first one then the other, seeking continually to improve the correlation between them.

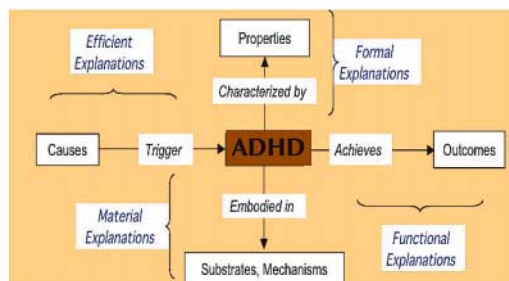
What are the 4 “causes” of ADHD (Figure 3)? Our answers must be tentative – hypotheses rather than conclusions. We believe

to throw light on the phenomenon from new directions, to see finer distinctions where they exist, greater commonalities where they are latent.

One hundred years after Plato, Aristotle set the mold for careful scientific classification of phenomena. He recognized that we must know at least 4 things about a phenomenon in order to understand it (Figure 2). We must know what causes it: The efficient causes of a phenomenon are those which, if present will bring it about (sufficient causes); or if absent will obviate

Figure 3. Sagvolden's group applies Aristotle's template to clarify the nature of Attention Deficit/Hyperactivity Disorder (ADHD).

A beCausal Analysis of ADHD



the material cause may be a weakness in the energetics of dopamine transport. Dopamine is a neuromodulator that serves many functions in the body. One of these appears to be to signal that a positive state of affairs has occurred – a reinforcer – increasing the conductivity of the neurons active at that time, and thus possibly responsible for the reward. Insufficiency of this neurochemical may hinder the association of chains of productive activity with their eventual reward, thus making it difficult for children to learn sedulous tasks. Several genes have been associated with ADHD, moving our knowledge of its material causes even deeper.

The efficient causes are uncertain, but it is known that prenatal insult can cause ADHD symptoms; some scholars at the CAS are especially concerned with the role of PCBs as possible triggers. Efficient causes also operate on a faster timescale: Children with ADHD sometimes act quite normal; at others disruptively distractable. What are the circumstances in which their disability is most likely to manifest?

It seems strange to ask what function a malady such as ADHD serves: ADHD appears to be a failure mode, analogous to a broken bone, serving no function. But that could be misleading. Think of another disruptive event, pain. Pain is a sign of a failure somewhere in the system, but it is highly adaptive. Given the severe problems ADHDers can have as adults, and its relatively high (~5%) prevalence and heritability, we must ask what are the circumstances that maintain it in the population. The adventurer, the risk-taker, those easily distracted by novelty would not last in Henry Ford's factories. But perhaps some will find ways to eliminate the boring tasks, leap to visualizing other modes of transport, discover their own continents. Or perhaps they will be attractive enough or assertive enough to leave more offspring than the more careful, providential individual. Many roads lead to Rome, and the citizens that built it. The problem child may be just too far along otherwise useful dimensions, an extension that tips the balance into the problematic. How is such a boy best protected from extremes, while protecting what is valuable and unique in him?

The fourth Aristotelian question asks how we might represent the essence of the phenomenon. The group leader, Terje Sagvolden, has promulgated one of the most encompassing theories of ADHD, involving both neurophysiological and behavioral mechanisms. Other members of the research team pursue other hypotheses, such as the heightened delay aversion shown by the ADHD child. None of these hypotheses, or others current in the field, are definitive. One of our purposes here is to test these theoretical structures and ascertain which one, or which parts of several, provides the best modern interpretation.

Aristotle also mentioned a fifth causal structure, circular causality. A man who exercises becomes more healthy, and thus is able to exercise

Functions compromised by ADHD

- Function is the *raison d'être* of behavior and cognition
- Effects modify input → Attention
- Effects modify substrate → Learning
- Effects modify model → Framing



Figure 4. Aristotle's 5th Cause – the feedback of action back into the system – affects the crucial higher functions of intellect: The objects we attend to, the things we learn about them, how we represent them and give them meaning by context.

more, becoming more healthy, Such feedback loops also exist in the behavior of organisms. It is this feedback which is particularly compromised in ADHD. Figure 4 shows how the output of a system feeds back to change it. If we are interested in an object we focus our attention on it, and thus come more strongly under the control of its nuances. But as the first letter of the disorder suggests, attention is one of the most severely compromised functions of afflicted individuals. When behavior has good results, it is reinforced, and we learn to engage in the behavior more effectively and regularly. This is learning. Learning is compromised in ADHD,

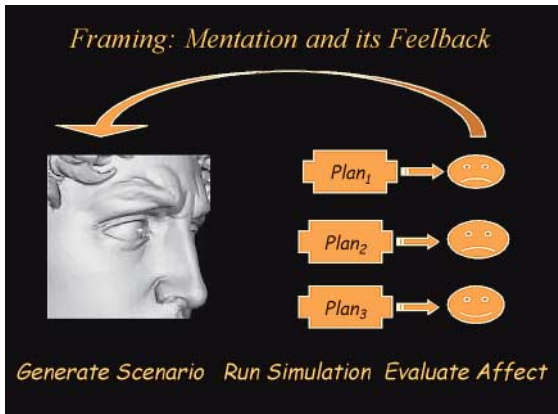


Figure 5. Generating alternative action plans, evaluating their likely emotional impact, and then selecting among them, is a singular human activity. In their rush to action, such deliberation is often severely compromised in ADHD children. We seek ways to give them back this gift of foresight.

as extended endeavors cannot be maintained without much higher rates of reinforcement than those that work for normal kids. When we lay plans to achieve goals, to do good, to enjoy goods, or to avoid harm, we may then be rehearsing the optimal scenario. This process greatly enhances our ability to achieve those

goals (Figure 5). ADHDers routinely fail to plan adequately, take precautions, or be guided by long-term goals.

Plato's Cave reminds us of the multiple perspectives that are necessary to resolve our shadows into a real form. Aristotle's model of comprehension identifies five of those perspectives which contribute to a complete understanding. It takes time and concentration to step back, pull apart, clarify, then re-weave these causal threads, time that we have found at the CAS. When Queen Victoria asked Michael Faraday of what use was the awkward toy device he was fabricating – something he called a “dynamo” – Faraday replied: “Madame, of what use is a baby?” Not all babies turn out well, nor do all ideas; but given a nurturing environment, both have enormous potential.

The Plasticity of Universal Grammar

There is no denying the great diversity of human languages and the deep differences among them, not just in vocabulary – that practically goes without saying – but in phonology, inflection, and the structure of sentences. These are things anyone can observe by comparing a few examples of sentences in just a handful of languages from different continents.

Linguists have taken two radically different views of this diversity, perhaps reflecting different metatheoretical orientations. On the one hand, it has been claimed that languages can vary without limit. Obviously this claim cannot be demonstrated or falsified by looking at the 6,000 or so languages spoken today. It would not even help to have access to all the thousands of languages spoken by our species over the last perhaps 100,000 years. Logically this is not an empirical claim, but it might still be true. On the other hand, it has been claimed that “grammar is substantially one and the same in all languages, and that surface differences between them are merely accidental variations”; thus Francis Bacon [1]. This old idea of a universal grammar underlying all languages has dominated linguistic thinking periodically since the Middle Ages and is still current.

These diametrically opposite views may seem irreconcilable, but they are actually not incompatible. The first is surely a useful reminder for the linguist who begins the investigation of a new language; he should be able to draw on previous experience without being constrained by it; he should keep an open mind and be prepared for the unexpected; we never do know what the next language will be like. The second view implies a serious research program, that of uncovering the principles of structure that can be hypothesized to underlie all human languages. Such a program was implicit in the theorizing of European structuralists in the last century, especially Hjelmslev and Jakobson, and has been advanced by their American successors, most forcefully, since the 1970s, by Noam Chomsky and his disciples.

Unlike his predecessors, Chomsky explicitly addressed the question of the nature of our innate capacity for language. In his view, every individual is born with a ‘Universal Grammar’, which is understood as a language matrix (he has called it a ‘language organ’ in the mind/brain) with a set of structural options for the syntax (and the phonology), and some basic principles of grammar formation, and, of course, plenty of storage space for a vocabulary (or lexicon). In this perspective, the ‘task’ of

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the language learner who is exposed to a community language is to select options (or set parameters) and acquire the lexicon in accordance with the way that language is spoken.

This conception of Universal Grammar assumes that the categories of language are universal and correspond to our equally universal cognitive categories. But there is in fact one cognitive category that is well represented in some languages but practically or totally absent in others. What is even more remarkable, in languages where this category is represented it shows an extreme degree of syntactic idiosyncrasy. Indeed this category gives the impression that it does not fit well into the normal molds of languages. It appears to test the limits of Universal Grammar, or, if we look at the matter from another angle, it demonstrates the plasticity of Universal Grammar.

The cognitive category in question is that of numbers.

Here I will say very little about the fact that some languages have no number words, or numerals (section 1) and only a little more about two problems numerals appear to represent for Universal Grammar. One problem is what we can call nomination. This is the problem of naming higher numbers by means of lower numerals – in the larger perspective, of coping with the infinity of numbers by means of finite linguistic means (section 2). The other problem is that of fitting number expressions into clauses, which is to assign them to (one or more) syntactic classes. This will be the topic of section 3.

Languages without numerals

Neurological research has determined that infants 5 months of age have a clear sense of numbers [2; see also 3, 4]. From this one might expect that numbers are universal, and that all languages would have numerals to represent them. But in fact languages are known that make or made no use of numbers and have no native numeral expressions, in New Guinea, Australia, the Andaman Islands, Brazil. There are not many languages in this category, but from the ones that are known we can confidently infer that where numeral systems exist, they are a cultural attainment, that is, they have developed (or been borrowed from other languages) because they were culturally motivated. This means that languages entirely without numerals, such as Dani (Papua) [5] or Pirahã (Brazil) [6] represent the original state of affairs of human languages. Such languages have the universal quantifiers (one, some, all, none) and relative quantifiers (many, few), but no numerals or no precise numerals; cf. Nadëb in (1). Some languages have ‘minimal’ systems, such as Amanab (2). In others, a minimal system has been supplemented with words for ‘hand’, ‘foot’ as in Alamblak (3). They suggest how minimal systems of numerals may have been elaborated in the past and, in time, begun to reach toward infinity.¹

(1) Nadëb (Brazil) 1: šæd, 2: pəwəp (also ‘3, a few’), 3: tamawəb; and words for ‘several’, ‘many’, ‘all’ [7].

(2) Amanab (Papua) ¹munɡu, ²sabaga, 3: ²sabaga ¹munɡu, 4: ²sabaga ²sabaga, 5: ²sabaga ²sabaga ¹munɡu [5].

(3) Alamblak (Papua) ¹rpa, ²hos, 3: ²hos-f-i-¹rpa-t, 4: ²hos-f-i-²hos-f, 5: ^{tir} ‘hand’, 10: ^{5tir} ²hos-f

15: ^{5tir} ²hos-f-i ^{5wura} yoht-t ‘two hands and one whole foot’.

6: <i>tir</i>	<i>yoht-t-i</i>	<i>anakor</i>	<i>tir-t-ho</i>	<i>rpa-t</i>
hand	whole-3SG:F-CONJ	other=side	hand-3SG:F-POSS	one-3SG:F

‘one whole hand and one from the other hand’ [5].

The nomination of numbers

The basic device for naming a higher number by means of lower numerals is to dissolve the number into addends, as in (2). Addends may be joined with a word for ‘and’ or ‘over’, as in the nursery-rhyme’s 24: ⁴four-and-²twen-¹⁰ty, German 24: ⁴vier-und-²zwan-¹⁰zig or Welsh 14: ⁴pedwar ar ¹⁰ddeg, or without one, as in Gm. 14: ⁴vier-¹⁰zehn, W. 15: ⁵pym-¹⁰theg, cf. W. 16: ¹un ar ⁵bym-¹⁰theg.

Addition may be supplemented with some use of subtraction (e.g., Latin 17: ⁷septen-¹⁰decim, but 18: ²duo-de-²⁰viginti, 19: ¹un-de-²⁰viginti) or with ‘overcounting’, e.g., Tibetan 15: ¹⁰teri ⁵pungu, but 16: ²⁰metsv maben ⁶trok, ... 19: ²⁰metsv maben ⁹tko, 20: ²⁰metsv, where *maben* means ‘before (i.e. on the way to)’ [9]. Addends may be more or less implicit as in Finnish 15: ⁵viisi-toista ‘five of the second [ten]’, as may other relational numbers, cf. Old Church Slavonic 25: ⁵pēti meždu ¹⁰desętima ‘five between (two) tens’; and, with overcounting, Lithuanian 15: ⁵penkio-lika ‘five left behind [towards 20]’.

Where multiplication occurs, it implies addition. Factors can be small or large. Karen (4) uses the most elementary one, *swá* ‘doubled’. Welsh and Breton are notable for their formations of 18: W. ²deu-⁹nau, Br. ³tri-⁶wec’h. Common factors are 10, as in English (²twen-¹⁰ty, ³thir-¹⁰ty, etc.), and 20, as in Dzongka (5) and Danish (6). These two also illustrate the use of fractions (divisions) in overcounting (e.g., Danish ‘half the third’ for ‘two and a half’), Danish, an explicit word for ‘times’ as well.

- (4) Karen (Tibeto-Burman) ¹ṑ- ²nṑ̃ ³sō, ⁴lwī, ⁵ngē, 6: ³sō swá, 7: ³sō swá ¹ṑ-, 8: ⁴lwī swá, 9: ⁴lwī swá ¹ṑ-, ¹⁰chṑ̃: swá ‘doubled’ [9].
- (5) Dzongka (Tib.-Burm.) 20: ²⁰khe ¹ci:, 30: ²⁰khe ¹2pjhe-da-²ñi: ‘twenty, half [a twenty] to two, 40: ²⁰khe ²ñi:, 50: ²⁰khe ¹2pjhe-da-³sum ‘twenty, half [of twenty] to three’, 55: ²⁰khe ³4ko ³sum ‘twenty, three quarters [of twenty] to three’, 60: ²⁰khe ³sum, ..., 100: ²⁰khe ⁵nga, 200: ²⁰khe ¹⁰cu-thām (thām ‘complete’), 300: ²⁰khe ¹⁰ce-⁵nga, 400: ⁴⁰⁰ñiçu ¹ci:, 600: ⁴⁰⁰ñiçu ¹2pjhe-da-²ñi: ‘four hundred, half [of four hundred] to two’, 1100: ⁴⁰⁰ñiçu ³4ko ³sum ‘four hundred, three quarters [of four hundred] to three’ [9].
- (6) Danish. 20: ¹⁰slyve [lit. ‘tens’], 40: ⁴fyrre-¹⁰slyve [‘four-tens’], 50: ¹2halv-³rdred-sinds-²⁰tyve [lit.: half-the-third-times-twenty], 60: ³tre-sinds-²⁰tyve [‘three-times-twenty’].
- (7) No. 10: *ti*, 10²: *hundre*, 10³: *tusen*, 10⁶: *million*, 10⁹: *milliard*, 10¹²: *billion*, 10¹⁵: *billiard*, ...
- (8) Mayan 10: *lahun*, 20: *hun*, 20²: ⁴⁰⁰bak, 20³: ⁸⁰⁰⁰pik, 20⁴: ^{160,000}calab [10].

Among languages that utilize multiplication, some make use of exponentiation. Base-10 languages like Norwegian (7) and base-20 languages like Mayan (8) are illustrative.

Thus, when we compare systems of numerals we see a progression from no numerals to atomic numerals, to numerals formed through arithmetic operations, and among these, from addition (and subtraction) through multiplication (and division) to exponentiation. It is reasonable to suppose that this progression in arithmetic sophistication has been driven by advances in cultural complexity [10].

Although many languages make use of words for the arithmetic operations required to compute a number from a phrasal (or compound) numeral (e.g., ‘and’, ‘times’), most commonly, addends and factors are simply juxtaposed; cf. (2), (4). This presupposes (i) that addition and multiplication are signified by distinct orders, as in Danish 104: ¹⁰⁰hundrede ⁴fire and 400: ⁴fire ¹⁰⁰hundrede; (ii) alternatively, if the same order is used for

addition and multiplication, then any numerals that serve both as addends and factors must have distinct shapes (or allomorphs) as in Eng. ⁻¹⁰*teen* and ⁻¹⁰*ty* (cf. 16: ⁶*six*-¹⁰*teen* and 60: ⁶*six*-¹⁰*ty*).

This seems perfectly reasonable, *ex post facto*. But it is in fact remarkable that these expression devices – allomorphy and element order – have been harnessed to those functions. Outside of phrasal (or compound) numerals, allomorphs are systematically synonymous and do not occur in the same environment. But these apparent allomorphs have been specialized to co-signify a number and an operation. On the other hand, alternative orders of identical lexemes are either excluded in a given language (cf. Eng. *(the) blue dress*, but not **(the) dress blue*), or they serve to indicate different information structure (cf. Russian *goluboe plat'e ~ plat'e goluboe* ‘(the) blue dress’), but not distinct ways of combining the referents of lexemes. In the construal of *(the) blue dress*, the reference potential of the phrase is the union of some individual dress and all things blue; there is no way the referents of the two constituents could be either added or multiplied.

What we have in the formation of phrasal (or compound) numerals such as 16: ⁶*six*-¹⁰*teen* and 60: ⁶*six*-¹⁰*ty* or Da. 104: ¹⁰⁰*hundrede* ⁴*fire* and 400: ⁴*fire* ¹⁰⁰*hundrede* are examples of linguistic means – allomorphy and element order – employed in functions that are alien to non-numeral language.

The external syntax of numerals

Unlike any other semantic class, numerals occur in different languages variously as verbs, as adjectives, and as nouns.

One specialist has inferred from this fact that numerals must basically be adjectives [11]. But one might as well draw the inference that Universal Grammar has no pre-ordained part of speech for numerals. In fact, a close look at numeral systems reveals that although numerals form a well-defined semantic class, they do not fit any part of speech particularly well and are commonly distributed among several.

Yurok is a language in which numerals are verbs, that is, 1–4 are verbs, whereas higher numerals 5 and 10 are nouns, constructed with a verb meaning ‘it is a collection’. The Yurok verb includes a classifier that shows what kind of thing the sentence is about; likewise also when there is a multiple of 10. The expression for ‘thirty-one logs’ breaks up into ‘there are three tens and there is one log’; see (9).

In other languages, numerals are adjectives or nouns. In Latin, all are adjectives except the plural of ‘thousand’ (10); in Lithuanian, 1–9 are adjectives, the rest are nouns (11); whereas in Old Church Slavonic, only 1–4 are adjectives and the rest are nouns (12). But note how in Latin, many numerals deviate from normal adjectives by having no inflection; in Lithuanian, it is 10 and its multiples that are uninflected. This morphological coyness of numerals fits in well with the fact that even though they sometimes look like adjectives (e.g., *the old books* like *the three books*), they mostly do not behave like adjectives. Books can be *old and dusty*, but not **three and eight*; they can be *very dusty* or *dustier*, but not **very eight* or **eighter*. Numerals are not a class of adjectives.

(9) Yurok *ceyk-ok* ‘it is narrow’ (*-ok*’s- CL ‘flat thing’), *¹koht-ok* ‘it is one (flat thing)’, *²no-ok* ‘it is two (flat thing)’, *³nahks-ok* ‘it is three (flat thing)’, *¹koht-e-r* ‘it is one’ (*-e-r*- CL ‘stick-like thing’); 1: *¹koht-e-r tektoh* ‘it is one log’, 2: *²na-a-r tektoh*, 3: *²nahks-e-r*

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tektoh, 5: ⁵*meruh tom-u'r tektoh* (tom- 'be a collection'), 10: ¹⁰*wehlowaa tom-u'r tektoh*, 13: ¹⁰*wehlowaa nima* ³*nahks-e'r tektoh*, 15: ¹⁰*wehlowaa nima* ⁵*meruh tom-u'r tektoh*, 20: ²*na'-ami* (-ami- CL 'numeral'), ¹⁰*wehlowaa tom-u'r tektoh*, 31: ³*nahks-emi* ¹⁰*wehlowaa nima* ¹*koht-e'r tektoh* 'there are thirty-one logs' [12].

(10) Latin [10].

Adjectives	Simple	Complex
Declined	¹ <i>unus</i> , ² <i>duo</i> , ³ <i>tres</i>	²⁰⁰ <i>ducenti</i> ³⁰⁰ <i>trecenti</i> ... ⁹⁰⁰ <i>nongenti</i>
Indeclinable	⁴ <i>quattuor</i> ... ⁹ <i>novem</i>	¹¹ <i>undecim</i> ... ¹⁷ <i>septendecim</i>
	¹⁰ <i>decem</i> , ¹⁰⁰ <i>centum</i> , ¹⁰⁰⁰ <i>mille</i>	²⁰ <i>viginti</i> , ³⁰ <i>triginta</i> ... ⁹⁰ <i>nonaginta</i>
Nouns	¹⁰⁰⁰ <i>milia</i> , nt.pl.	

(11) Lithuanian

	Simple	Complex
Adjectives	¹ <i>vienas</i> , ² <i>du</i> ... ⁹ <i>devyni</i> (pl.t.)	
Nouns	¹⁰⁰ <i>šimtas</i> , ¹⁰⁰⁰ <i>tūkstantis</i> , <i>milijonas</i> , ...	¹¹ <i>vieniolika</i> , ... ¹⁹ <i>devyniolika</i> (sg.t.)
Indeclinable	¹⁰ <i>dešimt</i>	²⁰ <i>dvi-dešimt</i> , ... ⁹⁰ <i>devynias-dešimt</i>

(12) Old Church Slavonic. Adjectives: ¹*jediniŭ*, ²*dŭva*, ³*trŭje*, ⁴*četyre*:

Nouns: ⁵*pęti* ... ¹⁰*desęti*, ¹⁰⁰*sŭto*, ¹⁰⁰⁰*fysqŭsta*, ^{10,000}*tŭma*.

What numerals really are is something different. Semantically they differ radically from nouns, adjectives and verbs. These parts of speech are used to describe what sorts of things, properties, or situations sentences are about; but numerals have no descriptive content. While the descriptive content of, say, a noun can help us identify its referent, a numeral can only tell us how many there are of whatever the noun refers to; thus the noun and the numeral provide us with truly complementary kinds of information, descriptive and quantitative [14]. It is significant that in some of the simplest numeral systems, such as Nadëb, the words for 'two' and 'three' have overlapping meaning; see (1) again. Here the kinship between numerals and the relative quantifiers 'few', 'many' is obvious. It is only through their later development that numerals have become distinct from the relative quantifiers by their absolute numerical value. Maybe such precise values arose only with the introduction of addition, as in Amanab (2).

It appears that throughout their development, numerals have been a liminal category in languages. We cannot say that numeral systems can vary without limit, but they stand out by their diversity of syntactic properties, often mixed and varying from language to language, evidence of makeshift extensions of grammatical devices that are basically used for other purposes. By their historical dependence on the development of cultures, numerals suggest an evolutionary perspective on Universal Grammar. It is apparent that during the time that numerals have existed in languages, our innate capacity for language has not evolved to accommodate this cultural attainment as a basic lexical/syntactic category. One can imagine that the existence of numerals will favor such an evolutionary step some time in the future. Looking back, one can wonder what sequence of prior developments in human culture have favored the gradual evolution of existing grammatical parameters and principles of grammar formation.¹

End-notes

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References

- [1] Robins, R. H. 1967. *A Short History of Linguistics*. London: Longmans.
- [2] Kobayashi, Tessei, Kazuo Hiraki, Ryoko Mugitani, Toshikazu Hasegawa. 2003. “Baby arithmetic: one object plus one tone”. *Cognition* 91.B23–B34.
- [3] Dehaene, Stanislas, E. Spelke, P. Pinel, R. Stanescu, S. Tsivkin. 21999. “Sources of mathematical thinking: behavioral and brain-imaging evidence”. *Science* 284.970–974.
- [4] Dehaene, Stanislas, Nicolas Molko, Laurent Cohen and Anna J. Wilson. 2004. “Arithmetic and the brain”. *Current Opinion in Neurobiology* 14.218–224.
- [5] Claudia Gerstner-Link. MS. “Typology of numeral systems in Papua languages”. Paper presented in a Workshop on Numerals in the World’s Languages, Max Planck Institute for Evolutionary Anthropology, March 2004.
- [6] Daniel L. Everett. MS. “On the absence of number and numerals in Pirahã”. Paper presented in a Workshop on Numerals in the World’s Languages, Max Planck Institute for Evolutionary Anthropology, March 2004.
- [7] Pattie Epps. MS. “Tracing the development of numerals in the Guaviareã-Japuraã (Maku) family”. Paper presented in a Workshop on Numerals in the World’s Languages, Max Planck Institute for Evolutionary Anthropology, March 2004.
- [8] Jadranka Gvozdanović. 1992. *Indo-European Numerals*. Berlin–New York: Mouton de Gruyter.
- [10] Martine Mazaudon. 2002. “Les principes de construction du nombre dans les langues tibéto-birmanes”. *Mémoires de la Société de linguistique de Paris* (Nouvelle série) 12.91–119.
- [11] Karl Menninger. 1958. *Žahlwort und Žiffer. Eine Kulturgeschichte der Žahl*. (2. neubearbeitete und erweiterte Auflage.) Göttingen: Vandenhoeck und Ruprecht.
- [12] James R. Hurford. *Language and Number. The Emergence of a Cognitive System*. Oxford: Basil Blackwell.
- [13] Juliette Blevins. MS. “The morphology of Yurok numerals”. Paper presented in a Workshop on Numerals in the World’s Languages, Max Planck Institute for Evolutionary Anthropology, March 2004.
- [14] Henning Andersen. 1998. “Does the past have a future. Reflections on the Jakobson Heritage”, *The Roman Jakobson Centenary Symposium, Copenhagen 10–12 October 1996* ed. by Per Aage Brandt et al., *Acta Linguistica Hafniensia* 29.149–177.

What is Space Weather?

Introduction

According to the US National Space Weather Programme (1995, 2000) space weather is defined as “conditions on the Sun and in the solar wind, magnetosphere, ionosphere and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and can endanger human life or health”. As our society becomes increasingly dependent on advanced technology systems, we become more vulnerable to the malfunctions of these systems. Sophisticated technology has reduced society’s risk from many natural disasters and increased safety and comfort in life, but through its own vulnerability, it has increased the risk of disturbances of the Earth’s environment that originate on the Sun.

For that reason, research on space weather is rapidly expanding. The main goals of space weather research are: (1) improvement of our understanding of the physical processes that shape solar-terrestrial relationships, (2) improvement of the empirical and physics-based models that can be used in forecasting, (3) development of tools to provide necessary data as the input for models.

In this article, intended for non-specialists, I will try to explain briefly what space weather is and why research in this area is so important. For those readers who are interested, a more complete review of space weather achievements and goals can be found in the references.

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Solar effects on the Earth’s environment

Earth does not float in empty space, but is immersed in the escaping outer atmosphere of the Sun (Figure 1). This ‘solar wind’ consists of ionized particles, mostly protons and electrons with a small admixture of helium ions. The density of solar wind is low, about 10 particles per cc. Solar wind also carries the Sun’s magnetic field, which at the Earth’s orbit has a strength of only a few nT, i.e. about 3000 times less than the magnetic field at the Earth’s surface. The wind speed at the Earth’s orbit is about 450 km/s or more. On its way the solar wind encounters the Earth’s magnetic field, which deflects the particles and shields the Earth from the direct effects of the solar wind.

In the absence of solar wind the geomagnetic field can be approximated by a dipole field with an axis tilted about 11 degrees from the spin axis. The force of the solar wind modifies this field, creating a cavity called the magnetosphere. The boundary between the geomagnetic field and solar wind, the magnetopause, is located at a distance of about 10 Earth’s radii from the Earth’s centre, but can move closer during high

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solar activity periods. In the anti-sunward direction the magnetosphere is extended into a long (~ 80 Earth' radii) tail, the magnetotail, filled with magnetic field lines that connect to the polar regions of the Earth. At the low-altitude limit, the magnetosphere ends at the ionosphere. The magnetosphere is filled with plasma that originates both from the ionosphere and the solar wind.

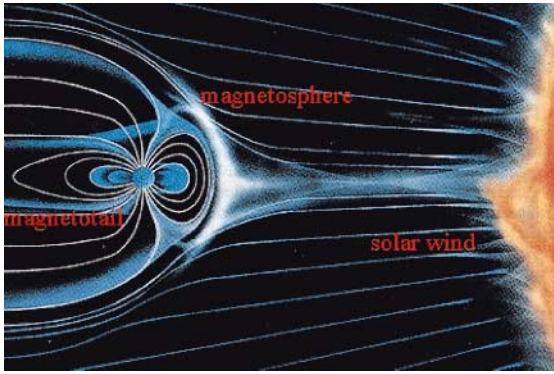


Figure 1. Solar wind overflowing the Earth's magnetosphere. (From *Meteorology Today* by C. Donald Ahrens © 1994 West Publishing Company)

The Sun is not a quiet, steady star, but undergoes considerable changes, sometimes extremely violent ones. These changes are transferred by the solar wind to the Earth and disturb its magnetic field. The regular changes in the level of solar activity over long-periods are known as the solar cycle. The duration of the solar cycle varies between 9.5 and 11 years. Usually, solar activity is measured by the number of sunspots on the solar surface (Figure 2). The solar cycle is also seen in the number and strength of the solar flares – tremendous explosions, in a localized region on the Sun. In a matter of just a few minutes they heat material to many millions of degrees and release as much energy as a billion megatons of TNT.

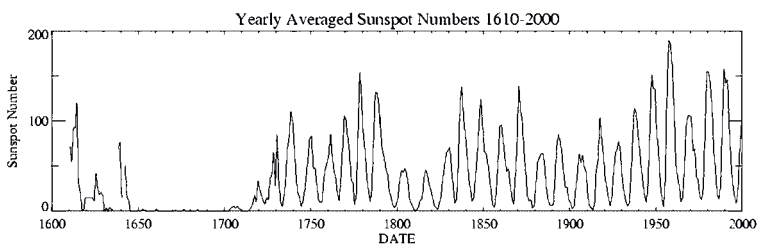


Figure 2. Yearly averaged sunspot numbers from 1610 to 2000. Note a virtual absence of sunspots from 1645 to 1715. This period is called the Maunder minimum or little ice age. (<http://www.spaceweather.com/glossary/sunspotnumber.html>)

The coronal mass ejections (CMEs) are yet another manifestation of solar activity. Coronal mass ejections are huge bubbles of gas threaded with magnetic field lines that are ejected from the Sun over the course of several hours. CMEs sometimes have higher speed, density and magnetic field strength than is typical of the solar wind and disrupt its flow producing disturbances that strike the Earth with sometimes catastrophic results. Large CME can contain a billion tons of matter that can be accelerated to many tens of MeV. The coronal mass ejection on April 7th, 1997 as observed by the SOHO spacecraft is shown in Figure 3. The structure travelled with a speed of 700 km/s. On April 11th, at 3 o'clock

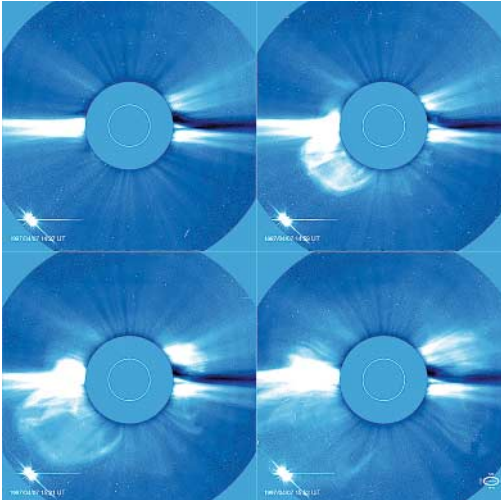


Figure 3. A sequence of images of the coronal mass ejection on April 7th, 1997 taken with LASCO (Large Angle and Spectrometric Coronagraph) on board the SOHO spacecraft. The radius of the large circle corresponds to 32 solar radii (approx. 22.4 million km). (<http://sohowww.estec.esa.nl/gallery/current/19970407/>)

After one solar rotation lasting 27 days, the active region reappeared on the solar disk again initiating an intense magnetic storm.

Solar energetic particle events precede CMEs. Particles ejected from the Sun are accelerated to very high energies by interplanetary shocks. The most energetic particles arrive at Earth within tens of minutes after the event on the Sun, penetrate into the Polar Regions to low altitudes and enhance electron density below 100 km.

Magnetic storms are usually the magnetosphere's response to the passage of the coronal mass ejection. During a storm, portions of the solar wind's energy is transferred to the magnetosphere, causing Earth's magnetic field to change rapidly in direction and intensity and energize the particle populations within it. At the same time the electrical currents are enhanced in the ionosphere and induced in the ground.

Associated with magnetic storms are ionospheric disturbances, manifestations of which are changes in the electron density and currents, and the appearance of electron density irregularities with sizes from thousands of kilometres down to centimetres.

The aurora is a light emitted from the polar upper atmosphere as the high-energy electrons bombard it from space. The aurora is probably the oldest known geophysical phenomenon. To an observer, the aurora is an exciting spectacle. Greenish or reddish strips forming draperies, rays and arcs, often stretching over a large portion of the sky, constantly moving and changing, appearing and disappearing. The altitude of the bottom edge of auroral structures is about 100 km. Figure 4 shows one of many woodcuts made by Fritjof Nansen depicting an aurora. In

universal time, the ground-based magnetometers recorded the sudden commencement of a severe magnetic storm. On the same day an aurora was observed in the northern part of the United States.

More recently, on October 29th, 2003, a huge CME reached the Earth, following a series of intense solar flares detected one day earlier. The CME had a speed well over 1500 km/s. The magnetic storm associated with this CME was one of the strongest ever observed.

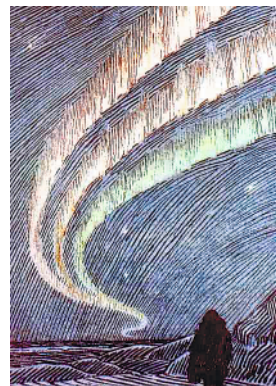


Figure 4. Aurora - a woodcut by Fridtjof Nansen. (<http://www.bellpondbooks.com/aurora4.htm>)

What is Space Weather?

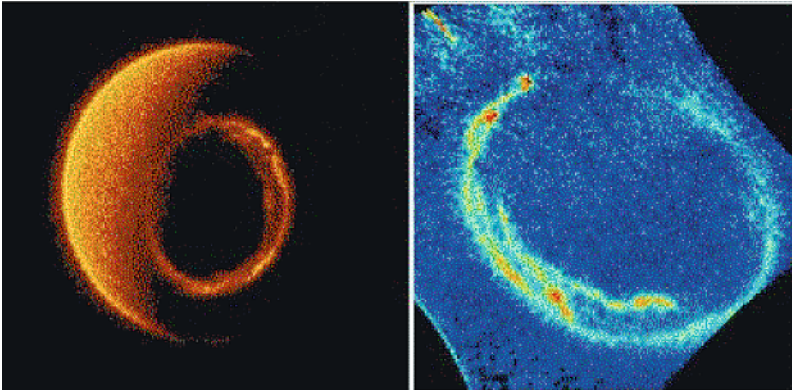


Figure 5. Satellite images of the auroral oval. Left panel: A Dynamics Explorer image from an altitude of 21000 km. The bright crescent is the sunlit dayside.

(<http://www-pi.physics.uiowa.edu/sai/gallery/>)

Right panel: A Viking image from an altitude of 6000 km taken at ultraviolet wavelengths. The Earth's magnetic pole is in the centre of the ovals.

(<http://www.phys.ucalgary.ca/satellites/html/viking.html>)

Figure 5 satellite images of aurorae are reproduced. The brightest aurorae form an oval with the magnetic pole at its centre. It expands equatorward during magnetically active periods, when aurorae become brighter and it contracts poleward during magnetically quiet periods.

Practical consequences of space weather

Many of the described phenomena associated with solar activity also have important practical consequences and must be taken into account in the design and operation of technological systems. Figure 6 illustrates some of the effects of solar activity on various systems.

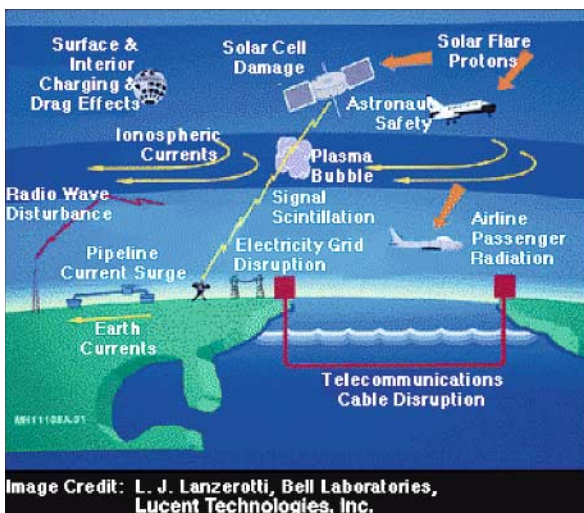


Figure 5. Some of the effects of solar activity on technical systems deployed on the Earth's surface and in space.

Radio communication and navigation

Radio communication links at all frequencies are affected by space weather. Especially sensitive are kHz and MHz links because they rely on wave reflection from the ionosphere. Changes in electron density may cause degradation, or disruption of radio waves propagating within the ionosphere. Ionospheric irregularities may produce signal fading so strong that a signal loss is encountered. Broadband radio noise emitted by strong

solar flares may interfere with a wanted signal making its detection impossible. At high latitudes streams of high-energy particles could increase ionization causing enhanced absorption of radio waves and preventing radio communication. Such radio ‘blackouts’ may last for many hours. Likewise, radio waves at higher frequencies (hundreds of MHz and GHz) that penetrate the ionosphere and are used on satellite radio communication links and navigation systems are affected when solar activity causes sudden variations in the density of the ionosphere. For instance, the Global Positioning System (GPS) uses signals from several satellites to measure the range to the satellites and determine the position of the receiver. Actually the range is determined from the propagation time between the transmitter and the receiver. This propagation time is dependent on the ionosphere electron density and therefore will change with solar activity. Use of dual-frequency GPS receivers can, to some extent, compensate for this effect. However, another ionospheric effect, scintillation or rapid fading of the amplitude and phase of the signal, can not be conquered so easily. Scintillation is caused by electron density irregularities that scatter and diffract radio waves. When the depth of fading exceeds a certain limit, the receiver fails to track the signal and the propagation time can not be measured.

Power systems

Geomagnetic storms can have a devastating and expensive effect on power systems. Currents induced by a variable magnetic field in the long transmission lines cause saturation of the transformer core. Associated increased heat may damage the transformer and release the relays shutting off the power. That is exactly what happened on March 13, 1989 when the whole of Quebec province was left without power for over 9 hours. The net cost of this ‘Quebec blackout’ was estimated at 13.2 million Canadian dollars. In addition to that, the purchase of replacement power cost about 17 million dollars.

Pipelines

A variable magnetic field can induce currents in long pipelines and surrounding soil. Under normal conditions, to protect against corrosion, the pipelines are equipped with special devices that keep the pipeline at a small negative potential with respect to the soil. During a magnetic storm this potential may increase above the safe value, the pipeline corrosion protection system fails, corrosion attacks the pipeline joints and its lifetime is reduced. In addition to that, possible leaks through the pipeline cracks may constitute a threat to the environment.

Radiation hazards

Normally, the atmosphere and magnetosphere protect us sufficiently well from solar high-energy radiation, but satellite operations, astronauts, and even passengers in commercial jets travelling at high altitudes are subject to elevated dosages of radiation. During severe magnetic storms, occurring on average 3 times per solar cycle, strong radiation affects computer memory chips causing loss of control, solar panels may be degraded, imaging equipment may be subject to noise, tracking instruments can lose orientation. At the same time, astronauts and aircraft passengers are

What is Space Weather?

exposed to the radiation equivalent of more than 10 chest x-rays. A primary means of reducing this hazard is to modify the flight path, which requires the ability to predict the occurrence of solar particle events.

Climate

There is increasing interest in the long-term effect of solar activity on climate change. There are well known periods when low sunspot activity was associated with cold climate conditions. The famous example is the Maunder minimum (see Figure 2) when the weather was so cold that ice covered the Baltic Sea.

Recent measurements show that solar irradiance varies over the solar cycle by as much as 0.1 %. It is very unlikely that such a small variation produces measurable climate changes. Antropogenic agents are probably of higher importance. However, we can expect that long-term variation, possibly with larger amplitude, could influence the global climate.

Final remarks

Accurate specification and forecasting of space weather may help system operators to take necessary action in advance and will aid in the design of less vulnerable technological systems. For this purpose, special space weather services, similar to the meteorological services, have been formed in many countries. They use large banks of data and sometimes very sophisticated models to provide necessary information to interested services, military and civil. However, one should understand that solar-terrestrial relationships are extremely dynamic and complex, and some requirements established by users are difficult or not possible to meet. As yet!

Acknowledgements

Let me express my sincere thanks to my hosts Prof. Hans Pecseli and Prof. Jan Trulsen for inviting me to CAS. I am also grateful to Prof. Willy Østreng who encouraged me to transform the lunch talk into this article.

References

- Carlowich, M., R. Lopez, Storms from the Sun: the Emerging Science from Space Weather, National Academies Press, 2002.
- Freeman, J. W., Storms in Space, Cambridge Univ. Press, 2001.
- Lanzerotti, L. J., D. J. Thomson, and C. G. MacLennan, Engineering issues in space weather, in Modern Radio Science 1999, ed. M. A. Stuchly, International Union of Radio Science, Oxford Univ. Press, 1999.
- National Space Weather Program, Strategic Plan, FCM-P30-1995, Washington DC, 1995.
- National Space Weather Program, The Implementation Plan, FCM-P31-2000, Washington DC, 2000.
- Space Weather, eds. P. Song, H. J. Singer, and G. L. Siscoe, American Geophysical Union, Washington DC, 2001.

Neural Assemblies, Corticostriatal Interactions, and the Serial Organisation of Behaviour: Steps toward a Formal Theory

The cerebral cortex of the brain (see Fig. 1A) is the grey matter that covers its surface. It is composed of nerve cells, the majority of which are pyramidal neurons. Deep in the cerebral cortex lies a large mass of subcortical grey matter known as the striatum. The majority of the nerve cells in the striatum are spiny projection neurons. The nerve cells within the cerebral cortex and the striatum are interconnected with each other by excitatory and inhibitory synaptic connections, respectively, and the two nuclei are connected together to form a re-entrant circuit (Fig. 1B). Although many of the brain's higher functions, such as perception, cognition and language, have been attributed to the cerebral cortex, the functions of the striatum have remained poorly understood. Because diseases of the striatum (such as Parkinson's disease and Huntington's disease) are associated with conspicuous disorders of movement, the striatum has been considered to be a centre for the control of movement, subservient to the cerebral cortex. Recently this view has changed. We now recognise that the striatum is involved in many aspects of behaviour, including but not limited to movement, and extending to higher functions such as thought, language and learning.

The theory of the cerebral cortex is more advanced than the theory of the striatum. In 1949 the

psychologist, Donald Hebb, proposed a theory for how things might be represented in the brain. In Hebb's theory, things are represented by assemblies of active nerve cells, each of which individually encodes

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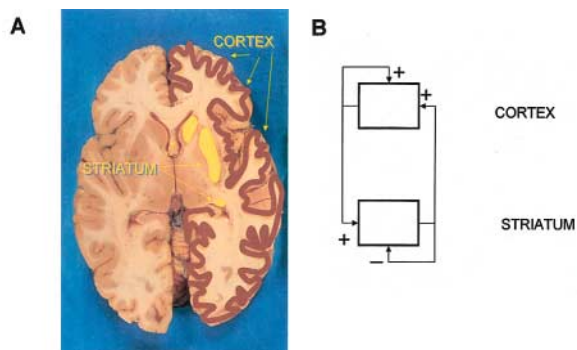


Figure 1. Anatomy of the corticostriatal system. A. Location of the cerebral cortex and striatum in the human brain. Horizontal section. B. Diagram of major excitatory and inhibitory interactions within and between the cerebral cortex and striatum.

specific features of the thing (Hebb 1949). For example, a cell assembly for an equilateral triangle might be composed of nerve cells that represented different corners (with angles of sixty degrees) or edges (of certain orientation). Activation of the nerve cells in an assembly would then correspond to getting the idea of the thing.

Hebb proposed that the nerve cells in an assembly are more strongly connected to each other than to other nerve cells that are not part of the assembly. Activity in some subset of the assembly could spread along the stronger neural connections and lead to ignition of the whole assembly. For example, if we just present the corners of a triangle, without the edges, the cell assembly for the whole triangle can be ignited by spreading activation. The ignition of a cortical cell assembly is a kind of information processing that arises naturally from the dynamics of brain-like networks of nerve cells (Wickens and Miller 1997). This brain-style information processing in the cerebral cortex has useful properties. For example, ignition of cell assemblies is a fast way to perform computations that are quite demanding for digital computers, such as completing a pattern.

Cell assemblies are formed by a process of synaptic modification which strengthens the connections between cells which are repeatedly coactivated. This occurs according to a synaptic modification rule (Hebb 1949), which states that the connection from one neuron to another will be strengthened if the first neuron repeatedly and persistently takes part in firing the second. Synaptic modification according to this rule has been described in many brain areas. Experimentally, Hebbian synaptic modification has been studied in the form of long-term potentiation (LTP). This is a long-lasting increase in synaptic efficacy which follows a conjunction of presynaptic and postsynaptic activity (Bliss and Lomo 1973).

In the past, cell assembly theory has mainly been applied to perception (Braitenberg 1978; Palm 1982). It provides a good model for pattern completion, in which a pattern is recognized despite having missing pieces. After a pattern has been presented many times, the neurons which respond to its presentation become bound together into an assembly by the synaptic modification rule described above. Recognition of an incomplete pattern occurs because the incomplete pattern activates a sufficiently large subset of the elements to bring about rapid spread of activity to all the elements of the cell assembly. In this way the representation of the whole pattern can be recovered from a part of it.

Application of the cell assembly to the question of motor programming began with the proposal (Braitenberg and Schüz 1991) that a cell assembly which included cortical neurons with axonal connections to the motor output organs could represent a motor response in addition to representing the perception that led to it. Assuming that the ignition of a cell assembly occurs in a certain sequence, for example based on the different threshold of the pyramidal cells, this could provide a temporal structure for the activation of muscles involved in a movement (Wickens et al. 1994). However, the time-scale of such a process is probably less than a second. Thus, while it might explain the serial organisation of a sequence of muscle contractions involved in one syllable, it is not a promising explanation for the serial organisation of words in a sentence (Pulvermüller 2002). This requires a mechanism that can orchestrate the sequential activation of different assemblies.

Several pieces of evidence suggest that the striatum may be important in the serial organisation of complex behaviour. Electrical stimulation of the striatum, conducted in the course of neurosurgery, resulted in disturbances of verbal counting behaviour (Van Buren 1962). Another piece of evidence comes from an inherited speech and language disorder due to a mutation of FOXP2. This gene is associated with abnormalities in the striatum (Watkins et al. 1999). FOXP2 is found highly expressed in the striatum (Takahashi et al. 2003). These observations suggest that abnormalities in the striatum may be associated with impaired sequencing, but

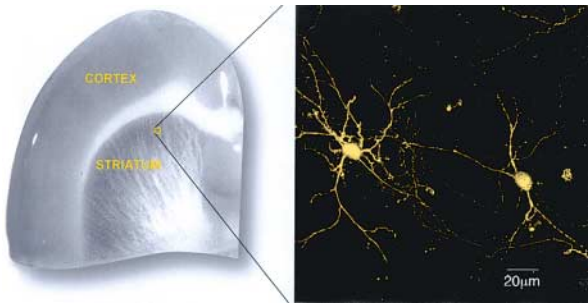


Figure 2. Experimental preparation for measuring inhibitory interactions in the striatum. Rat brain slice, showing region from which simultaneous recordings of pairs of spiny cells were made. Enlargement shows a pair of spiny cells filled with dye in the course of intracellular recording.

do not explain how the striatum normally contributes to this function.

What is the mechanism by which the striatum contributes to the organisation of sequences of neural assemblies? One possibility is that inhibitory interactions among

the spiny projection neurons bias these neurons to respond in a certain order. We have recently demonstrated inhibitory interactions between the spiny projection neurons (Tunstall et al. 2002). This was done by making simultaneous measurements from inside two spiny neurons, of the effect that the firing of one spiny neuron had on the other (Fig. 2). These interactions were asymmetrical, in that they were not reciprocal. Computer simulations (Wickens et al. 1995) have shown that a network of spiny neurons interconnected by asymmetrical inhibitory connections will exhibit slow travelling wave activity in response to a constant, uniform input (Fig. 3).

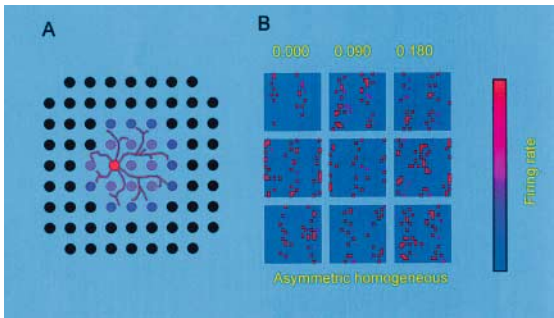


Figure 3. Simulation of network activity of the striatum. A. Connectivity of individual nerve cells in the model network. The edges of the network are connected to their opposite sides to form a 2D torus, in order to avoid edge effects. Asymmetric connectivity is assumed in this model. B. Slow travelling waves arising in response to uniform synaptic input. Panels in the vertical direction are 30 msec apart.

In the context of corticostriatal interactions, this bias to respond in a certain order may help to ensure that certain sequences of neural assembly activation are permitted, while others are prevented from occurring. To illustrate this idea with an example from language, if we assume that each neural assembly represented a word, the striatum may ensure

that only certain sequences are possible (Fig. 4). In the example, for instance, “the man with the tie” is allowed, but a sequence such as “the with” or “the the” would be prevented by the inhibitory connections between the corresponding striatal cells.

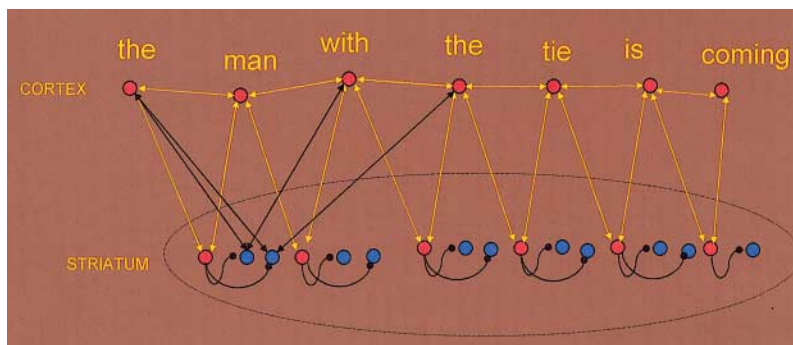


Figure 4. Conjecture about the contribution of the striatum to serial activation of neural assemblies. Inhibitory connections in the striatum create a bias towards certain sequences of neural assembly activations that are supported by corticostriatal interactions. Arrows represent excitatory connections. Black dots represent inhibitory connections. Yellow connections are active. Black connections are inactive.

In order to make flexible use of the sequencing potential of the striatal network some plasticity is required. This probably occurs at the level of the corticostriatal synapses. These synapses are modifiable by a mechanism that is similar to LTP in some ways, but different in others. Potentiation of corticostriatal synapses requires, in addition to a conjunction of presynaptic and postsynaptic activity, the release of dopamine (Reynolds et al. 2001; Wickens et al. 1996). Dopamine is a neurochemical released in response to rewarding events, and required for certain types of learning. Thus, the corticostriatal system can be thought of as an adaptive sequencing device.

In attention-deficit hyperactivity disorder (ADHD) there is thought to be a dysfunction of some corticostriatal circuits, particularly those involving projections to the striatum from the prefrontal cortex. These circuits are not primarily associated with speech and language, but play an important role in planning action and maintaining a working memory during task performance. There is also thought to be a dysfunction of the dopamine system in ADHD. One aspect of ADHD to which the foregoing may be especially relevant, is the difficulty that children with ADHD have in integrating the consequences of their past actions into the organisation of their future actions. The foregoing suggests that this difficulty may reflect an impairment of the adaptive sequencing capabilities of the corticostriatal system.

Summary

Hebb (1949) proposed that neural assemblies may constitute the neural substrate of representation in the brain. This is a powerful idea which is consonant with many results of experimental research. The theory of neural assemblies was originally developed to explain perceptual phenomena, such as pattern recognition. Recently, the theory has been extended to the representation of movements and complex behaviour. Such behaviour is generally governed by rules. The serial ordering of actions involved in speech provides an excellent example, where the rules

constitute a grammar. Interactions between the cerebral cortex and the striatum, a subcortical nucleus in the basal ganglia of the brain, may be necessary to account for rule-governed progression of neural assembly activity. Anatomical details of the microcircuitry of the striatum and its interconnections with the cerebral cortex suggest a plausible mechanism for the serial organisation of behaviour. Dysfunction of the corticostriatal interactions may contribute to problems in the serial organisation of behaviour in children with ADHD.

References

- Bliss, T.V.P. and Lomo, T. Long-lasting potentiation of synaptic transmission in the dentate area of the unanaesthetized rabbit following stimulation of the perforant path. *J Physiol* 232: 331–356, 1973.
- Braitenberg, V. Cell assemblies in the cerebral cortex. In: Heim R, Palm G (eds), *Theoretical approaches to complex systems*, Springer: Berlin, 1978, p. 171–188.
- Braitenberg, V. and Schüz, A. *Anatomy of the cortex: Statistics and geometry*. Berlin: Springer, 1991.
- Hebb, D.O. *The organization of behaviour: A neuropsychological theory*. New York: Wiley, 1949.
- Palm, G. *Neural Assemblies*. Berlin, Heidelberg and New York: Springer, 1982.
- Pulvermüller, F. A brain perspective on language mechanisms: from discrete neuronal ensembles to serial order. *Prog Neurobiol* 67: 85–111, 2002.
- Reynolds, J.N.J., Hyland, B.I. and Wickens, J.R. A cellular mechanism of reward-related learning. *Nature* 413: 67–70, 2001.
- Takahashi, K., Liu, F.C., Hirokawa, K. and Takahashi, H. Expression of Foxp2, a gene involved in speech and language, in the developing and adult striatum. *J Neurosci Res* 73: 61–72, 2003.
- Tunstall, M.J., Oorschot, D.E., Kean, A. and Wickens, J.R. Inhibitory interactions between spiny projection neurons in the rat striatum. *J Neurophysiol* 88: 1263–1269, 2002.
- Van Buren, J.M. Confusion and disturbance of speech from stimulation in vicinity of the head of the caudate nucleus. *J. Neurosurg* 20: 148–157, 1962.
- Watkins, K.E., Gadian, D.G. and Vargha-Khadem, F. Functional and structural brain abnormalities associated with a genetic disorder of speech and language. *Am J Hum Genet* 65: 1215–21, 1999.
- Wickens, J.R., Begg, A.J. and Arbuthnott, G.W. Dopamine reverses the depression of rat cortico-striatal synapses which normally follows high frequency stimulation of cortex in vitro. *Neuroscience* 70: 1–5, 1996.
- Wickens, J.R., Hyland, B. and Anson, G. Cortical cell assemblies: A possible mechanism for motor programs. *J. Mot Behav* 26: 66–82, 1994.
- Wickens, J.R., Kotter, R. and Alexander, M.E. Effects of local connectivity on striatal function: Simulation and analysis of a model. *Synapse* 20: 281–298, 1995.
- Wickens, J.R. and Miller, R. A formalisation of the neural assembly concept: 1. Constraints on neural assembly size. *Biol Cybern* 77: 351–358, 1997.

Turbulence in the Environment: Why should we Care?

Turbulence in fluids and plasmas is one of the least understood topics in classical continuum physics. The problem is inherently related to chaotic, randomly varying flows, and a simple visual inspection of one single realization might indicate that any attempt to make a nontrivial prediction will be futile. Figure 1 shows an illustrative experiment, where turbulence develops at injection of a high speed “jet” into quiescent surroundings. It came as a surprise when it was demonstrated in the beginning of the 1940-ies that accurate and surprisingly simple analytical expressions could be obtained for some basic statistical averages. For neutral flows, the interest was first concentrated on the *structure functions*, describing some



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average properties of the spatial velocity variations. These analytical predictions were verified experimentally to a good level of accuracy.

In spite of significant progress in the studies of turbulence in neutral flows (in water, the atmosphere, etc.), there are still several basic problems, which are not fully understood. As far

as plasmas are concerned (i.e. gases composed of charged particles) the situation is even more unfavourable. In this case the sensitivity of the gas to electric and magnetic forces adds to the complexity of the problem, and progress has only been made by significant simplifications, which are not always justifiable. It is, however, important that we improve our understanding of turbulent plasmas, since most of the matter on astrophysical and heliospheric scales is in the plasma state, and is often found to be strongly turbulent.

One of the most important properties of turbulent fluctuations in fluids as well as plasmas is their ability to

Figure 1. The figure shows results from a laboratory experiment with a “jet”, where an energetic fluid beam is injected from a localized region in the system. The evolution of a random, turbulent flow is evident, as the injected material propagates at high speed from bottom to top in the figure. Note that the turbulence is manifested in the form of many vortex-like structures, with widely differing scales. Strong turbulence is characterized by having substantial energy distributed over scales of many different sizes.



disperse particles at an anomalously large rate. It is easily demonstrated that in the atmosphere, for instance, the diffusion due to thermal fluctuations is totally negligible. Pollution due to the dispersal of industrial waste would not pose any significant problem, if we had to be concerned with only this mechanism for long distance dispersal of contaminants.

Unfortunately, at least in this respect, the atmosphere is usually in a turbulent state, and the turbulent motions are very effective in dispersing particles. Similar observations apply to matter in the plasma state. This implies, for instance, that boundaries in space are maintained only to the extent allowed by the “smoothing out” due to turbulent transport. Magnetized plasmas pose here a particularly important problem: at least under ideal conditions, it should be possible to confine hot dilute plasmas indefinitely by magnetic fields. The fact that turbulent electric fields are transporting plasma across magnetic field lines poses a serious problem for plasma confinement. From a technical point of view, it is expected that turbulent transport across magnetic field lines constitutes the ultimate limitation for confinement of hot plasmas in magnetic fusion experiments, and a number of turbulence related problems have been intensively studied in that context. It has also been found that the conductivity of plasma is controlled by turbulence. This latter problem has been studied even less than turbulent transport, but it is expected to be central for the understanding of the large scale current systems associated with the Earth’s magnetosphere.

As an illustrative example for demonstrating the importance of turbulence in the environment, we discuss here the case of aquatic micro-organisms. It is well known that micro organisms in the oceans have very little motion of their own, and can be seen as small particles passively carried along with the local flow velocity. Their food (plankton etc.) is also passively convected by the flows in the environment.

In quiet waters, micro-organisms (fish larvae and similar) will therefore be starving because no food enters their immediate vicinity, unless there is a “mixing”, which changes the relative distances between predator and prey. The only effective agency for mixing in the environment is turbulent motion. Turbulence is therefore very important for the feeding processes of micro organisms, and studies of the problem of turbulent transport are consequently a mainstream activity in biological sciences. From a mathematical point of view, this problem becomes interesting by involving an “active” boundary, here being the surface of the sphere and having the “reach” of the micro organism as a radius (see Figure 2). This is in contrast to the more standard problem with open systems. This active

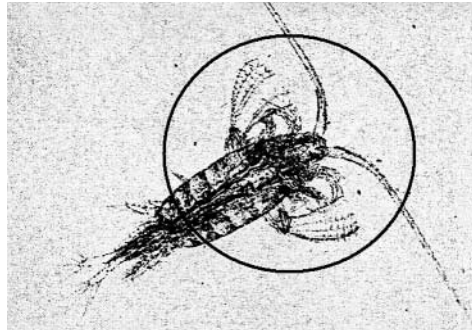


Figure 2. We show here as an illustration “Centropages violaceus”, a marine-planktonic copepod. Surrounding it, we might draw a circle, with radius R , illustrating an imagined sphere of influence, with the implication that any prey entering this sphere can be captured.

boundary can here be seen as a perfect absorber, in the sense that we can expect the micro-organism to capture and digest food particles that come within its reach.

Some basic results can be argued by simple dimensional reasoning: We can thus state that the flux, \mathcal{J} , to the surface of interception is measured in units of prey pr. time unit. The density of prey, \mathcal{N} , is not a significant parameter, since by doubling the prey density we simply double the prey flux. We are thus lead to consider the quantity \mathcal{J}/\mathcal{N} , which is measured in units of $length^3/time$, but it is up to the observer to decide what the actual units for length and time are. For length, we can take the radius, R , in the sphere of interception, which is the only natural length scale for the problem, as long as R is larger than scales where viscous dissipation is important (for most relevant problems approximately $0.1 - 0.2$ mm), while at the same time R is much smaller than the largest structures characterising the turbulence. The relevant time scale must somehow depend on the intensity of the turbulence: with the expectations outlined before, nothing happens without turbulence, and the corresponding time scale is infinite! Turbulence is best characterized by its energy supply, ϵ , which is defined here as the energy dissipated pr. gram fluid pr. time unit. Now, the units of ϵ are $length^2/time^3$, and the only way we can construct a unit of time is by the combination $(R^2/\epsilon)^{1/3}$. Consequently, we expect that we can write the normalized flux as $\mathcal{J}/\mathcal{N} = R^{7/3} \epsilon^{1/3} f(t(\epsilon/R^2)^{1/3})$, with f being a dimensionless function of a dimensionless time-variable. We do not know the function f , but might argue that it approaches a constant for $t \rightarrow \infty$. This conjecture is reasonable from a physical point of view, and it can be tested experimentally. Since f was dimensionless, its asymptotic

value is just a universal number, and the parameter variation of \mathcal{J}/\mathcal{N} is then given by the coefficient $R^{7/3} \epsilon^{1/3}$. This scaling law has found experimental support, see Figure 3. It predicts, maybe somewhat unexpectedly, that in order to double the prey flux to an aquatic micro-organism, the energy to the turbulence must be increased eightfold! On the other hand, by doubling its reach, a

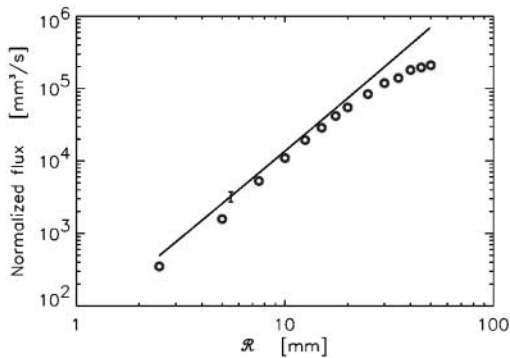


Figure 3. Experimental results from a model laboratory experiment, where the role of micro organisms is taken by small polystyrene spheres. The circles indicate the observed average particle fluxes to a representative “predator”, as a function of its “reach” R on a double logarithmic scale. The full line gives the theoretical $R^{7/3}$ result.

micro-organism gains more than the factor of four increase in the surface of it sphere of interception, which would only give $R^2 \equiv R^{6/3}$, so the last factor $R^{1/3}$ is gained due to the distribution of energy in the turbulent scales.

This simple model problem (yet important in nature) can, however, also illustrate one of the central, and for the time being not fully resolved, problems in studies of turbulence. We have thus implicitly assumed that

EVERY predator was exposed to the same fluctuation level, as accounted for by ϵ . This is of course not correct: it is easily verified that some regions of space have enhanced levels of turbulent fluctuations, other smaller, and that the distribution of these regions varies randomly with time. When we take the appropriate averages, we have made an approximation which is unaccounted for, by implicitly replacing ϵ by its average $\langle \epsilon \rangle$. In other words: for a dimensional analysis as the one advocated before, we have both $\langle \epsilon^{1/3} \rangle$ and $\langle \epsilon \rangle^{1/3}$ being dimensionally correct (here, $\langle \rangle$ denotes statistical averages), but with ϵ being a randomly varying quantity, the two quantities are of course different. Experience shows that the approximation obtained by identifying ϵ by $\langle \epsilon \rangle$ works well in practice for the present class of problems, but it is nonetheless a flaw in the analysis, which is closely related to the so-called “intermittency” problem.

The analysis outlined before was somewhat restrictive, in assuming the predator to be absolutely immobile with respect to the flow. Such a simple model is a useful starting point, but studies of movement strategies for small organisms in a turbulent environment indicate that such an organism is in general able to move, at least a little, with respect to the surrounding flow, which itself is in turbulent motion. This problem is presumably studied best by numerical simulations, which are now in progress.

References

- J. Mann and S. Ott, H. L. Pécseli, and J. Trulsen, *Predator-prey encounters in turbulent waters*, Physical Review E, Volume 65, 026304 (2002)

Language Acquisition as the Locus of Grammatical Change

Modern linguistics makes a fundamental distinction between linguistic *utterances* and *grammar*. The utterances are observable manifestations of language – spoken, written, or signed. The grammar is the system underlying the linguistic utterances, a set of rules and principles which *generate* the language. The grammatical system is the real object of theoretical linguistics. We are interested in the system underlying the observable linguistic utterances, not the utterances *per se*. They are our *data*, not our object of study. Our project here at the CAS is concerned with change in language through history. Not changes in the inventories of linguistic utterances, but changes in the grammatical system underlying the utterances.



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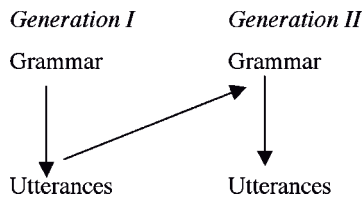
Our most important historical data are of course written documents, which can be of many different kinds, depending on the age, the type of culture, the writing system, etc. It is the task of philologists to interpret the documents and establish what is actually written in them. But there is

further challenge facing historical linguists, in fact all linguists to varying degrees, and that is to try to establish the relationship between the observable linguistic utterances and the underlying grammatical system.

A grammar is a kind of *knowledge* about the system which generates language, and which enables us to produce and understand utterances in our own language (Chomsky 1986, Anderson & Lightfoot 2002). Knowledge is a state of mind, a mental object, and it is thus a property of the *individual*. Linguistics is the science studying a particular kind of human knowledge. This creates a paradox for historical linguistics: if language belongs to the individual, it dies with the individual, and has thus no history beyond the life span of the individual. Although no one will deny the individual mental existence of language, historical linguistics also sees language in another perspective, as a property of the community. This mode of existence is of course what makes it possible to use language as a means of communication, and this *communal* language certainly has a history.

Language has its historical communal existence because it is acquired by the children of each new generation. The acquisition of the mother tongue by infants is perhaps the most perplexing mystery of linguistics. Perhaps the greatest challenge facing theoretical linguistics is to try to understand how this is possible. Children start the process of learning their first language as soon as they are born, perhaps even before, and by the age of four at an average, they master the grammar of their first language perfectly. This is a spectacular achievement, given the enormous

complexity of human language. All normal children who grow up under regular circumstances automatically learn to speak. It is not something they decide to do or are forced to do, and they do it on the basis of rather poor and inadequate stimulus. Children are exposed to lots of incomplete and ‘incorrect’ utterances, and all sorts of sounds that are not language at all. Learning a language seems to be a kind of instinct (Pinker 1994), and what makes the acquisition possible is an innate language faculty, also called *Universal Grammar* (UG). The two necessary conditions for acquiring a mother tongue in infancy are then the innate language faculty and the linguistic input from the environment. UG gives you what is common to all languages and determines what is a possible language, and the utterances in the environment determine which language you are learning, and which of the alternatives that are offered by UG becomes your language. Here is a model of language acquisition:



Historical linguistics is interested in how and why grammars change from one generation of speakers to the next, but as you can see from this model, grammars are not transmitted directly between generations. Generation II acquires its grammar, not from the grammar of Generation I, to which they have no direct access, but by abduction from the concrete utterances of the previous generation (Andersen 1973, Faarlund forthcoming). On the basis of this input, they construct their own grammar.

If there is a universal grammar and a shared human capacity to learn language, the question is of course why there are different languages in the world. The reason is that languages do change. If groups of users of the same language for some external reason are separated and cease to communicate with each other, their respective languages may change in different directions up to the point where they become so different that they no longer understand each other. At this point we have two different languages.

The question is, however, why languages and grammars change at all. Why don't new generations always acquire the same grammar as that of previous generations? UG contains a set of *parameters*, which can be understood as a choice between two values for a certain grammatical feature. When the infant analyzes the linguistic utterances of the environment in order to establish its own grammar, it has to set the value for each of those parameters. One way that languages may differ, is in the order of elements within the sentence. There is thus a parameter which determines the order of verb and object in the sentence. In many languages the rule is that the verb precedes its object, as in English: *He has read the letter*. We find the same order in today's Scandinavian languages. In other languages the order is the opposite, as in German: *Er hat den Brief gelesen* (lit. 'he has the letter read'). Those languages then have different values for this parameter. On the basis of the linguistic input from the environment, the infant sets the value for this parameter. Now it turns out that in many languages, including many Germanic languages, there has been a change from

object-verb order to verb-object order. In the oldest Scandinavian texts we find the object-verb order. Here is an example from a text written in the runic alphabet on a golden horn from the 5th century AD, found in Jutland in Denmark:

ek hlewagastiz holtijaz horna tawido

I, Hlewagasti of-Holt, horn made

The two final words show the object-verb order, so there has been a change taking place in Scandinavian, as in English, and several other languages. This means that at some point in history, children learning a Scandinavian language have changed the value of this parameter from object-verb to verb-object. This can only have happened on the basis of the linguistic input from the environment. We do not know precisely what happened at that time, but at some point new learners of the language must have been exposed to utterances with the object after the verb. This may have happened because some speakers began to place the object at the end in certain contexts, perhaps in order to obtain a certain stylistic effect or in order to emphasize a word, or it may have been due to influence from speakers of a foreign language.

In many cases the actual external causes are hidden in the darkness of prehistory, but we believe that we are gradually uncovering enough of the nature of human language at least to understand the general principles underlying language change.

References

- Andersen, Henning. 1973. Abductive and deductive change. *Language* 49, 567–595.
- Anderson, Stephen R. and David W. Lightfoot. 2002. *The language organ. Linguistics as cognitive physiology*. Cambridge: Cambridge University Press.
- Chomsky, Noam. 1986. *Knowledge of language: its nature, origin, and use*. New York: Praeger Publishers.
- Faarlund, Jan Terje (forthcoming) *A mentalist interpretation of grammaticalization theory*.
- Pinker, Steven. 1994. *The Language Instinct*. London: Penguin.

Language and Mental Health Disorders: The Case of ADHD

Introduction

The faculty of language, conceptualized as an outward behavioural expression of one mode of thought (symbolic representation), appears to be a uniquely human capacity.¹⁻² On the one hand its precise nature and evolution remain resistant to full understanding by its human users. On the other hand, both lay and professional members of a particular language community develop clear intuitions about the community norms of language behaviour, adjusted for speakers of different ages and cultures, and for different social purposes. These intuitions are then used to judge when an individual's language behaviour is atypical.³⁻⁴ This essay concerns the recognition, characterization, and pathogenesis of atypical language in a common mental health disorder of childhood – Attention-Deficit/Hyperactivity Disorder.

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Attention-Deficit/Hyperactivity Disorder (ADHD)

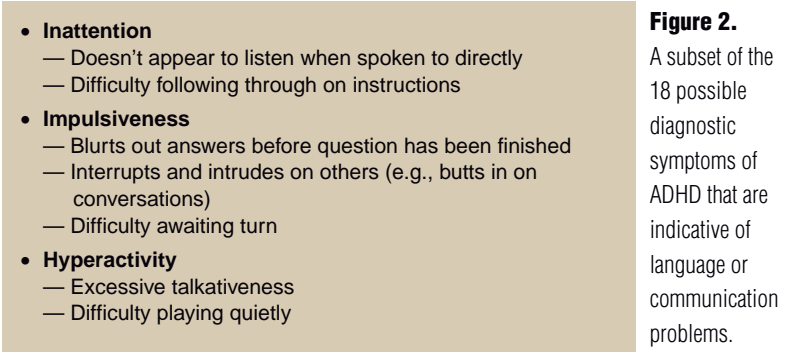
ADHD is characterized by persistent, cross-situational, developmentally inappropriate and impairing levels of inattentive, impulsive and hyperactive behaviour. It is a major public health concern because of its prevalence (occurs in about 10% of children and 4% of adults across different cultures and countries), chronicity, increased risk for additional and serious psychopathology in adulthood, and detrimental effects on the

individual's educational, social, and occupational attainments that are valued by society.⁵⁻⁷ Conceptualized as a neurobiological disorder, ADHD has high heritability (comparable to that of height) and a genetic basis.⁸ Yet, this common 'disorder' lacks any biological markers and the diagnosis relies on descriptions

Child: "What are we gonna do next? Huh? What's in there? What's that?" (interferes by grabbing test materials)
Adult: "You'll see *in a sec*"
(adult reaches into case for next set of test materials)
- a few minutes later, child interrupts testing -
Child: "Where's the um...the things...um...where's the um...bugs?" (climbs on seat to peer into case)
Adult: "Pardon? What bugs? There are no bugs here. Now, tell me what –"
- child interrupts again -
Child: (loud unmodulated voice) "–The bugs. You said I'll see the bugs. I don't wanna do this. I wanna see the bugs...the...um...secs... the *insecs!*"

Figure 1. A case of behavioral symptoms of ADHD or language problems? This language sample occurs 20 minutes after the start of a psychoeducational assessment of an 8-year-old boy who has received a diagnosis of Attention-Deficit/Hyperactivity Disorder. Text in red ink reflects defining behavioral symptoms of ADHD, according to DSM-IV.

of the child’s behavior by parents, teachers, and significant others. It is not surprising then that two centuries after its initial recognition by the medical community, ADHD continues to defy understanding and remains suspended between medical reductionism and social skepticism. Here, I highlight various clinical and scientific interpretations of language difficulties exhibited by individuals with ADHD (see Figure 1), including a subset of the defining behavioral symptoms of ADHD (see Figure2), which may be the outward behavioral expression of underlying problems in symbolic representation and/or motoric control.*



Two conceptions of the language faculty

The meaning of the word ‘language’ itself is divergent and varies across contexts and disciplines. Two conceptions, proposed by Hauser and colleagues ¹ are used here because they reflect the differential perspectives on atypical language in ADHD that are evident in medicine and allied health disciplines (psychiatry, psychology, speech/language pathology) and linguistics (Formal/Structural Linguistics, Functional Systemic Linguistics). One conception reflects a narrow sense of the word – an *abstract linguistic computational system* with a core property of recursion (i.e., use of a finite set of elements to yield a potentially infinite set of discrete expressions – discrete infinity), which is attributable to narrow syntax and is perhaps uniquely human. The second conception reflects a broader and more inclusive sense – a *social communication system* – which includes the internal abstract linguistic computational system and at least two other internal systems: sensory-motor and conceptual-intentional. The discrete expressions generated by the linguistic computational system are transmitted to, processed and elaborated by, the sensory-motor and conceptual-intentional systems in the *use* of language, with each expression reflecting a pairing of sound and meaning.¹ Thus, I debate whether ‘language’ problems in ADHD reflect problems in the abstract linguistic computational system, the social communication system, sensory-motor systems, or in all systems.

Multidisciplinary perspectives on atypical language in ADHD:

Clinical/Psychiatric perspectives

Psychiatric taxonomies impute diagnostic boundaries between several behavioral/psychological syndromes in childhood that are defined on the basis of deviancy from societal standards of normality.⁹⁻¹⁰ For example, unexpected and impairing problems in understanding and producing spoken language (Communication Disorders) are distinguished from

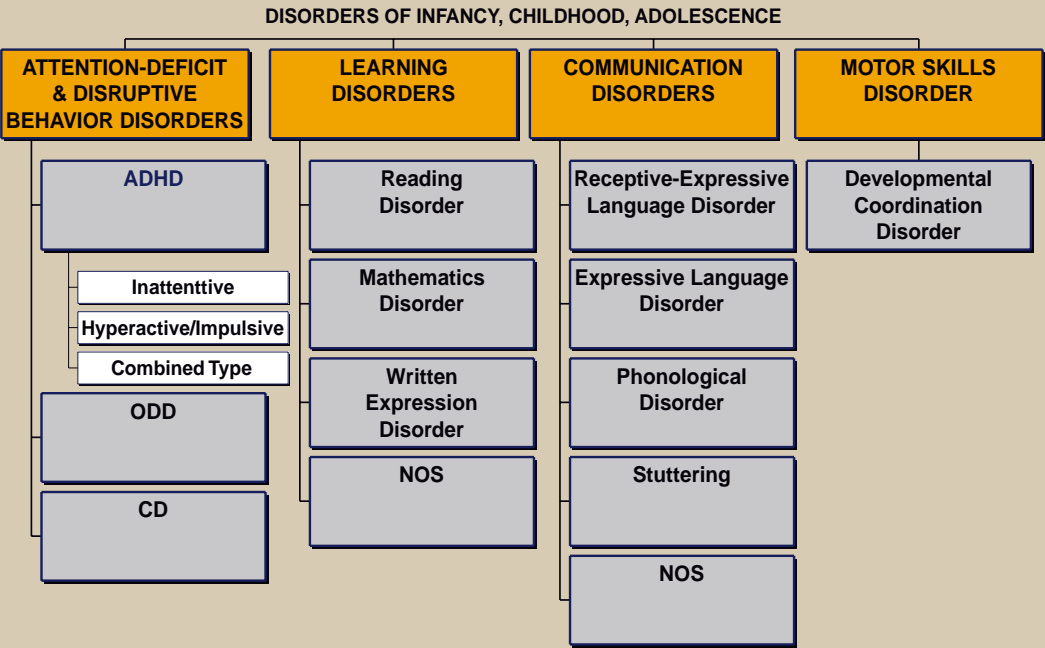


Figure 3. Categorical distinctions between ADHD and Communication Disorders according to the DSM-IV taxonomy of mental health disorders of infancy, childhood, and adolescence.

otherwise-unexplained and impairing developmental problems in attention, impulsivity, and hyperactivity (ADHD), motor skills (Developmental Motor Coordination Disorder) and learning (Learning Disorders) (see Figure 3). The inherent assumption is that these disorders (like medical diseases) represent distinct categories in terms of their pathophysiology, etiology, outcomes, and treatments, despite inadequate validation in some instances.

Paradoxically, although the psychiatric diagnostic classification of “Communication Disorders” implies a focus on language as a social communicative system, clinical/medical investigations rely almost exclusively on standardized language tests purported to measure the abstract linguistic computational system. Epidemiological studies suggest that 30% to 50% of children with ADHD are impaired in receptive and/or expressive components of the linguistic computational system, with the implication being that the remaining children with ADHD do not exhibit any language or communication problems.¹¹ Conversely, about 60% of children in kindergarten who manifest specific speech and language impairments (communication disorders) also meet diagnostic criteria for ADHD.¹²

Several problems exist with this medical/clinical approach to understanding language problems associated with ADHD. First, current behavioural genetics indicates that human traits (e.g., inattention, impulsivity, hyperactivity, language abilities) are distributed as continuous quantitative traits rather than qualitatively discrete categories.^{13–14} Thus, children who do not meet the full diagnostic criteria for Communication Disorder may still manifest problems that fall along a continuum of severity. Also, clinical tests of language abilities place heavy demands on other cognitive functions, such as working memory, organization, and attention. Moreover, these tests assess small and decontextualized units of language (e.g., word, phrase, sentence or utterance), and so may be insensitive to problems manifest in discourse or other forms of extended text. Thus poor test performance may not necessarily indicate deficits in the abstract linguistic computational system; and adequate test performance may not necessarily indicate problem-free language or communication.

Cognitive psychology perspective

By contrast to clinical measures of language which focus on the number of correct responses, cognitive methods permit more precise fractionation of performance parameters (e.g., error analysis, response latencies) in an attempt to delineate reasons for poor performance. Error analysis has indicated that underlying problems in cognitive control processes and inadequate evaluation of the social context and demands of the task rather than basic linguistic difficulties contribute to poor performance by children with ADHD on specific subtests of expressive language.^{15–18} Additional evidence of the impact of cognitive control failure on spoken language in ADHD comes from investigations of children's generated narratives based on a wordless picture-book – a well-established research procedure used internationally – using story grammar theory and causal network models.^{19–21} Children with ADHD are less likely to include the attainment of the overall goal – the *sine qua non* of a complete story representation – or exhibit sustained use of a goal plan in their narration. Also, they make more errors (ambiguous references, dysfluencies) and are less able to stop quickly to correct the detected errors.^{20–22} Moreover, analysis of children's elicited conversations reveal problems in use of social communication conventions (e.g., failure to mark topic changes, turn-taking) and in dysfluency (e.g., false starts, hesitations, repetitions) rather than in components of the linguistic computational system.^{21–22} These narrative problems are believed to reflect the well-documented inhibitory control and planning deficits inherent in ADHD.⁸ Notably, stimulant medication, which improves sustained attention and inhibitory control, also improves relevant aspects of the children's narratives.²⁵

Problems in comprehension of extended stretches of spoken language emerge as the linguistic material becomes more complex. For example, students with ADHD exhibit marked difficulty making inferences and self-monitoring their own comprehension when required to listen to expository texts (e.g., science lectures).²⁶ These problems are associated with deficits in working memory – a specific executive control process that is impaired in ADHD²⁷ and is a powerful predictor of later academic attainment.²⁸ By contrast, children with SLI or with ADHD and comorbid SLI manifest grammatical errors (grammatical abandonment and omission, morphosyntactic errors), which are indicative of impairments in the abstract linguistic computational system.^{17, 24}

Analysis of speech parameters during conversation, such as voice rhythm (rate and duration of pauses and vocalization, response latency), intensity, and frequency, has revealed marked differences in the timing and modulation of speech between children with ADHD and those with and without specific learning disabilities.²⁹ They speak louder, fail to modulate their voice volume, speak for much longer at a stretch with many short pause durations during their talk, but take much longer to respond to the conversational partner. Voice modulation requires continuous fine muscle adjustments of the vocal tract, suggesting an immature motor system may underlie these speech problems in ADHD. Pauses during continuous speech are believed to reflect the planning of forthcoming verbal output (what to say and how to articulate it).^{30–31} The frequent pauses in the speech of children with ADHD appear too short to permit thought, organization of information, or speech planning, as well as too short to

permit others from taking a turn. Moreover, the marked dysfluency in their spoken language is indicative of verbal retrieval problems, often resulting in a higher frequency of non-specific terms (see Figure 1).

Thus, the application of methods from cognitive psychology to investigate comprehension and production of extended contextualized language (e.g., narratives, discourse, expository lectures) have delineated socially based communication difficulties, as well as motorically based speech problems in individuals with ADHD in the presence of a seemingly intact linguistic computational system.

Systemic functional linguistics perspective

By contrast to formal linguistic theory, Systemic Functional Linguistics (SFL) is concerned with language in everyday discourse: on what language accomplishes during social interaction.^{4, 32} It starts from the premise that language is used primarily to convey meanings in contexts and views grammar, vocabulary, and the sounds of language (components of linguistic computational system) as linguistic resources used by speakers to encode the meaning. SFL analysis of children’s disruptive talk in a classroom revealed nine subtypes of disruptive talk, most of which could be related to the diagnostic criteria for ADHD, as well as one subtype (“Broken Record”) which mapped onto a cognitive feature of persistence (periodic difficulty in shifting mental set) that has not been recognized clinically as a characteristic of ADHD.³³ Also, by contrast to clinicians’ and teachers’ beliefs, the disruptive talk did not usually occur as a result of failure to listen; rather the children incorporated the preceding verbal or nonverbal contexts into their disruptive talk. An accompanying novel Phasal Analysis reveals the temporal patterning of the children’s disruptive talk and its detrimental impact on the ongoing lesson (see Figures 4–5).

According to an SFL perspective, language

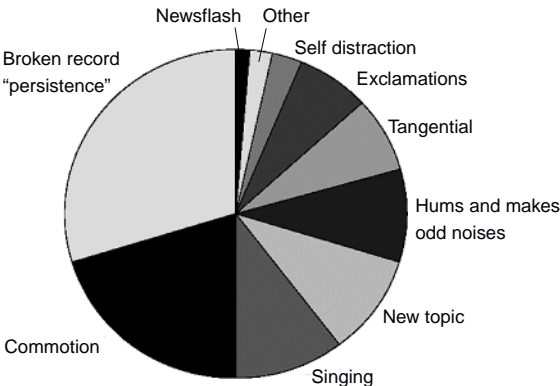
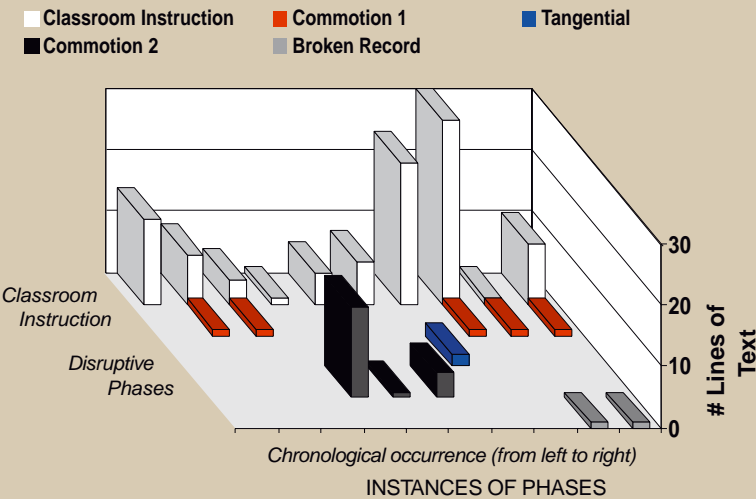


Figure 4. Distribution of various types of disruptive talk manifest by a small group of children with ADHD during a reading lesson in a special education classroom, as identified by phasal analysis based on functional systemic linguistics.

Figure 5.

Disruptive talk in the classroom. An example of phasal coding of 3 pages of transcript of all instances of verbal and vocal behavior produced by the teacher and children with ADHD.



ADHD Symptoms & their linguistic manifestation	Examples of linguistic manifestation
Problems sustaining attention	
<ul style="list-style-type: none"> • Jumps stages of social process (e.g., inappropriate responses) 	<i>Adult:</i> "Hi how are you?" <i>Child:</i> "I want to play with that"
<ul style="list-style-type: none"> • Changes in topic of interaction 	<i>Adult:</i> "What flavour would you like?" <i>Child:</i> "Well, I want a chocolate one...no, a vanilla one with chocolate... no, with um...You know what? My brother is going to get his...um...badge-thing"
Doesn 't appear to listen	
nonverbal	<i>Adult:</i> "So, Jonathan, tell me what happened yesterday – first thing in the morning and then later in the afternoon" <i>Child:</i> Looks away, pulls at shirt sleeve, turns to look at picture on wall...while speaker is talking
verbal (e.g., fails to respond contingently in set of verbal exchanges; uses ellipsis inappropriately)	<i>Adult:</i> "So what happened, what did you do?" <i>Child:</i> "Can't" (as in can't remember)
Always on the go, driven like a motor Talks excessively	
<ul style="list-style-type: none"> • Fails to pause or use other turn-passing signal to allow others to take a turn • Talks fast in run-on sentences, stringing sentences together with 'and' 	<i>Teacher:</i> "How old was the boy?" <i>Child:</i> "Grade one...seven and...so she..um.. we went on it and he was... he got pushed a little bit on the swing you know and then...pow...down he falls and then we called his brother over...he was really really rough and...he was really light too and um he went on the swing and...and my friend you know she put it in again and we said come on and I don't know I ...forget the boy's name...but we...told him to come over and sit on the swing and...so he came over and sat on the swing..."

Figure 6. Linguistic manifestation of ADHD symptoms (derived from Fine J. (2005). *Language in psychiatry: a handbook of clinical practice*. London, U.K.,: Equinox Textbooks & Surveys in Linguistics)

problems are inherent characteristics of ADHD because clinicians use (albeit implicitly and non-systematically) both verbal and nonverbal communicative behaviour as evidence of the core behavioral symptoms.⁴ That is, the characteristics of ADHD may be defined in terms of the language that is indicative of the disorder (see Figure 6).

Neuroscience and evolutionary linguistics perspectives

Functional neuroimaging studies suggest that the neural basis of human language is not compartmentalized in modules as proposed by many linguists and cognitive psychologists, but rather it is intertwined with other aspects of cognition, motor control, and emotion.³⁴ Also, some evolutionary linguists propose that language evolved from gesture, rather than as a unique and modular human capacity.^{34–37} A full discussion is beyond the scope of this essay; thus I focus on the cerebellum, which plays a



Gustav Vigeland: Sculptures from the Vigeland Park. © Vigeland-museet/BONO 2005. Photo: © Rosemary Tannock

Figure 7. Problematic social communication in Vigeland Park, Oslo

Figure 8. Effective social communication in Vigeland Park, Oslo



Gustav Vigeland: Sculptures from the Vigeland Park. © Vigeland-museet/BONO 2005. Photo: © Rosemary Tannock

critical role in gesture, as well as in the planning and execution of articulatory movements involved in speaking, speech perception, the temporal organization of inner speech, and verbal fluency (particularly in phonemically related retrieval strategies that are impaired in ADHD).^{18, 35–39}

Gesture both precedes and acts as a harbinger of oncoming changes in the child’s developing language system and may serve as a temporary symbolic representation.⁴⁰ Moreover, gesture appears to ease the process of speech production in that conveying information manually rather than verbally is less demanding in terms of fine motor control, and it also reduces cognitive load.⁴⁰ Thus use of gesture frees up cognitive resources for the production of more complex thought and its translation to verbal utterances. Given the robust evidence that the cerebellum differs in both size (smaller) and function in ADHD^{41–43} it is plausible that cerebellar dysfunction contributes to many of the documented social communication problems in ADHD. Perhaps the combined problems of cerebellar dysfunction and cognitive control deficits (e.g., inhibitory control, emotional regulation), might account for why children with ADHD communicate by action (fists, stamping and yelling) rather than by words (see Figures 7 & 8).

Conclusions

Interdisciplinary collaboration from multiple fields (e.g., psychiatry, speech-language pathology, education, developmental psychology, cognitive psychology, linguistics, neuroscience, evolutionary biology) is required to advance scientific and clinical understanding of atypical language in childhood mental health disorders, such as ADHD. Current understanding is limited by lack of data as well as by lack of interdisciplinary collaboration. To date, there is little evidence that the abstract linguistic computational system is impaired in ADHD, but rather the available data suggest that the problems reside in components of the social communicative system. Social proficiency in oral communication and movement may have a common genesis.

* My scientific thinking has been shaped further during my year at CAS, during which time I was living in a different culture – one that often necessitated on-line changes in my social communication and timing of movement. For example, by contrast to the fast-paced, unpredictable, and egotistical monologues common among North-Americans, Norwegians (at least from my perspective) emphasize calmness, order, and societal dialogue. In North America, pedestrians must move rapidly and give way to cars, whose pacing is externally controlled by Stop-signs at

every intersection: generally in Norway, cars still give way to the slower-pace of pedestrians and self-regulate their progress through intersections! Also, appreciative applause at the end of public performances in North America is individualistic and asynchronous, but collective and synchronous in Norway. Moreover, this year at CAS offered opportunities to think about behaviour, language, and movement under different contexts and time scales – as studied by historical linguists and plasma physicists, respectively, and while reflecting and walking in Vigeland Park (see Figures 7–8 for examples of effective versus problematic communication between Gustav Vigeland's life-size human statues).

References

1. Hauser, M. D., Chomsky, N., and Fitch, W. T. (2002). The faculty of language: What is it, who has it, and how did it evolve? *Science* 298: 1569–1579.
2. Deacon, T.W. (1997). *The Symbolic Species: the co-evolution of language and the brain*. London, U.K.: W. W. Norton & Company Inc.
3. Fine, J. (2001). Using language in psychiatry. *Canadian Journal of Psychiatry*; 46:916–922
4. Fine J. (2005). *Language in psychiatry: a handbook of clinical practice*. London, U.K.: Equinox Textbooks & Surveys in Linguistics.
5. Harpin VA. (2005). The effect of ADHD on the life of an individual, their family, and community from preschool to adult life. *Arch Dis Child* 90(Suppl I):i2–i7.
6. Kessler RC, Adler L, Ames M, Barkley RA, Birnbaum H, Johnston JA, Spencer T, Üstün TB (2005). The prevalence and effects of adult attention deficit/hyperactivity disorder on work performance in a nationally representative sample of workers. *J Occup Environ Med* 47: 565–572
7. Curry J, Stabile M (2004). *Child mental health and human capital accumulation: The case of ADHD*. National Bureau of Economic Research [http://www.nber.org/papers/w10435]
8. Tannock R. (1998). Attention deficit hyperactivity disorder: Advances in cognitive, neurobiological, and genetic research. *J Child Psychol Psychiat* 39: 65–99
9. American Psychiatric Association (1994). *Diagnostic and statistical manual of mental disorders* (4th edn.) Washington, DC: Author.
10. World Health Organization (1993). *The ICD-10 classification of mental and behavioral disorders: Diagnostic criteria for research*. Geneva: Author.
11. Tannock, R., & Schachar, R. (1996). Executive function as an underlying mechanism of behavior and language problems in Attention-Deficit/Hyperactivity Disorder. In J.H. Beitchman, N.Cohen, M.M. Konstantareas, & R. Tannock (Eds.) *Language, Learning, and Behavior Disorders: Developmental, Biological, and Clinical Perspectives*. (pp. 128–155). New York: Cambridge University Press
12. Beitchman J, Beitchman, J. H., Nair, R., Clegg, M., Ferguson, B., & Patel, P. G. (1986). Prevalence of psychiatric disorders in children with speech and language disorders. *Journal of the American Academy of Child Psychiatry*, 25, 528–535
13. Pennington B. (2002). *The development of psychopathology. Nature and nurture*. New York: Guilford.
14. Levy F, Hay D.A., McStephen M, Wood C, Waldman I (1997). Attention-deficit hyperactivity disorder: a category or a continuum? Genetic analysis of a large-scale twin study. *J Am Acad Child Adolesc Psychiatry* 36: 737–744
15. Oram J, Fine J, Okamoto C, Tannock R (1999). Assessing the language of children with attention deficit hyperactivity disorder. *Am J Speech Lang Path* 8 (1): 72–80
16. Kim OH, Kaiser Ap (2000). Language characteristics of children with ADHD. *Comm Dis Quarterly* 21:154–165
17. Redmond S.M. (2005). Differentiating SLI from ADHD using children's sentence recall and production of past tense morphology. *Clinical Linguistics & Phonetics* 19: 109–127
18. Hurks PPM, Hendriksen JGM, Vles JSH, Kalf AC, Feron FJM, Kroes M, van Zeben TMCB, Steyart J, Jolles J (2004). Verbal fluency over time as a measure of automatic and controlled processing in children with ADHD. *Brain and Cognition*, 55:535–544
19. Slobin DI, Berman RA (Eds.). Different ways of relating events in a narrative: A cross-linguistic study. Hillsdale, NJ: Erlbaum (1994)
20. Renz K, Lorch E. P., Milich R, Lemberger C., Bodner A, Welsh R. (2003). On-line story representation in boys with attention deficit hyperactivity disorder. *J Abnorm Child Psychol* 31: 93–104.

21. Peets, K, Tannock R. (1997) *Errors and Self-Correction in Narrative Distinguish ADHD from ADHD with Language Impairment*. International Systemic Functional Linguistics Conference, Toronto, July 1997.
22. Purvis K.L., Tannock R. (1997). Language abilities in children with attention deficit hyperactivity disorder, reading disabilities, and normal controls. *J Abnorm Child Psychol* 25:133–144.
23. Miranda C.A., Yguel F.A., Rosel, R.J. (2004). Grammatical complexity and cohesion mechanisms in the communication pragmatics of children with attention-deficit/hyperactivity disorder. *Rev Neurol* 38 (Suppl.): S111–116.
24. Redmond S.M. (2004). Conversational profiles of children with ADHD, SLI and typical development. *Clinical Linguistics & Phonetics* 18: 107–125.
25. Francis S, Fine, J., Tannock R. (2001) Methylphenidate selectively improves story retelling in children with attention-deficit/hyperactivity disorder, *J Child Adolesc Psychopharmacology*, 11: 217–228. [Dennis Cantwell Award for the best article of the year by a trainee in psychiatry or psychology].
26. McInnes A, Hmphries T, Hogg-Johnson S, Tannock R. (2003). Listening comprehension and working memory are impaired in attention-deficit hyperactivity disorder irrespective of language impairment. *J Abnorm Child Psychol* 31:427–443.
27. Martinussen R, Hayden J, Hogg-Johnson S, Tannock R. (2005). A meta-analysis of working memory impairments in children with attention-deficit/hyperactivity disorder. *J Am Acad Child Adolesc Psychiatry* 44: 377–384.
28. Jarvis H.L., Gathercole S.E. (2003). Verbal and non-verbal working memory and achievement on national curriculum tests at 11 and 14 years. *Educ Child Psychol* 20:123–140.
29. Breznitz Z. (2003). The speech and vocalization patterns of boys with ADHD compared to boys with dyslexia and boys without learning disabilities. *J Genetic Psychol* 164:425–452
30. Goldman Eisler F (1972). Pauses, clauses, sentences. *Lang Speech* 15:103–113
31. Kircher T.T.J, Brammer MJ, Levelt W, Bartels M, McGuire PK (2004). Pausing for thought: engagement of left temporal cortex during pauses in speech. *Neuroimage* 21: 84–90.
32. Halliday, M.A.K. (2004). *An Introduction to Functional Grammar*. 3rd ed., Revised by C.M.I.M. Matthiessen. London: Arnold.
33. DeVilliers J, Tannock R (submitted). “Hums and makes odd noises” *Linguistic phasal analysis of classroom discourse of children with ADHD*. [Presented to Georgetown Round Table on Applied Linguistics, Georgetown, 2001].
34. Lieberman P (2002). On the nature and evolution of the neural bases of human language. *Yearbook of Physical Anthropology* 45:36–62.
35. Hauk O, Pulvermüller F (2004). Neurophysiological distinction of action words in the fronto-central cortex. *Hum Brain Mapp* 21:191–201.
36. Corballis MC (2003). From mouth to hand: Gesture, speech, and the evolution of right-handedness. *Behavioral and Brain Sciences* 26:199–260.
37. Jansen A, Floel A, Van Randenborgh J, Konrad C, Rotte M, Forster A.F, Deppe M, Knecht S (2005). Crossed cerebro-cerebellar language dominance. *Hu Brain Mapp* 24:165–172.
38. Ackermann H, Mathiak K, Ivry RB. (2004). Temporal organization of ‘internal speech’ as a basis for cerebellar modulation of cognitive function. *Behav Cogn Neurosci Rev* 3:14–22.
39. Mathiak K, Hertrich I, Grodd W, Ackermann H (2002). Cerebellum and speech perception: a functional magnetic resonance imaging study. *J Cogn Neuro Sci* 14:902–912.
40. Özçalışkan Ş Goldin-Meadow S. (2005). Gesture is at the cutting edge of early language development. *Cognition* 96: B101–B113.
41. Castellanos et al (2002). Developmental trajectories of brain volume abnormalities in children and adolescents with attention-deficit/hyperactivity disorder. *JAMA*, 288(4), 1740–1748.
42. Durston S, Hulshoff Pol HE, Schnack HG, Buitelaar JK, Steenhuis MP, Minderaa RB, Kahn RS, van Engeland H. (2004). Magnetic resonance imaging of boys with attention-deficit/hyperactivity disorder and their unaffected siblings. *J Am Acad Child Adolesc Psychiatry* 43:332–40.
43. Anderson CM, Polcari A, Lowen SB, Renshaw PF, Teicher MH (2002). Effects of methylphenidate on functional magnetic resonance relaxometry of the cerebellar vermis in boys with ADHD. *Am J Psychiatry*. 159:1322–8.

Looking at the Overlooked

Still life painting “lavishes attention on those things normally overlooked”.

Norman Bryson

Introduction

Linguists working on phenomena that are statistically rare in language use, face the problem of possible accidental gaps in the corpus. This problem is particularly relevant in historical linguistics as it raises the methodological issue of the amount of linguistic data needed to draw conclusions about the grammar of “dead” languages, i.e. languages attested only in texts from earlier periods. Such languages can be divided into what German scholarly tradition calls *Grosskorpussprachen* (‘large

corpus languages’; e.g. Latin, which, as is well known, has been abundantly attested over many centuries), *Kleinkorpussprachen* (‘small corpus languages’; e.g. Gothic, which is almost exclusively attested in a translation of parts of the Greek Bible dating from about AD 380), and *Rest- und Trümmersprachen* (fragmentary

languages, languages ruins; e.g. Ancient Nordic, which survives in a couple of hundred inscriptions carved in runes from ca. AD 150–550).

Clearly, the more text material that is available, the less the chances are that lack of documented linguistic phenomena is due to accidental gaps, and the higher the chances that the data are representative of the language in question. Traditional philological wisdom holds that “one example is no example” (cf. the Latin slogan *unus testis – nullus testis*).

Contrary to this, I would like to defend the view that what really matters in determining the status of rare linguistic phenomena is not the quantity but the quality of the attested examples. Even for a well-documented language like Old Norse-Icelandic (a *Grosskorpussprache* by the definition given above, copiously attested in manuscripts dating from ca.

1150–1540), a linguistic analysis based solely on the most frequently occurring forms and structures in the texts runs the risk of overlooking rare but important patterns, which may have been perfectly grammatical for the speakers of these languages, but which, for some reason, are underrepresented in the texts. Thus, all occurring linguistic phenomena, both frequent and infrequent, have their place in the language system. In fact, the occurrence of even a single, philologically and linguistically unambiguous example of a particular structure may suffice to establish that it is part of the grammar of the language in question (although its status may, of course, be less central than the status of high-frequency structures). By “philologically and linguistically unambiguous” I mean examples whose grammatical analysis depends on solid arguments, and



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which can be justified on the basis of the textual evidence (manuscripts, inscriptions and other kinds of documents) considered most reliable by leading experts.

The story of oblique (“quirky”) subjects – again

I will use evidence from Old Norse-Icelandic to demonstrate the validity of the above considerations. First, however, I must briefly mention that in Modern Icelandic (and the closely related Faroese) the subject of the sentence is not necessarily in the nominative case. Rather, the subject can be in any of the four morphological cases: nominative, accusative, dative or genitive. Thus, case and agreement with the finite verb are not SUBJECT PROPERTIES in Icelandic and Faroese, which distinguishes them from many other languages. In the sentence in (1a) the subject is in the nominative, but in (1b) the subject is in the dative.

- (1) a. **Íslendingurinn** étur þennan hákarl.
 Iclander.the-NOM eats this-ACC shark-ACC
 ‘The Iclander eats this shark’
 b. **Íslendingnum** líkar þessi hákarl.
 Iclander.the-DAT likes this-NOM shark-nom
 ‘The Iclander likes this shark’

The subject status of oblique noun phrases of the kind shown in (1b), termed OBLIQUE SUBJECTS, has been established in Modern Icelandic on the basis of the fact that they pass all SUBJECT TESTS applicable to Icelandic (Andrews 1976, Zaenen, Maling & Thráinsson 1985, and subsequent work). These tests for subjecthood include long distance reflexivisation and control infinitives, both of which I will explain shortly (see 2.1 and 2.2 respectively).

For a historical linguist, the natural question to ask is: What is the diachrony of oblique subjects in the Nordic languages? In other words, are oblique subjects an innovation in Modern Icelandic and Faroese, separating these Insular Scandinavian languages from the related languages on the Scandinavian mainland? Or are oblique subjects an archaism – an old linguistic feature that these languages have preserved while their mainland relatives have lost it?

Whereas the facts of Modern Icelandic are unanimously accepted in the linguistic community, there has been a debate in the literature on the syntactic status of subject-like obliques in Old Norse-Icelandic. A number of scholars have argued that the oblique noun phrases are subjects just as in Modern Icelandic (Rögnvaldsson 1996, Barðdal & Eythórsson 2003). Others argue that they are not subjects, but rather objects (Faarlund 2001). On the latter view there would have been a change in the history of Icelandic and Faroese, whereby the original objects were reanalyzed as subjects. On the former view, however, there has been no change in the history of Icelandic (and Faroese). The problem is that the relevant structures required to test the grammatical function of the potential oblique subjects are hard to come by in a “dead” language, and in some cases even totally absent. The question to be determined is whether this lack of the crucial examples is coincidental or systematic. Linguists working on living languages mostly have an easier task as they can either obtain the relevant examples by introspection (in the case of their own native

language), or by asking their informants for judgments; particularly important is the solicitation of negative evidence, supplying information on what speakers **cannot** say. Historical linguists, on the other hand, must rely on their philological skills and thorough knowledge of the languages in question; but there is no substitute for the negative evidence provided by actual speakers.

Long distance reflexivisation

As mentioned above, one of the tests for subjecthood of oblique subjects in Modern Icelandic is LONG DISTANCE REFLEXIVISATION (LDR); this involves a reflexive pronoun in a subordinate clause referring to an antecedent in a matrix clause. There is no question that nominative subjects can be antecedents of reflexives in Old Norse-Icelandic. However, only **three** examples of potential oblique subjects functioning as antecedents for a long distance reflexive have been reported in the scholarly literature. One of these three examples from Old Norse-Icelandic is shown in (2); the dative noun phrase in the matrix clause is the antecedent of the reflexive pronoun in the subordinate clause (both shown in boldface).

- (2) ok þótti **honum** [sem fóstira **sínum** myndi mein at verða]
and seemed him-DAT as fosterfather-DAT self-DAT would harm to
become
'and it seemed to him as if his fosterfather would be harmed'
(Ljósvetninga saga)

It is important to note that there are **no** examples of unambiguous objects functioning as antecedents for LDR in Old Norse-Icelandic. However, if an example were found of a reflexive referring back to an unambiguous object (say, in a hitherto unknown Icelandic saga, if such a text were discovered – something which is not very likely), LDR would be shown to be invalid as a subject test for Old Norse-Icelandic (even though it holds for Modern Icelandic). The reason is that it is in principle not excluded that a reflexive may refer back to a non-subject. But until such a counterexample is found, the above example is in accordance with the OBLIQUE SUBJECT HYPOTHESIS for Old Norse-Icelandic.

Control infinitives

A further argument for the existence of oblique subjects in Old Norse-Icelandic involves infinitive clauses whose subject is omitted on identity with the subject of the matrix clause. This argument is much more persuasive than the one discussed above because only subjects can be omitted in such infinitive clauses (so-called CONTROL INFINITIVES), given standard assumptions about grammatical functions. Only six unambiguous examples bearing on this issue have been reported for Old Norse-Icelandic (Rögnvaldsson 1996, Barðdal & Eythórsson 2003:458–59), including the one in (3).

- (3) Höskuldr **kvaðsk** ____ þat mikit **þykkja** ...
Höskuldr-NOM said Ø-DAT it-NOM much-NOM seem-INF
'Höskuldr said that it concerned him greatly ...' (Laxdæla saga)

In this example the matrix control verb is *kveðask* ‘say (of oneself)’ which takes a nominative subject. The control infinitive is *þykkja* ‘seem (here: concern)’, which selects for a subject-like dative. It should be emphasized that the subject behaviour here lies in an argument’s **ability to be left unexpressed**, as opposed to being obligatorily overt. In the example in (3) the unexpressed argument of the infinitive (indicated here as Ø-DAT) corresponds to a dative argument of the finite *þykkja* ‘seem’.

It may be objected that the examples of potential oblique subjects being unexpressed in control infinitives are quite few, and that if this was a structural property of Old Norse-Icelandic we would expect it to be more pervasive in the texts. The force of this objection, however, is not as strong as it might seem because predicates selecting for oblique subjects are also extremely rare in control constructions in Modern Icelandic, yet they are accepted by native speakers (cf. Rögnvaldsson 1996:50, Barðdal & Eythórsson 2003:461). It was not until after the dawn of the World Wide Web that it became possible, without vast efforts, to find such examples in written Modern Icelandic. However, the fact that a particular structure is rare is not equal to its being unacceptable or non-existent. If there is any difference at all between Modern Icelandic and Old Norse-Icelandic with regard to structures like (3), it would seem to be quantitative and not qualitative in nature. The six examples are from the oldest and most reliable manuscripts of the classical Old Norse-Icelandic period (cf. Barðdal & Eythórsson 2003:458–59). Therefore, although extremely few in number these examples must on both philological and theoretical grounds be considered valid evidence for the subjecthood of potential oblique subjects, given that only subjects, and not objects, can be left unexpressed in control infinitives.

References

- Andrews, Avery D. 1976. The VP complement analysis in Modern Icelandic. *Proceedings of the North East Linguistic Society* 6.1–21.
- Barðdal, Jóhanna, and Thórhallur Eythórsson. 2003a. The change that never happened: The story of oblique subjects. *Journal of Linguistics* 39.439–72.
- Eythórsson, Thórhallur, and Jóhanna Barðdal. 2005. Oblique subjects: a Germanic inheritance! *Language* 81.
- Faarlund, Jan T. 2001. The notion of oblique subject and its status in the history of Icelandic. In Faarlund, Jan T. (ed.) 2001, *Grammatical relations in change*. Amsterdam: John Benjamins. 99–135.
- Rögnvaldsson, Eiríkur. 1996. Frumlag og fall aʋ fornu [Subject and case in Old Icelandic]. *Íslenskt mál* 18.37–69.
- Zaenen, Annie; Joan Maling; and Höskuldur Thráinsson. 1985. Case and grammatical functions: The Icelandic passive. *Natural Language and Linguistic Theory* 3.441–83.

ADHD: Beyond the Child

Attention deficit hyperactivity disorder (ADHD) is a chronic and debilitating disorder affecting a significant number of individuals throughout their childhood and beyond.¹ There is growing awareness that the negative impact of the disorder extends beyond the affected individual to his or her family, place of learning/work, and the wider community. This paper focuses on the impact of ADHD on children’s parents, in particular, the stress they experience in their parenting roles.

Several reports in the literature indicate that mothers of children with ADHD experience increased levels of parenting stress compared with the mothers of non problem children.²⁻⁵ These elevations in parenting stress begin early,⁶ and appear chronic in nature.⁷ Evidence is emerging that fathers of children with ADHD also experience increased levels of parenting stress.^{3,8}

Elevated levels of parenting stress are associated with disruptions to the parent-child relationship and parenting practices^{2,9-12} and disruptions in parent psychological functioning.¹⁰⁻¹² The hypothesised reciprocal relationships between these factors and child behaviour are



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depicted in figure 1.

Parenting stress is generally understood to arise from characteristics of the parent, the child, and the environment, and interactions among these factors. For families with a child with ADHD the characteristics of the child are thought to be the primary contributor to parenting and family stress.^{2,11,13,14} To date three studies have assessed the contribution of a range of parent, child, and family/environmental characteristics to parenting stress in mothers^{2,15} and mothers and fathers³ of children with ADHD. In each of these studies the Parenting Stress Index¹⁶ was used to assess the level of parental stress in the parent-child dyad. This measure

provides a Child Domain (stress perceived to result from child characteristics), Parent Domain (stress perceived to result from parent characteristics), and Total Stress Score.

In all three studies the children’s problem behaviour

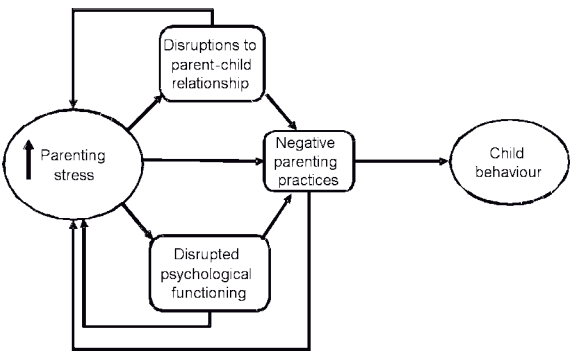


Figure 1. Hypothesized links between parenting stress, the parent-child relationship, parent psychological functioning, parenting practices, and child behaviour.

contributed significantly to overall levels of parenting stress^{2,15} and parenting stress in the child domain.³ Maternal psychopathology and health status² and perceived control over child behaviour¹⁵ also made a significant contribution to mothers' reported parenting stress. Baker³ found family characteristics made a small, but significant, contribution to parenting stress in the child domain (number of years married, socioeconomic status, and sex of parent) and parent domain (socioeconomic status) parenting stress. Although this latter study included fathers, predictors of parenting stress were not considered separately for mothers and fathers.

We recently assessed the predictors of child domain and parent domain parenting stress in 113 parents (71 mothers and 42 fathers) of 79 children diagnosed with DSM-IV ADHD. Parents completed the Parent Stress Index as well as measures designed to assess depressive symptomology, parenting style and beliefs, family functioning and relationship quality, perceived social support, and child behaviour. Correlational analyses assessed the direction and strength of relationships between scores on these measures and levels of parenting stress, separately for mothers and fathers. The results of these analyses, together with the findings of previous research, were used to guide variable selection and entry for a series of hierarchical multiple regression analyses to identify predictors of parent domain and child domain parenting stress. Levels of parenting stress were found to be elevated for both mothers and fathers in this sample.

Child domain parenting stress, in mothers and fathers, was predicted by child externalizing behaviour, family socioeconomic status, and aspects of parent locus of control. For mothers, and to a lesser extent fathers, the effect of socioeconomic status was mediated by the child externalizing behaviour, i.e., lower socioeconomic status was associated with increased perceptions of externalizing child behaviour which in turn predicted child domain parenting stress. Child externalizing behaviour was the major contributor to child domain parenting stress, explaining over 35% of the variance in reported stress for both mothers and fathers.

Parent locus of control and depressive symptomology predicted parent domain parenting stress in mothers and fathers of children with ADHD. In mothers, the effect of depression was mediated by locus of control, i.e., greater depressive symptomology was associated with a parent locus of control characterized by beliefs of reduced efficacy, increased child control over parent's lives and decreased parental control over child behaviour, which in turn predicted increased parent domain parenting stress for mothers. Child externalizing behaviour and social support network size also made small, but significant, contributions to fathers parent domain stress.

These data indicate that the predictors of parenting stress in mothers and fathers of children with ADHD are similar, **but** not identical. Consistent with previous research, the children's externalizing behaviour emerged as the primary predictor of child domain parenting for mothers and fathers. It made a smaller, but still significant, contribution to fathers' parent domain stress. Parent and family/environmental factors, namely locus of control and socioeconomic status also contributed to child domain parenting stress. For mothers, predictors of parent domain stress

were limited to parent characteristics. In the case of fathers, parent, child, and family/environmental factors all contributed to reported parent domain parenting stress.

The links between elevated parenting stress, disruptions to the parent-child relationship, and parenting practices, together with the distress experienced by the parents themselves, argue for treatment programmes that reduce parenting stress in the families of children with ADHD. Although the importance of considering parents' psychological functioning in the management of ADHD has been acknowledged for some time,^{2,17} very few studies have addressed this issue directly. In response we developed and evaluated a nine week, group administered, stress management programme for the parents of children with ADHD.¹⁸

The content and format of the programme was designed to address parent and environmental characteristics thought to contribute to elevations in parenting stress. Session content focused on the provision of accurate information to assist parents in developing realistic expectations of their children, together with skills training to reduce emotional arousal and to improve communication and problem solving. Sixty-three parents from 42 families participated in a randomized wait-list control trial.

Results demonstrated that for mothers completion of the programme was associated with a significant reduction in parent domain parenting stress together with significant improvements in reported parenting style. A trend toward improved mood was also observed. For fathers completion of the programme was associated with reported improvement in some aspects of parenting style only. Treatment effects were maintained at six and 12-month follow-up. Overall parents were highly satisfied with the programme and no parents voluntarily dropped out of treatment.

The programme's success in reducing parent domain parenting stress is consistent with its focus on reducing parents' emotional arousal through education and skill training. The observed changes in parenting style are consistent with suggestions that elevated parenting stress negatively impacts parenting practices. The lack of significant reduction in child domain parenting stress may be explained by the programme's limited focus on changing actual child behaviour.

Possible explanations for differential effects of the programme for mothers and fathers include lower levels of pre-treatment stress in fathers compared with mothers, fathers attendance prompted by a sense of duty to partners rather than perceived need, programme content based on predictors of maternal rather than paternal parenting stress, and group facilitation by female group leaders.

The negative impact of elevated parenting stress on parents, children, parenting practices, and the parent-child relationship argue strongly for the inclusion of programmes such as the one described in the comprehensive management of ADHD. The treatment of ADHD should focus on enhancing parents' coping resources as well as directly targeting the child's symptoms of ADHD and associated difficulties.

References

1. American Psychological Association (1994). *Diagnostic and Statistical Manual of Mental Disorders – Fourth Edition*. Washington DC: Author.
2. Anastopoulos, A.D., Guevremont, D.C., Shelton, T.L., & DuPaul, G.J. (1992). Parenting stress among families with attention deficit hyperactivity disorder. *Journal of Abnormal Child Psychology*, 20, 503–520.

3. Baker, D.B. (1994). Parenting stress and ADHD: A comparison of mothers and fathers. *Journal of Emotional and Behavioural Disorders*, 2, 46–50.
4. Beck, S.J., Young, G.H., & Tarnowski, K.J. (1990). Maternal characteristics and perceptions of pervasive and situational hyperactives and normal controls. *Journal of the American Academy of Child and Adolescent Psychiatry*, 29, 558–565.
5. Mash, E.J., & Johnston, C. (1983). Parental perceptions of child behaviour problems, parenting self esteem, and mothers reported stress in younger and older hyperactive and normal children. *Journal of Consulting and Clinical Psychology*, 51, 86–99.
6. DuPaul, G.J., McGoe, K.E., Eckert, T.L., & VanBrakle, J. (2001). Preschool children with Attention-Deficit/Hyperactivity disorder: Impairments in behavioral, social, and school functioning. *Journal of the American Academy of Child and Adolescent Psychiatry*, 40, 508–515.
7. Barkley, R.A., Fischer, M., Edelbrock, C.S., & Smallish, L. (1991). The adolescent outcome of hyperactive children diagnosed by research criteria, III: Mother-child interactions. *Journal of Child Psychology and Psychiatry*, 32, 233–255.
8. Podolski, C-L., & Nigg, J. T. (2001). Parent stress and coping in relation to child ADHD severity and associated child disruptive behavior problems. *Journal of Clinical Child Psychology*, 30, 503–513.
9. Abidin, R.R. (1992). The Determinants of Parenting Behaviour. *Journal of Clinical Child Psychology*, 21, 407–412.
10. Belsky, J. (1984). The Determinants of Parenting: A Process Model. *Child Development*, 55, 83–96.
11. Mash, E.J., & Johnston, C. (1990). Determinants of parenting stress, illustrations from families of hyperactive children and families of physically abused children. *Journal of Clinical Child Psychology*, 19, 313–328.
12. Rodgers, A. Y. (1998). Multiple sources of stress and parenting behavior. *Children and Youth Services Review*, 20, 525–546.
13. Fischer, M. (1990). Parenting stress and the child with attention deficit hyperactivity disorder. *Journal of Clinical Child Psychology*, 19, 337–346.
14. Johnston, C., & Mash, E.J. (2001). Families of children with attention-deficit/hyperactivity disorder: Review and recommendations for future research. *Clinical Child and Family Psychology Review*, 4, 183–206.
15. Harrison, C. & Sofronoff, K. (2002). ADHD and parental psychological distress: Role of demographics, child behavioural characteristics and parental cognitions. *Journal of the American Academy of Child and Adolescent Psychiatry*, 41, 703–711.
16. Abidin, R. R. (1995). *Parenting Stress Index – Third Edition: Professional Edition*. USA: Psychological Assessment Resources.
17. Anastopoulos, A.D., Shelton, T.L., DuPaul, G.J., & Guevremont, D.C. (1993). Parent training for attention deficit hyperactivity disorder: Its impact on parent functioning. *Journal of Abnormal Child Psychology*, 21, 581–596.
18. Treacy, L. Tripp, G., & Baird, A. (in press). Parent stress management training for attention deficit hyperactivity disorder (ADHD). *Behavior Therapy*.

Exposure to Polychlorinated Biphenyls (PCBs) Produces Hyperactivity Differentially in Male and Female Rats

Introduction

This paper is based on an examination of some of the behavioral and physiological effects of exposure to polychlorinated biphenyls (PCBs). The examination started in response to a request from colleagues at the NY State Department of Health who were involved in a USA Environmental

Protection Agency Superfund grant studying the effects of contamination at the St. Regis Reservation on the St. Lawrence River near Massena (see Figure 1). We wondered whether exposure to that PCB-contaminated environment could produce the symptoms of attention deficit/hyperactivity disorder (AD/HD) in the Mohawk children, and, decided to use Terje Sagvolden's procedures to measure the effects of exposure to environmental levels of PCBs on the behavior of normal (non-hyperactive) Sprague-Dawley (SD) rats. The majority of this presentation was focused on the recent results of our studies, much of which has not yet been published.



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Polychlorinated biphenyls

PCBs are a family of 209 manufactured compounds (congeners) that was once produced in large quantities in the USA for use as

Figure 1. The Great Lakes – St. Lawrence River System.

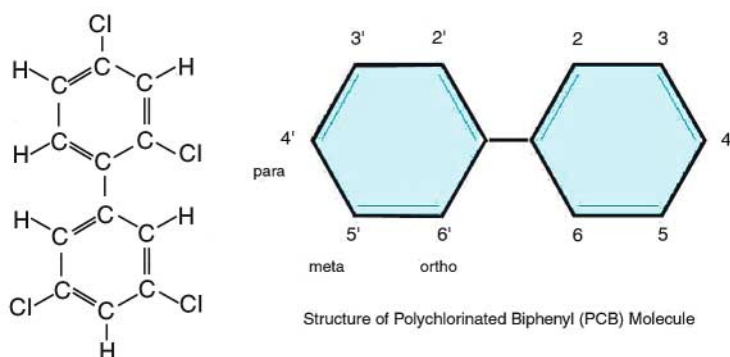
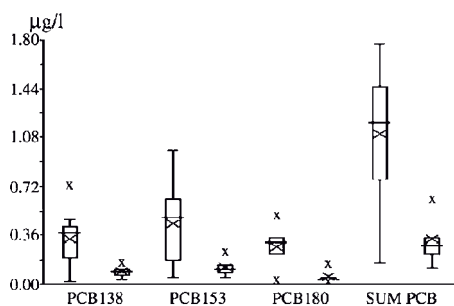


Figure 2. Chemical Identity.

heat resistant electrical insulators, brake liners, etc. An Aroclor is a commercial mixture of PCB congeners. Large amounts have leached or been dumped into bodies of water, including the Great Lakes, and the St. Lawrence and Hudson Rivers, where they continue to be found today. PCBs are highly stable, bioaccumulate, and because of their stability, have entered the food chain, even north of the Arctic Circle. Diagrams of their chemical identity are shown in Figure 2. A specific example of a congener is shown on the left, and the general structure of the molecules on the right. Congeners are formed by the addition of Chlorine (Cl_2) to Biphenyl ($\text{C}_{12}\text{H}_{10}$), which is a dual-ring structure comprising two 6-carbon Benzene rings linked by a single carbon-carbon bond. The nature of an “aromatic” (Benzene) ring allows a single attachment to each carbon. This means that there are 10 possible positions for chlorine substitution (replacing the hydrogens in the original Biphenyl).

The positions of the chlorine substituents on the rings are denoted by numbers assigned to each of the carbon atoms, with the carbons supporting the bond between the rings being designated 1 and 1'. Manufacture of PCBs was banned in 1977 because of evidence that they were persistent in the environment and because of wide spread concern that they were associated with health risks. By the end of 1980 worldwide production of PCBs totaled 1,054,800 tons. For many purposes they are divided into classes based on whether and how many chlorines are found



Box and Whisker-diagram of serum PCB concentrations (PCB congeners 138, 153, 180 and Σ PCB) in breast-fed (left column) and bottle-fed (right column) infants at the age of six weeks.

Figure 3. Organochlorine Compounds in Breast-Fed vs. Bottle-Fed Infants: Preliminary Results at Six Weeks of Age. From: Lachmann et al. (2004). *Science of the Total Environment*, 329, 289–293.

on ortho positions or are not present in any ortho position, where the compound is called a coplanar PCB. Without ortho-substituted chlorines the molecule can assume a coplanar configuration and exert some actions similar to 3,4,7,8-tetrachloro-dibenzo-dioxin (TCDD), the most toxic of dioxin congeners. Unlike the coplanar, ortho-substituted PCBs have the

ability to reduce levels of the neurotransmitter dopamine, both in vivo and in vitro. Unfortunately, when ingested, PCBs are readily absorbed, and because they are lipophilic and resistant to metabolism they can persist in fat tissue and human breast milk. Lachmann et al. (2004) demonstrated this recently by comparing concentrations of specific congeners in the sera of breast- versus bottle-fed infants (see Figure 3).

Attention Deficit Hyperactivity Disorder

AD/HD is the most commonly diagnosed disorder in children (Barkley, 1989). It is estimated to affect between 3–7% of children (Barkley, 1997). However some (e.g., Gillis, et al., 1992) suggested that the percentage of affected children may be as high as 20%. The American Academy of Pediatrics (2000) indicated that between 2% and 12% of grade school children are affected. Cantwell (1996) suggested that between 50% and 70% of children diagnosed with this disorder will have problems related to social adjustment and functioning, and/or psychiatric problems as adolescents and young adults. For example, Barkley et al. (2003) and Murphy et al. (2002) pointed out that affected adolescents and adults are at increased risk of developing conduct disorder, dysthymia, alcohol-cannabis abuse/dependence to receive psychiatric medication and other mental health services. In these individuals there is also an increased risk of suicide (Murphy et al., 2002). One peculiar aspect of the disorder is that it affects more boys than girls. The behavioral problems of ADHD boys seem to differ from those of ADHD girls. The primary deficit in girls may be associated with attention problems, without hyperactivity (Predominantly Inattentive Type) whereas the primary deficit in the boys may be associated with overactivity, impulsiveness (Predominantly Hyperactive-Impulsive Type).

Research Précis

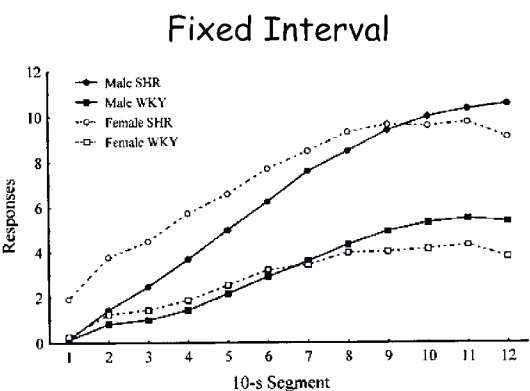
Validating the SHR as an animal model. The behavioral apparatus for the operant conditioning procedures used by Sagvolden and associates to establish the viability of the SHR as an animal model of AD/HD are shown in Figure 4. The animals are trained to press the lever for drops of



Figure 4. The Research Apparatus for Rats and Children.

water (left panel), and the children press the nose of the clown (right panel) for plastic toys and Norwegian Crowns. The operant training is with a multiple fixed interval (FI), extinction (EXT) schedule of reinforcement.

Hyperactivity is indicated by the tendency to press the lever more often, and to produce more response bursts – responses with short (≤ 1.0 s) interresponse times (IRTs) – than the comparison groups. For our purposes impulsiveness is responding prematurely in anticipation of the end of the fixed time interval prior to the next reinforcer. Berger and Sagvolden (1998) reported this behavior in male and female SHRs (Figure 5, left panel), and Sagvolden et al. (1998) with children diagnosed with AD/HD (Figure 5, right panel), compared to their respective comparison

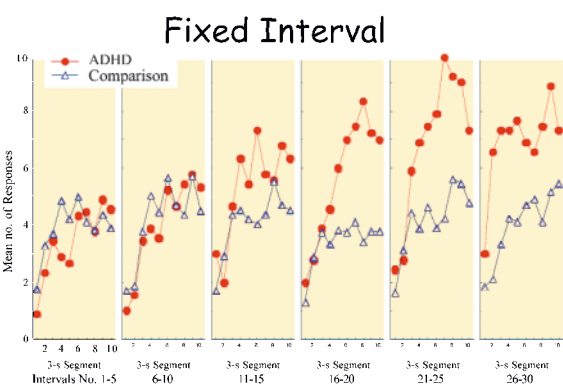


Berger & Sagvolden (1998). *Behavioural Brain Research*, 94, 73–82.

Figure 5.
The Operant Behavior of the SHR (Animal Model) and Children Diagnosed With AD/HD

groups. The obvious similarity between the children’s behavior during the final sessions, to that of the animals, helps establish the external validity of the animal model. A compilation of the FI timing behavior of various strains of rats by Sagvolden (2000) is shown in Figure 6. Data from Holene et al. (1998) are included (marked in the figure as PCB 153 hnss) showing hyperactive/impulsive behavior, similar to that of SHRs, but produced in male rats by exposure to PCB congener 153 in their mother’s milk.

Findings from our laboratory. Instead of using individual congeners, we exposed male and female SD rats to environmentally relevant concentrations of the PCB mixtures found in the St. Lawrence River (Aroclor 1248) or Lake Ontario (Aroclors 1254 & 1260) via ingestion or inhalation around puberty, or during the perinatal period (in *utero* and during lactation). The experimental protocol for the ingestion and inhalation studies is presented in Figure 7. Berger et al. (2001)



Sagvolden et al. (1998). *Behavioural Brain Research*, 94, 61–71.

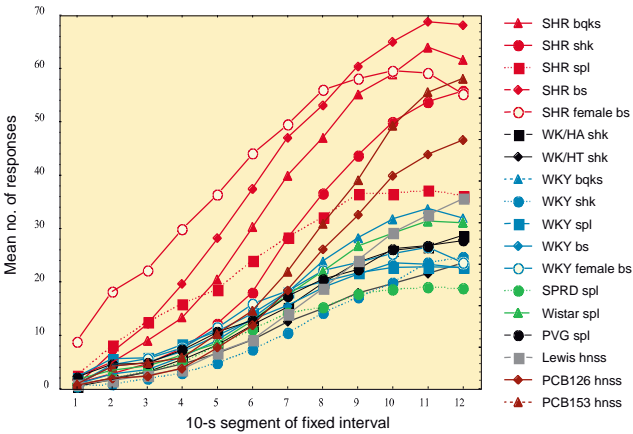


Figure 6. Comparison of the Operant Behavior of the Spontaneously Hypertensive Rat With Other Animals. From: Sagvolden, T. (2000). *Neuroscience and Biobehavioral Reviews*, 24, 31–39.

Procedure	Duration	Comments
Exposure Phase	30 Days – 1 hr per day	Age of rats – 35–64 Days
Habituation to apparatus	1 Day – 30-min session	House-Lights off
Dipper Training	4 Days – 30-min sessions	Begin 22-hrs Water deprivation House-Lights on
Lever Press Training	5 Days	Shaping Procedure – House-Lights on
Continuous Reinforcement	5 Days – 40-min sessions	House-Lights on
FI 30 s-EXT 5 min	2 Days – 40-min sessions	FI-lights on, EXT – House-lights off
FI 60 s-EXT 5 min	2 Days – 40-min sessions	FI-lights on, EXT – House-lights off
FI 120 s-EXT 5 min	Until behavior stabilized – 40-min sessions	FI-lights on, EXT – House-lights off

Figure 7.
Experimental Protocol.

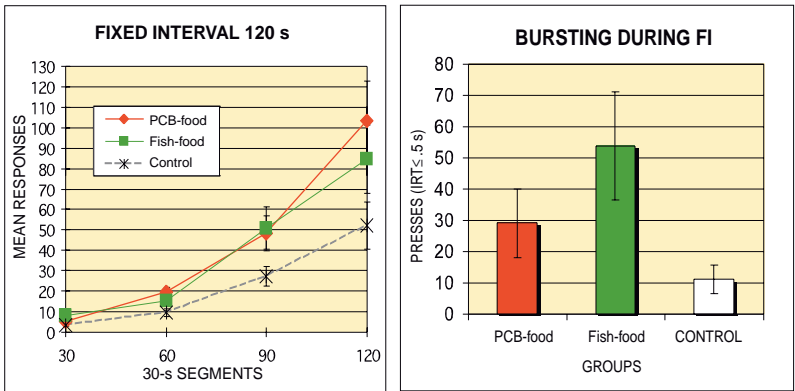


Figure 8. Ingestion Experiment – Males.
Berger, Lombardo, Jeffers, Hunt, Bush, Casey & Quimby (2001)

reported the behavioral effects, measured with FI-EXT procedure (e.g. Berger & Sagvolden, 1998), of ingestion by males of a diet augmented with either corn oil containing 0.5 µg/g Aroclor 1248 (PCB-Food), contaminated St. Lawrence River carp (Fish-Food, total PCBs ~0.72 µg/g), or corn oil alone (Control). The left panel of Figure 8 shows that both exposed groups lever pressed more often (hyperactivity) and earlier in the FI (impulsiveness) than controls, and the exposed groups also produced relatively more

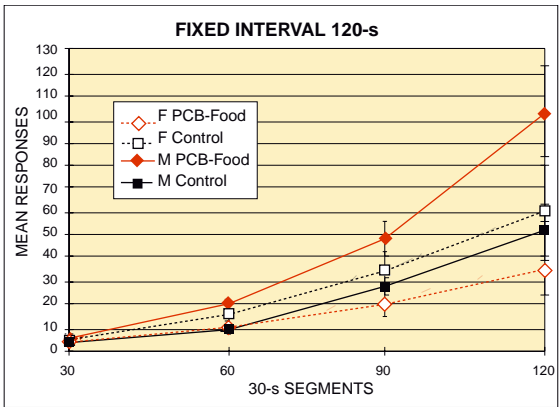


Figure 9. Ingestion of Aroclor 1248 (0.5 µg/g). Sex Differences.

response bursts (right panel). Thus, the PCB-exposed males behaved like genetically hyperactive SHR_s. However, hyperactive/impulsive behavior was not produced in females that ingested the same PCB-Food diet and were tested under conditions identical to those

used with the males. The sex difference displayed in Figure 9 indicates that the exposed females tended to be hypoactive compared to controls. These differential sex effects replicate, with a different exposure method, those of Holene et al. (1999).

Berger, Lombardo and Hunt (2004) exposed male and female SD rats, via inhalation, to either vapor from Aroclor 1248, or vapor generated from PCB-contaminated St. Lawrence River sediment. All were exposed for 23 hours per day in a sealed environment. The unexposed control groups lived in a similarly sealed environment containing essentially uncontaminated air. All animals were tested with FI-EXT procedure, as above. The differential sex effects are depicted in Figure 10. The sediment vapor (SED) produced hyperactivity in both sexes. In contrast, the Aroclor (PCB) produced relatively more responding in males than females, and compared to their respective unexposed controls; again in line with Holene et al. (1999).

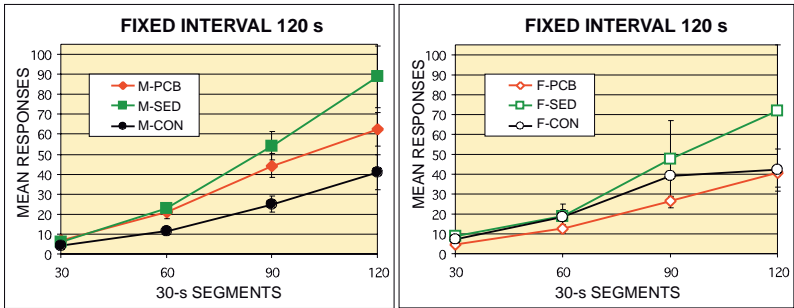


Figure 10. Inhalation Experiment. Sex Differences.

More recently, Lombardo, Berger, and Jeffers (2005) we examined the effects of perinatal exposure to the above diet conditions. Groups of pregnant rats were fed either the PCB-Food, Fish-Food, or Control diets used by Berger et al. (2001) during 9 days of their 21-day gestation period. After their pups were weaned at 21 days of age, all offspring received uncontaminated food for the remainder of the study. They were tested as adults using the same FI-EXT procedure as above. Figure 11 represents

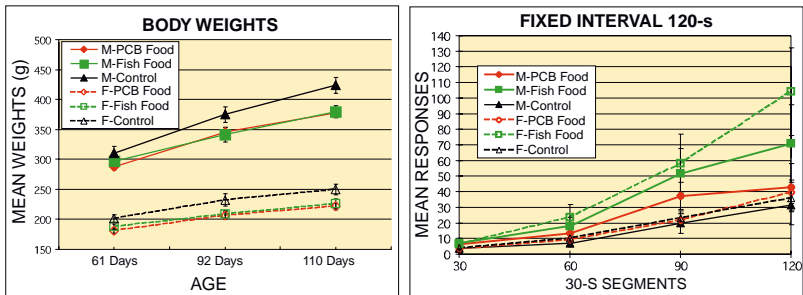


Figure 11. Effects of Perinatal Exposure to PCBs on the Male and Female Offspring.

the body weights of the male and female offspring from the three dams' diet groups. The mean body weights of the groups perinatally exposed to PCBs were lower than their unexposed same-sex counterparts. This observation serves as a manipulation check of exposure conditions. The mean number of responses by male and female offspring in the three dams' diet conditions is plotted in Figure 12 as a function of 30-s segments of the FI. The results show that only perinatal exposure to the PCB-contaminated fish was associated with hyperactivity and impulsiveness in both male and female offspring, relative to unexposed controls. This is the second time that we were able to observe these behavioral effects in female SD rats. In the present study perinatal exposure to the PCB-Food diet did not produce hyperactivity and impulsiveness in either the males or the females. The dose may have been too low, perhaps because the dams only consumed about 67% of their daily portions of the diet. However the reproductive (estrous) cycles of the female offspring were affected (see Figure 12). The peri-

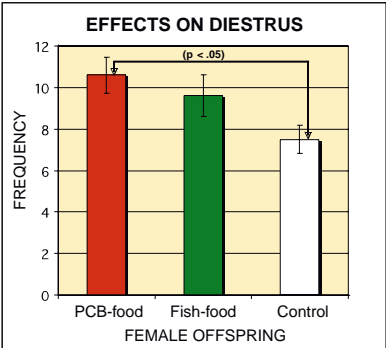


Figure 12. Effects of the Perinatal Exposure on Estrous Cycles.

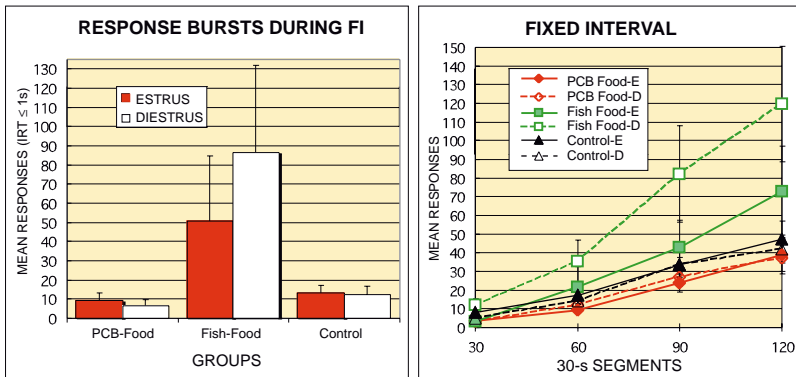


Figure 13. Perinatal Exposure to PCBs: Estrous-Effects on Behavior of the Female Offspring.

natal exposure to the PCB-Food diet resulted in this offspring group spending more time in the diestrus phase of their cycle than controls. Estrogen levels are lowest during this phase, and females will not accept a male. Interestingly, Mendola, Buck, Sever, Zielezny, and Vena (1997) had observed a reduction in the length of menstrual cycles in pre-menopausal women who had eaten PCB-contaminated fish more than once a month. The effects of perinatal exposure to the contaminated fish on the behavior of the female offspring were also more pronounced during diestrus than estrus. Figure 13 shows relatively more bursts (left panel) and hyperactivity and impulsiveness (right panel).

Most recently we replicated the sex differences in the effects of PCB exposure during adolescence, shown above, with the mixtures found in the Great Lakes and in mothers' milk, following the protocol presented in Figure 7. Groups of male and female SD rats ate cookies on to which two different doses had been placed prior to being tested with the FI-EXT procedure. Figure 14 shows the resulting dose-related hyperactive/impulsive behavior in the males (left), but the opposite in the females (right), compared to same-sex controls.

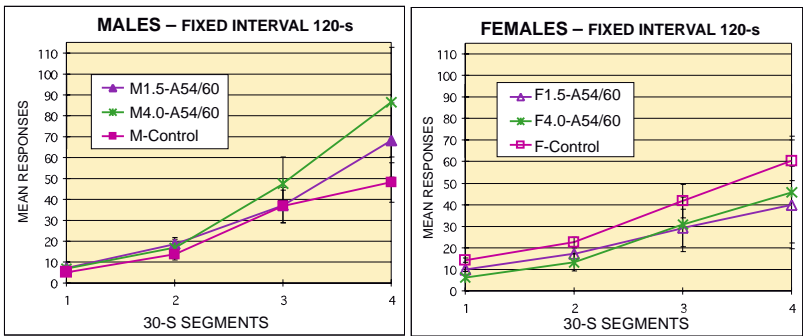


Figure 14. Ingestion of 1.5 v 4.0 $\mu\text{g/g}$ Aroclor 1254/1260. Sex Differences.

Clearly the PCB-contaminated St. Lawrence River sediment and fish contain other toxins such as methylmercury, organochlorine pesticides, polybrominated diethyl ethers, and hydroxylated metabolites of PCBs that may also affect behavior. Some of their neurotoxic and endocrine disruptive effects appear to be sex-specific. More research is needed to separate and elucidate all these effects.

In conclusion, we have shown that exposure to environmental levels of PCBs and related toxicants, by varied means and at different times during development, affects the behavior and physiology of an animal model

relevant for human beings. We believe it is important to study the effects of ingesting a contaminated food source because ingestion of PCB contaminated food, not a specific congener or Aroclor, is the main source of human exposure to PCBs. Our data and others suggest that exposure to PCBs and other environmental toxins are partly responsible for the increases in the prevalence of AD/HD in the USA and other parts of the world. A theoretical interpretation appears in a recent paper by Sagvolden, Johansen, Aase and Russell (in press), and from which Figure 15 was taken.

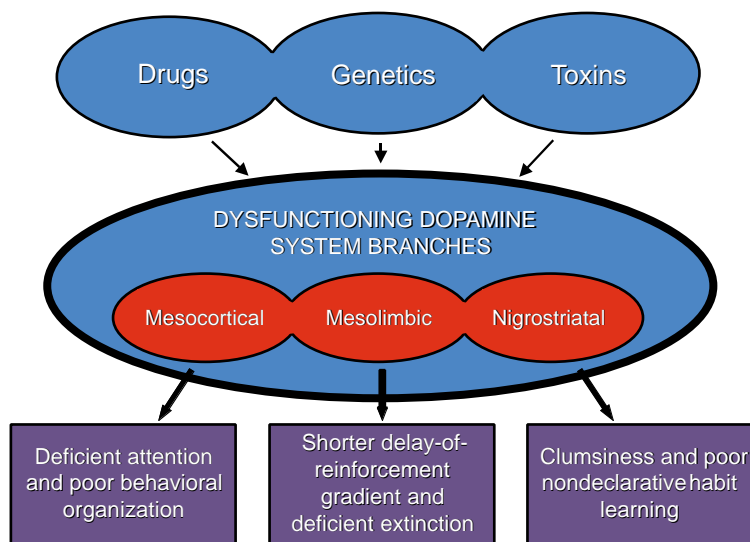


Figure 15. From Sagvolden, Johansen, Aase & Russell, BBS

References

- Barkley R.A (1989) The problem of stimulus control and rule-governed behavior in attention deficit disorder with hyperactivity. In L.M Bloomingdale, J.M Swanson (Eds.), *Attention Deficit Disorder: Current concepts and emerging trends in attentional and behavioral disorders of childhood*, (pp. 203–228). Oxford: Pergamon Press.
- Barkley R.A, Fischer M, Smallish L, Fletcher K. (2003). Does the treatment of attention-deficit/hyperactivity disorder with stimulants contribute to drug use/abuse? A 13-year prospective study. *Pediatrics*, 111, 97–109.
- Barkley, R.A (1997) Behavioral inhibition, sustained attention and executive functions: Constructing a unifying theory of ADHD. *Psychol Bull*, 121, 65–94.
- Berger D.F, Lombardo J.P, Jeffers P.M, Hunt A.E, Bush B, Casey A, Quimby F (2001) Hyperactivity and impulsiveness in rats fed diets supplemented with either Aroclor 1248 or PCB-contaminated St. Lawrence river fish. *Behav Brain Res*, 29, 126, 1–11.
- Berger D.F, Sagvolden T (1998) Sex differences in operant discrimination behavior in an animal model of Attention Deficit Hyperactivity Disorder. *Behav Brain Res*, 94, 73–82.
- Cantwell D.P, (1996). Attention deficit disorder: a review of the past 10 years. *J Am Acad Child Adolesc Psychiatry*, 35, 978–987.
- Gillis J.J, Gilger J.W, Pennington B.F, DeFries J.C. (1992). Attention deficit disorder in reading-disabled twins: evidence for a genetic etiology. *J Abnorm Child Psychol*, 20, 303–15
- Holene E, Nafstad I, Skaare J.U, Krogh H, Sagvolden T (1999) Behavioral effects in female rats of postnatal exposure to sub-toxic doses of polychlorinated biphenyl congener 153. *Acta Paediatrica* S88, 429, 55–63.
- Holene E, Nafstad I, Skaare J.U, Sagvolden T (1998) Behavioral hyperactivity in rats following postnatal exposure to sub-toxic doses of polychlorinated biphenyl congeners 153 and 126. *Behav Brain Res*, 94, 213–224.

Exposure to Polychlorinated Biphenyls (PCBs) Produces Hyperactivity ...

- Lachmann G.M, Schaller K.H and Angerer J. (2004). Organochlorine compounds in breast-fed vs.bottle-fed infants:preliminary results at six weeks of age, *Science of the Total Environment*, 329, 289–293.
- Lombardo J.P, Berger D.F, Jeffers P.M. (2005). Hyperactivity and Impulsiveness Induced by Perinatal Exposure to PCB-Contaminated St. Lawrence River Fish. Being submitted to *Behavioral and Brain Functions*.
- Mendola P, Buck G.M, Sever L.E, Zielezny M, Vena J.E. (1997). Consumption of PCB-contaminated freshwater fish and shortened menstrual cycle length. *Am J Epidemiol*, 146, 955–960.
- Murphy K.R, Barkley R.A, Bush T. (2002). Young adults with attention deficit hyperactivity disorder: subtype differences in comorbidity, educational, and clinical history. *J Nerv Ment Dis*, 190, 147–57.
- Sagvolden T, Aase H, Zeiner P, Berger D.F (1998) Altered reinforcement mechanisms in attention-deficit hyperactivity disorder. *Behav Brain Res*, 94, 61–71.
- Sagvolden T, Johansen E.B, Aase H, Russell V.A. (in press). A dynamic developmental theory of attention-deficit/hyperactivity disorder (ADHD) predominately hyperactive/impulsive and combined subtypes. *Behavioral Brain Sciences*.
- Sagvolden T. (2000). Behavioral validation of the spontaneously hypertensive rat (SHR) as an animal model of attention-deficit/hyperactivity disorder (AD/HD). *Neurosci Biobehav Rev*, 24, 31–39.

Economy and Prescriptivism: Internal and External Causes for Linguistic Change

Language change is inevitable. In this paper, I show how Principles of Universal Grammar (UG), in particular Economy Principles, condition linguistic, i.e. internal, change. I then show how external factors such as prescriptive rules hinder internal developments. I will first provide some background to Chomskian Linguistics.

Universal Grammar

Chomsky examines two main problems in, for instance, his 1986 *Knowledge of Language*: (a) how do we know so much on the basis of so little evidence, and (b) how do we know so little given that we have so much evidence? These are referred to as Plato's Problem and Orwell's Problem respectively. The first problem

concerns what we know about language and how we acquire this knowledge. It will be dealt with in some detail. The second problem concerns the use of language and the mechanism of indoctrination. I cannot go into that here due to limitations of space.

Plato's problem is that of the 'poverty of the stimulus'. As speakers of a language we know so many rules without ever having been explicitly taught them. We can produce sentences that we have never heard before. The reason we know this much is because we have acquired a Grammar not on the basis of imitation but by using an innate Universal Grammar to acquire a grammar. This Universal Grammar (hereinafter UG) helps to interpret the language we hear around us and to build up our unique grammar. This process is schematized somewhat simplistically in (1):

$$1. \text{UG} + \text{L1} = \text{G1} \rightarrow \text{L2}$$

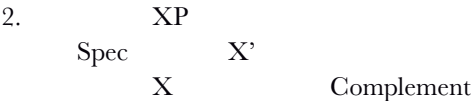
A child hears a language (L1 in (1)), and principles and rules of UG enable him or her to build up a grammar (G1 in (1)). The output of this grammar is a language (L2) not necessarily the same as L1. In principle, each speaker can have a slightly different grammar from other people speaking the 'same' language. Such 'imperfect' transmission is how language changes.

I'll now briefly give an example of a UG Principle. It is assumed that all languages use a form of (2) to represent their structure. Building the derivation, there are three positions, a specifier, a head, and a complement:

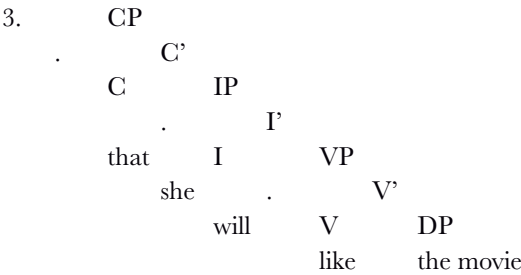
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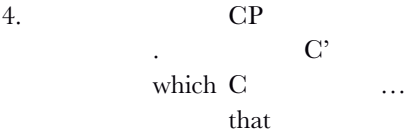
The specifier and the complement are positions that accommodate full phrases. All languages have structures such as (2) but the headedness varies. Thus, in English and Norwegian, verbs precede their objects (complement in (2)), but in Farsi, Urdu, and Japanese, the verb follows. Heads such as verbs (V), inflection markers (I), and complementizers (C) use (2) to derive (3), representing the three layers of an English subordinate sentence:



Economy Principles and Internal Language Change

Looking at linguistic change, I will argue that there is an Economy Principle that states that it is more economical in (2) to use the head position than the specifier position (see also van Gelderen 2004). Intuitively, this can be formulated as ‘be a head, rather than a full phrase’, or the Head Preference Principle. The only case I can discuss here is that involving English relative pronoun preferences.

The structural representation for English relative pronouns is one where pronouns such as *who*, *which*, and *from which* occupy the specifier position but where *that* occupies the head position, as in (4). In standard modern English, the two kinds do not occur together but in earlier English and in modern non-standard varieties they do, as in (5):



5. I wonder which dish that they picked (Henry 1995: 107).

The Head Preference Principle predicts either that *that* will be favored or that the *wh*-pronoun will shift from the specifier to the head position. Both can be argued to occur in sentences (6) to (8), quoted from Miller (1993: 111–2):

- 6. I haven’t been to a party yet that I haven’t got home the same night.
- 7. a cake where you don’t gain weight.
- 8. The girl that her eighteenth birthday was on that day.

In (6), *that* is used over *from which* which would be the prescriptively correct form; in (7), *where* is most likely in the head position; and in (8), *that* is used over a more complex form. In informal language, examples such as these abound.

Table 1: That versus who in the CSE

	the N	a(n) N
that	5637 (=82%)	1758 (=81%)
wh-form	1199 (=18%)	414 (=19%)
total	6836 (=100%)	2172 (=100%)

In a (2 million word) corpus of modern spoken formal English (www.athel.com), the preference is very clear. Table 1 shows that *that* is much more frequent after *the man...*, *the book* etc than *who* or *for*:

Montgomery & Bailey (1991: 155) analyze relative clauses in academic writing as well as speech. Out of 200 relative clauses in speech, 138 use *that*, 36 have no pronoun, and the remaining 26 (or 13%) use a *wh*-form. The writing sample is very different. There are 22 clauses with *that*, 6 with no pronoun, and the remaining 172 (or 86%) are *wh*-forms. This difference between spoken and written data shows that there is a prescriptive rule at work, typical for written language. I turn to that next.

External Prescriptivism stopping Internal Change

Many prescriptive rules concern relatives and these favor *wh*-relatives over *that*, going against the internal change. Prescriptive rules are external in that they make very little linguistic sense. For instance, there is a rule that *who* is to be used referring to humans. A recent usage guide says: “*who* refers to people or to animals that have names... [*w*]/*hich* and *that* usually refer to objects, events, or animals and sometimes to groups of people” (Kirsznier & Mandell 1992: 381). Anecdotal reports from English composition teachers say they often correct sentences such as (9):

9. The people that you should contact are ...

If the *wh*-preference is indeed a prescriptive rule, the difference between written and spoken, mentioned before, is completely expected.

There is a second prescriptive rule that favors *wh*-relatives, i.e. specifiers, namely, the rule against preposition stranding. Sentences that end with prepositions, such as (10), are judged to be incorrect, and (11) is preferred:

10. I met the woman who I had seen a picture of.

11. I met the woman of whom I had seen a picture.

The figures given in Montgomery & Bailey (1991: 156) for the spoken and written samples mentioned above are again interesting in showing that the written sample more closely mirrors the prescriptive norm. In speech, 86% of prepositions are stranded, whereas in writing, 7% are. Since (11) is only possible with *wh*-relatives, this second prescriptive rule (indirectly) also favors *wh*-relatives.

Conclusion

After giving some background on UG, I argue that an Economy Principle is responsible for certain kinds of language change. The example I discuss involves the English relative clause. I then show that there are various external factors hindering this development. This becomes especially obvious when one compares written and spoken data.

References

- Chomsky, Noam 1986. *Knowledge of Language*. New York: Praeger.
 Gelderen, Elly van 2004. *Grammaticalization as Economy*. Amsterdam: John Benjamins.
 Henry, Alison 1995. *Belfast English*. Oxford: Oxford University Press.
 Kirsznier, Laurie & Stephen Mandell 1992. *The Holt Handbook* [third edition]. Fort Worth: Harcourt Brace Jovanovich.
 Miller, Jim 1993. “The Grammar of Scottish English”. In: James Milroy & Lesley Milroy (eds), *Real English*, 99–138. London: Longman.
 Montgomery, Michael & Guy Bailey 1991. “*In Which*: A new form in written English”. *American Speech* 66.2: 147–163.

Validation of Animal Models of ADHD

Attention-deficit/hyperactivity disorder (ADHD) is a neurobehavioral disorder of childhood onset that is characterized by inattentiveness, hyperactivity, and impulsiveness. All clinical criteria are behavioural. Inattentiveness, overactivity, and impulsiveness are presently regarded as the main clinical symptoms.

The dynamic developmental behavioural theory (DDT) is based on the hypothesis that altered dopaminergic function plays a pivotal role by failing to modulate nondopaminergic (primarily glutamate and GABA) signal transmission appropriately (Johansen, Sagvolden, Aase, & Russell, 2005; Sagvolden, Johansen, Aase, & Russell, 2005a).



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A hypofunctioning mesolimbic dopamine branch produces altered reinforcement of behaviour and deficient extinction of previously reinforced behaviour (Figure 1). This gives rise to delay aversion, development of hyperactivity in novel situations, impulsiveness, deficient sustained attention, increased behavioural variability, and failure to “inhibit” responses (“disinhibition”).

A hypofunctioning mesocortical dopamine branch will cause attention response deficiencies (deficient orienting responses, impaired saccadic eye movements, and poorer attention responses toward a target) and poor behavioural planning (poor executive functions).

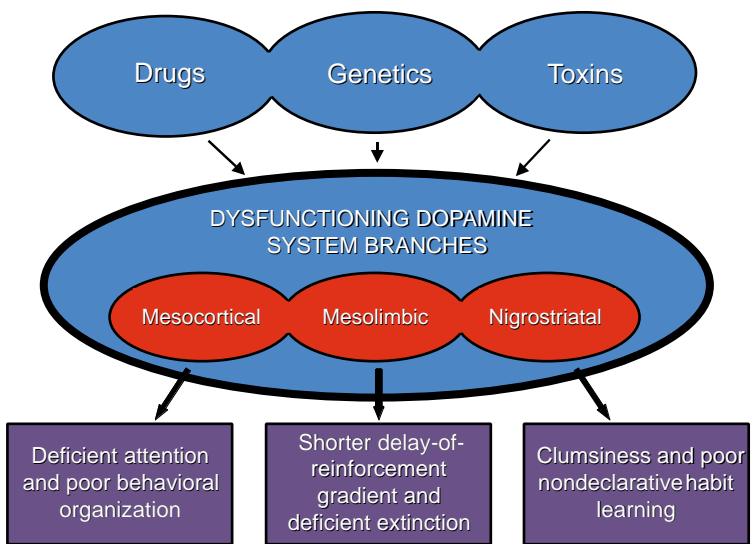


Figure 1. Dysfunction of dopaminergic systems resulting from drug abuse, genetic transmission, or environmental pollutants may cause ADHD symptoms by interacting with frontostriatal circuits (not shown) (Sagvolden et al., 2005a).

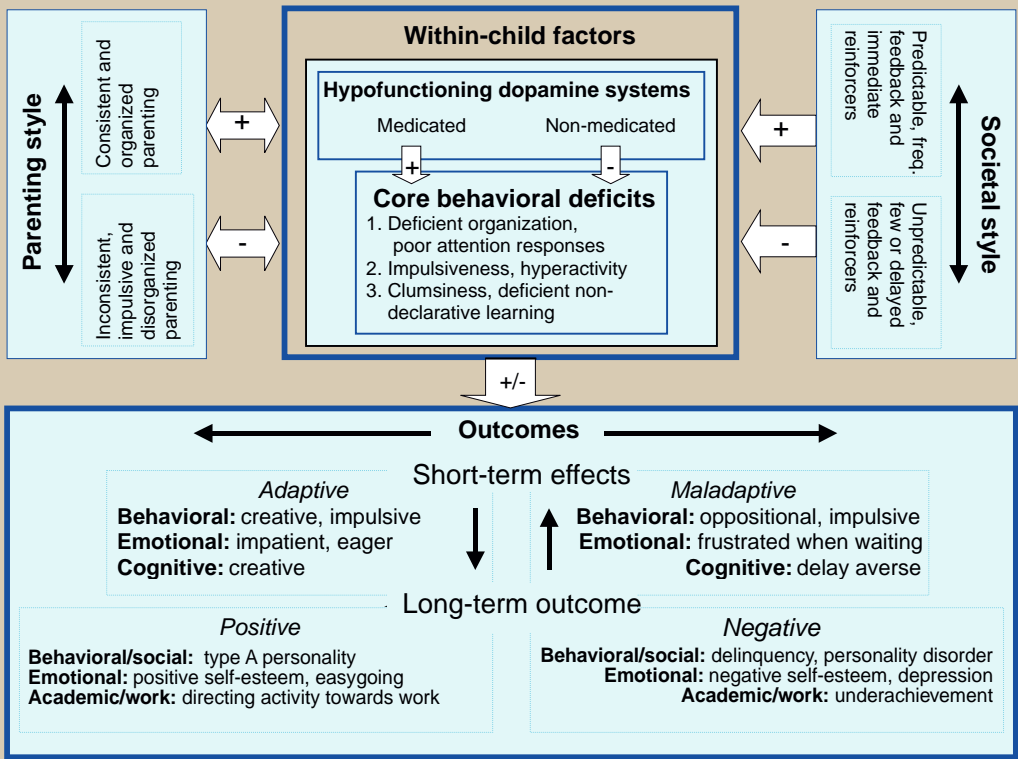


Figure 2. The dynamic developmental theory (DDT) predicts adaptive as well as maladaptive behavioural outcomes of the core deficits in interaction with medication, parenting, and societal styles. A plus sign (+) within an arrow means a beneficial interaction or influence, a minus sign (-) denotes an unfavourable interaction or influence. Parenting and societal styles and the behavioural outcomes are regarded as vectors, not as discrete categories in order to stress the dynamic and developmental aspects of ADHD behaviour (Sagvolden et al., 2005a).

A hypofunctioning nigrostriatal dopamine branch will cause impaired modulation of motor functions and deficient nondeclarative habit learning and memory. These impairments will give rise to apparent developmental delay, clumsiness, neurological “soft signs,” and a “failure to inhibit” responses when quick reactions are required.

Hypofunctioning dopamine branches represent the main individual predispositions in the DDT theory (Sagvolden et al., 2005a). DDT predicts that behaviour and symptoms in ADHD result from the interplay between individual predispositions and the surroundings. The exact ADHD symptoms at a particular time in life will vary and be influenced by factors having positive or negative effects on symptom development (Figure 2). Altered or deficient learning and motor functions will produce special needs for optimal parenting and societal styles. Medication will to some degree normalize the underlying dopamine dysfunction and reduce the special needs of these children. DDT describes how individual predispositions interact with these conditions and produce behavioural, emotional, and cognitive effects that can turn into relatively stable behavioural patterns.

Animal models

Although animals cannot be used to study complex human behaviour such as language, they do have similar basic functions. In fact, human disorders that have animal models are better understood than disorders that do not. An ideal animal model should be similar to the disorder it models in terms of aetiology, biochemistry, symptomatology, and treatment. Animal models provide several advantages over clinical research: simpler nervous systems, easily interpreted behaviours, genetic homo-

geneity, easily controlled environment, and a greater variety of interventions (Johansen, Aase, Meyer, & Sagvolden, 2002; Johansen & Sagvolden, 2004; Johansen & Sagvolden, 2005a; Johansen & Sagvolden, 2005b; Johansen, Sagvolden, & Kvande, 2005; Russell, Sagvolden, & Johansen, 2005; Sagvolden, Russell, Aase, Johansen, & Farshbaf, 2005b).

The ADHD diagnosis is behaviourally based; therefore, the validation of an ADHD model must be based in behaviour. An ADHD model must mimic the fundamental behavioural characteristics of ADHD (face validity), conform to a theoretical rationale for ADHD (construct validity), and predict aspects of ADHD behaviour, genetics, and neurobiology previously uncharted in clinical settings (predictive validity).

Spontaneously hypertensive rat (SHR)

SHR fulfil many of the validation criteria and compare well with clinical cases of ADHD (Figure 3) (Sagvolden, 2000; Sagvolden, Aase, Zeiner, & Berger, 1998; Sagvolden et al., 2005b). Poor performers in the five-choice serial reaction time task and Naples high-excitability rats (NHE) are useful models for attention-deficit disorder (Sagvolden et al., 2005b). Other animal models either focus on the less important symptom of hyperactivity and might be of limited value in ADHD research or are produced in ways that would not lead to a clinical diagnosis of ADHD in humans, even if ADHD-like behaviour is displayed.

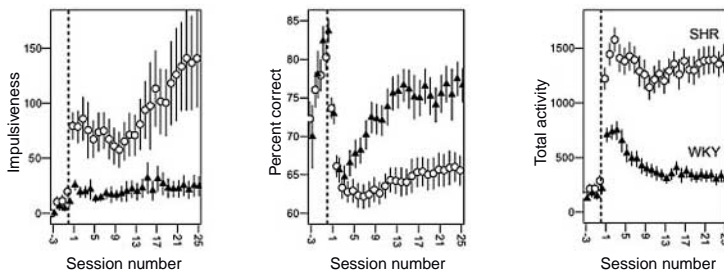


Figure 3. Correct responding in operant chambers was reinforced according to intermittent schedules of reinforcement. During the four initial sessions (session numbers -3 to 0), practically every correct response was reinforced; the average interval ranged between .1 and 15 s. From session 1 (at the vertical dotted line), responses were reinforced intermittently, with the average interval being 3 min. Rats were tested every day. Impulsiveness (premature responses with interresponse times less than .67 s) (A), sustained attention (percent correct lever choices) (B), and total activity (C) were measured. Results are mean \pm SEM of 83 spontaneously hypertensive rats (SHR, open circles) and 67 Wistar Kyoto rats (WKY, filled triangles) (Sagvolden et al., 2005b).

ADHD is a heterogeneous disorder. The relatively simple nervous systems of rodent models have enabled identification of neurobiological changes that underlie certain aspects of ADHD behaviour. Several animal models of ADHD suggest that the dopaminergic system is functionally impaired (Russell et al., 2005). Some animal models have decreased extracellular dopamine concentrations and upregulated postsynaptic dopamine D1 receptors (DRD1, Figure 4) while others have increased extracellular dopamine concentrations. In the latter case, dopamine pathways are suggested to be hyperactive. However, stimulus-evoked release of dopamine is often decreased in these models, which is consistent with impaired dopamine transmission. It is possible that the behavioural char-

acteristics of ADHD result from impaired dopamine modulation of neurotransmission in cortico-striato-thalamo-cortical circuits (Figure 1). There is considerable evidence to suggest that the noradrenergic system is poorly controlled by hypofunctional α_2 -autoreceptors in some models, giving rise to inappropriately increased release of norepinephrine. Aspects of ADHD behaviour may result from an imbalance between increased noradrenergic and decreased dopaminergic regulation of neural circuits that involve the prefrontal cortex. Animal models of ADHD also suggest that neural circuits may be altered in the brains of children with ADHD. In neurobiological and pharmacological studies it is therefore of particular importance to study animal models of the disorder and not normal animals.

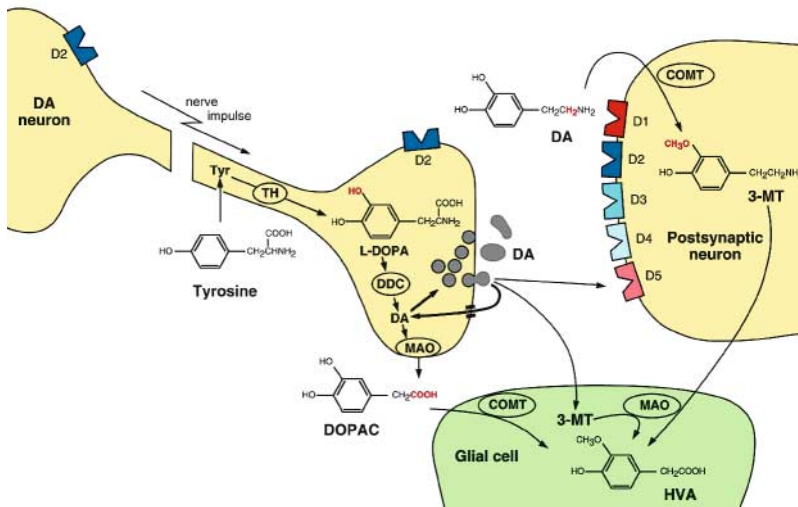


Figure 4. Neurons and glial cell showing dopamine synthesis, metabolism, and typical positions of dopamine receptors. Note that D1/5 and D2/3/4 receptors are not generally colocalized on the same neuron as they have opposite effects. Abbreviations: 3MT = 3-methoxytyramine, COMT = catechol-O-methyl transferase, D1–D5 = dopamine receptors 1 through 5, DA = dopamine, DDC = DOPA decarboxylase, HVA = homovanillic acid, MAO = monoamine oxidase, TH = tyrosine hydroxylase, Tyr = tyrosine. (Modified after (Waters, 1995)).

Evidence obtained from animal models suggests that psychostimulants may not be acting on the dopamine transporter to produce the expected increase in extracellular dopamine concentration in ADHD. There is evidence to suggest that psychostimulants may decrease motor activity by increasing serotonin levels. In addition to providing unique insights into the neurobiology of ADHD, animal models are also being used to test new drugs that can be used to alleviate the symptoms of ADHD (Russell et al., 2005).

Conclusions

ADHD is a heterogeneous disorder, suggested to result from combinations of genetic and environmental factors. Animal models can mimic only certain aspects of the complex symptomatology of ADHD, but may still provide feasible hypotheses regarding the underlying causes of specific

aspects of ADHD behaviour. These hypotheses can then be tested in the clinic. Animal models can also be used to test potential drugs for the treatment of ADHD.

Future research on animal models of human disorders will undoubtedly promote a better understanding of the contribution of specific neurobiological factors to behavioural components like attention, reinforcement and extinction that seem to be important for understanding ADHD.

References

- Johansen, E. B., Aase, H., Meyer, A., & Sagvolden, T. (2002). Attention-deficit/hyperactivity disorder (ADHD) behaviour explained by dysfunctioning reinforcement and extinction processes. *Behavioural Brain Research*, 130, 37–45.
- Johansen, E. B. & Sagvolden, T. (2004). Response disinhibition may be explained as an extinction deficit in an animal model of attention-deficit/hyperactivity disorder (ADHD). *Behavioural Brain Research*, 149, 183–196.
- Johansen, E. B. & Sagvolden, T. (2005a). Behavioral effects of intra-cranial self-stimulation in an animal model of attention-deficit/hyperactivity disorder (ADHD). *Behavioural Brain Research*, 162, 32–46.
- Johansen, E. B. & Sagvolden, T. (2005b). Slower extinction of responses maintained by intra-cranial self-stimulation (ICSS) in an animal model of attention-deficit/hyperactivity disorder (ADHD). *Behavioural Brain Research*, 162, 22–31.
- Johansen, E. B., Sagvolden, T., Aase, H., & Russell, V. A. (2005). The dynamic developmental theory of attention-deficit/hyperactivity disorder (ADHD): Present status and future perspectives. *Behavioral and Brain Sciences*, 28, 451–454.
- Johansen, E. B., Sagvolden, T., & Kvande, G. (2005). Effects of delayed reinforcers on the behavior of an animal model of attention-deficit/hyperactivity disorder (ADHD). *Behavioural Brain Research*, 162, 47–61.
- Russell, V. A., Sagvolden, T., & Johansen, E. B. (2005). Animal models of attention-deficit hyperactivity disorder. *Behavioral and Brain Functions*, 1, 9.
- Sagvolden, T. (2000). Behavioral validation of the spontaneously hypertensive rat (SHR) as an animal model of attention-deficit/hyperactivity disorder (AD/HD). *Neuroscience and Biobehavioral Reviews*, 24, 31–39.
- Sagvolden, T., Aase, H., Zeiner, P., & Berger, D. F. (1998). Altered reinforcement mechanisms in Attention-Deficit/Hyperactivity Disorder. *Behavioural Brain Research*, 94, 61–71.
- Sagvolden, T., Johansen, E. B., Aase, H., & Russell, V. A. (2005a). A dynamic developmental theory of Attention-Deficit/Hyperactivity Disorder (ADHD) predominantly hyperactive/impulsive and combined subtypes. *Behavioral and Brain Sciences*, 28, 397–419.
- Sagvolden, T., Russell, V. A., Aase, H., Johansen, E. B., & Farshbaf, M. (2005b). Rodent models of attention-deficit/hyperactivity disorder. *Biological Psychiatry*, 57, 1239–1247.
- Waters, N. (1995). *On the functional role of the dopamine D3 receptor*. PhD Goteborg University, Sweden.

Some General Grammatical Differences between the Modern Germanic Languages with a View to Language History

Ancient and modern Germanic

The recorded history of the Germanic languages is one of diversification. The oldest sources allow for the reconstruction of a fairly uniform pre-historical Germanic with fairly modest internal variation. The attested Old Germanic languages comprise the following: the mostly Scandinavian language of the runic inscriptions (from 2nd c.), Gothic (second half of the 4th c.), Old English, Old Saxon and Old High German (from 8th c.), Old Low Franconian as the forerunner of Dutch (9th c.), Old Norse and Icelandic (from 9th c.), and, but less important, Old Danish and Old Swedish, and Old Frisian (from 13th c.). These languages share, among other things, the following basic systematic traits: four, or five, morphological cases both in pronouns and in full noun phrases: nominative, accusative, dative, genitive and, limited to morphological relics, instrumental; two tenses, i.e., the present and the preterit (the later auxiliary constructions are absent from runic Nordic and Gothic and in a state of emergence at the oldest stages of the other languages); and word, or constituent, order is less restricted or “freer” than later on. Finite verbs may occupy different positions in main, assertive clauses – first (V-1), second (V-2), later (V-3, etc.), last (V-final), relative to subjects and objects.

Disregarding the non-European Germanic diaspora of Yiddish and Afrikaans, the main modern Germanic languages are the following (the approximate number of native speakers is given in parentheses): Icelandic (280,000), Faroese (50,000), Norwegian (4,600,000, with the two main written varieties Riksmål/Bokmål and Nynorsk ‘New-Norwegian’), Swedish (9,000,000), Danish (5,000,000), English (60,000,000 in Europe, 400,000,000 worldwide), (Modern West) Frisian (350,000 in the Dutch provinces Groningen and Vriesland), Dutch (20,000,000), and German (90,000,000).

The history of the development from Old to Modern Germanic is one of structural diversification.

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The position of the finite verb

The position of the finite verb in main and subordinate clauses varies among the modern languages. In main clauses, V-1 signals a yes–no question:

- (1) a. Kommt ('comes') er ('he')? (German)
- b. Did he do it?

In modern Icelandic, V-1 survives in narrative main clauses (as in Old Norse):

- (2) Leið nú til sumarmála, fór húsfreyja þá að ógledðjast. 'Midsummer approached, and the lady of the mansion began to turn morose.'

In all Germanic languages, V-2 is a mark of declarative main clauses:

- (3) Her mother has arrived.

3rd and later positions are found in English main clauses with a topicalized element:

- (4) a. Today her mother will finally arrive. (V-3)
- b. Today, her mother finally arrived. (V-4)

There is more variation of verb position in subordinate clauses but here it is not a functional means of distinguishing between declaratives and questions, but more strictly structural (typological). English and Icelandic (and optionally Faroese) basically have V-2 (not counting the complementiser) in subordinate clauses, as in declarative main clauses:

- (5) ...because he did not buy the book.

Norwegian, Danish, Swedish (and optionally Faroese) subordinate clauses are V-3:

- (6) ...fordi ('because') han ('he') ikke ('not') kjøpte ('bought') boken. (Norwegian)

German, Dutch and West Frisian subordinate clauses are verb-final (which includes having the finite verb as part of a clause-final verb complex; cf. below):

- (7) ... weil ('because') er ('he') das Buch ('the book') nicht ('not') kaufte ('bought'). (German)

With regard to subordinate clauses, one thus finds a geographical opposition between the continental languages, which have verb-final structures in subordinate clauses, and the other, non-continental, languages that do not. The positions of the finite verb in main clauses differ with regard to pragmatic function (assertion vs. question), whereas the position (positions) of the finite verb in subordinate clauses does (do) not have a similar functional basis.

Verb chains with non-finite verbs

Originally, Germanic had only the two finite tenses present and preterit, and, in addition, an infinitive and present and past (or passive) participles. By processes of grammaticalisation, new periphrastic perfect and passive constructions have come into being since around 800 A.D. Rules for forming more extensive ‘verb chains’, consisting of several verb forms, gradually established themselves. Such verb chains are structured in significantly different ways in the various modern Germanic languages. In the languages without verb-final constructions – Icelandic, Faroese, Norwegian, Swedish, Danish, and English – verb chains are in general straightforwardly right-branching, as in (8):

- (8) ...because he **had**¹ not **been**² **invited**³ to **contribute**⁴ to the festschrift.

The languages with verb-final constructions show different structuring of the clause-final verb complex. Modern West Frisian is straightforwardly left-branching:

- (9) ...wêrom’t ik de hiele dei **sitten**⁴ **bliuwe**³ **moatten**² **ha**¹. ‘...why I have had to remain sitting [there] all day long.’

German is basically left-branching but at a certain stage of expansion it adds, under certain conditions, right-branching:

- (10) a. ...weil er gestern Abend **gearbeitet**³ **haben**² **soll**¹.
 ‘...because he is reported to have been working yesterday evening.’
 b. ...weil ich den ganzen Tag **habe**¹ **arbeiten**³ **müssen**².
 ‘...because I have had to work all day.’
 c. ...weil ich den ganzen Tag **würde**¹ **haben**² **sitzen**⁵ **bleiben**⁴ **müssen**³. ‘...because I would have had to remain sitting [there] all day long.’

Dutch is partly left- and partly right-branching. It has certain restrictions against left-branching which do not apply in German and is therefore more right-branching than German.

- (11) a. ...omdat hij heden niet **zal**¹ **komen**²/**komen**² **zal**¹.
 ‘...because he won’t come today.’
 b. ...omdat hij gisteravond **zou**¹ **zijn**² **gekomen**³/**gekomen**³ **zou**¹ **zijn**²/**zou**¹ **gekomen**³ **zijn**²/***gekomen**³ **zijn**² **zou**¹
 ‘... because he is reported to have come yesterday.’
 c. ...waarom ik de hele dag **had**¹ **moeten**² **blijven**³ **zitten**⁴.
 ‘...because I would have had to remain sitting here all day.’

The geographical distribution of the main linearization patterns is illustrated in (12):

(12)

N

IV, III. Icelandic, Faroese, Norwegian,
Danish, Swedish, English:
V¹ V² Vⁿ

IIa. West Frisian:

$$V_n \quad V^2 \quad V^1$$
$$*V1 \quad V_n \quad V2$$
$$*V_1 \ V_2 \ V_n$$

W

IIb. Dutch:

$$V_1 \quad V_2 \quad V_n$$
$$V^1 \quad V^n \quad V^2$$
$$*V_n \quad V_2 \quad V_1$$

E

I. German:

$$V_n \quad V^2 \quad V^1$$
$$V1 \quad V_n \quad V2$$
$$*V_1 \ V_2 \ V_n$$

S

This geographically diversified system of ordering regularities has come into existence since the Late Middle Ages.

Case marking and verb order

In the early 1960s, Joseph H. Greenberg formulated a number of cross-linguistic statistical generalizations called ‘implicational universals’. One of the most famous of these is “Universal 41”: “If in a language the verb follows both the nominal subject and nominal object as the dominant order, the language almost always has a case system.” It is difficult to apply this implicational universal to the Germanic languages without modification. First, the languages with verb-final structures have them only in subordinate clauses. Second, the languages that neutralize case oppositions retain relics of case marking in personal pronouns. The modified criteria in (13a) result in the typological classification in (13b) and the geographical picture in (14):

- (13) a. +/- Verb-last (in subordinate clauses)
 +/- NP case marking (in full, non-pronominal NPs)
- b. Type I: + Verb-final, + NP case marking: German
 Type II: + Verb-final, - NP case marking: Dutch, West Frisian
- Frisian
- Type III: - Verb-final, - NP case marking: English, Danish,
 Norwegian,
 Swedish
- Type IV: - Verb-final, + NP case marking: Icelandic, Faroese

(14)	N	
	IV. Icelandic, Faroese:	
	– Verb-final	
	+ NP case Marking	
	III. English, Danish, Norwegian, Swedish:	
	– Verb-final	
	– NP case marking	
W	II. Dutch, West Frisian:	E
	+ Verb-final	
	– NP case marking	
	I. German:	
	+ Verb-final	
	+ NP case marking	
	S	

Conclusion

In a universal perspective, Greenberg’s “Universal 41” would seem to favour Type I and it is compatible with Type III and IV. According to “Universal 41”, Type II is disfavoured. Apparently, there exist non-trivial connections between Greenberg’s implicational “Universal 41” and the geographical picture presented in (14).

German, belonging to Type I, is morphologically and syntactically more conservative than the other languages. The North Atlantic languages are morphologically conservative to a greater (Icelandic) or lesser (Faroese) degree but they are arguably less syntactically conservative than German. (Cf. in particular the so-called ‘oblique subjects’ found in these languages, i.e. non-nominative NPs with subject properties associated solely with nominative NPs in German.) The central Mainland Scandinavian and English area belongs to the universally common Type III. The North Sea continental area belongs to the typologically disfavoured Type II. It shares case loss with its Northern and Western neighbours, and verb-final structures with its Southern neighbours. (A similar loss of morphological case has occurred in neighbouring European, Romance and Celtic, languages.) Presumably, the universally non-favoured Type II characteristic of this area is the result of typological contact pressure from the North and West as well as from the South. It is interesting to note that Dutch verb chains show a considerable amount of right-branching, which is the only ordering allowed in the neighbouring Type II languages. In a functional perspective, V-2 in main clauses in languages with verb-final structures may possibly be viewed as the superimposition on basic V-final of V-2 as a topological device for marking declarative function common to all modern Germanic languages.

References

- J.O. Askedal, “Geographical and Typological Description of Verbal Constructions in the Modern Germanic Languages”, in J.O. Askedal and H. Bjorvand (eds.), *Drei Studien zum Germanischen in alter und neuer Zeit*, Odense: Odense U. P., 1995, pp. 95–146.
- J.T. Faarlund (ed.), *Grammatical Relations in Change*. Amsterdam and Philadelphia, PA: Benjamins, 2001.

Some General Grammatical Differences ...

- J.H. Greenberg, “Some Universals of Grammar with Particular Reference to the Order of Meaningful Elements”, in J.H. Greenberg (ed.), *Universals of Language*, 2nd ed., Cambridge, MA, and London: The M.I.T. Press, 1966, pp. 73–113.
- P. Kiparsky, “Indo-European Origins of Germanic Syntax”, in A. Battye and I. Roberts (eds.), *Clause Structure and Language Change*, New York, NY, and Oxford: Oxford U.P., 1995, pp. 140–169.
- E. König and J. van der Auwera, *The Germanic Languages*, London: Routledge, 1995.

What can we learn from Animal Models of ADHD?

The brain uses chemicals called neurotransmitters to transmit signals from one nerve cell to the next in pathways that control specific aspects of human behaviour. The activity of neural circuits that send rapid signals through the brain can be modulated by monoamines such as norepinephrine and dopamine. Thanks to norepinephrine's action in the brain, we learn to avoid potentially harmful situations. Norepinephrine acts by strengthening synaptic connections between nerve cells in networks that give rise to appropriate behavioural responses to arousing, potentially threatening stimuli in the external environment. Thanks to dopamine's action in the brain, we tend to repeat behaviour that leads to reward. We also tend to avoid actions that lead to unpleasant consequences. Dopamine exerts strengthening effects on neural networks that give rise to behaviour that leads to reward. These neuro-modulators can also weaken synaptic connections in circuits that encode behaviour that may have been appropriate at an earlier stage but needs to be changed because the situation has changed. For example, dopamine plays an important role in extinction processes whereby learned responses to certain stimuli no longer produce reward and behaviour has to be changed.

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Although rodent brains cannot be used to study complex human behaviour such as language, they do have similar basic functions such as control of motor activity, response to stress, regulation of sleeping, eating, etc. We use animal models to identify changes in relatively simple nervous systems that are associated with behaviour that mimics the human disorder. Diseases that do not have animal models have made far less progress than those that do. Animal models of ADHD do not mimic ADHD. They can only mimic aspects of the complex cluster of behavioural symptoms displayed by children who are diagnosed as having ADHD. ADHD is a heterogeneous behavioural disorder caused by multiple genetic and environmental factors. Children diagnosed as having ADHD display different patterns of symptoms ranging from predominantly inattentive to the combined hyperactive/impulsive and inattentive subtype of ADHD. Genetic animal models of ADHD mimic groups of children with similar genetic predisposition and provide invaluable insight into the underlying cause of the disorder in those children. The strength of animal models of human disorders is that they permit in-depth investigation of relatively simple but dysfunctional nervous systems with associated behavioural disturbances (or other measure), that cannot be measured in humans.

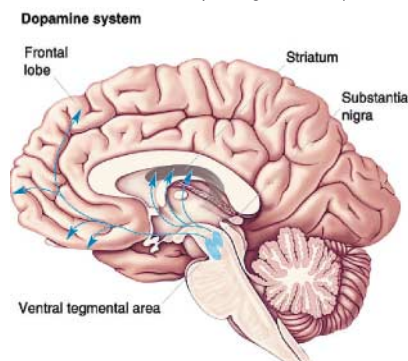
What can we learn from Animal Models of ADHD?

Animal models offer valuable information that can be used to generate hypotheses that can be tested in the clinical situation, to determine whether similar disturbances exist in the human disorder.

Several animal models have been proposed for ADHD. These models have been generated as a result of genetic manipulation, exposure to toxins or environmental deprivation. Many of these do not meet the criteria set out in the recent review by Sagvolden et al (2005), namely (i) an animal model should mimic the fundamental behavioural characteristics of ADHD (face validity), impulsiveness should be absent initially and develop gradually over time, sustained attention-deficit should be demonstrated only when stimuli are widely spaced in time, hyperactivity should not be observed in a novel, non-threatening environment, it should develop over time; (ii) the model should conform to a theoretical rationale for ADHD (construct validity) the two main behavioural processes that are proposed to be major contributory factors in the aetiology of ADHD, altered reinforcement of novel behaviour and deficient extinction of previously reinforced behaviour, should be demonstrated; (iii) the model should predict novel aspects of ADHD behaviour, genetics, and neurobiology (predictive validity); and (iv) it should be neurodevelopmental, preferably a genetic model. Several animal models do mimic critical aspects of ADHD behaviour, either impaired sustained attention and/or hyperactivity/impulsivity that develops over time in a familiar environment (Sagvolden et al, 2005) and provide useful information concerning neurochemical changes that accompany their particular behavioural disturbances. Animal models that have provided novel insight into the mechanisms underlying the behavioural disturbances of ADHD include the spontaneously hypertensive rat (SHR, Wultz et al, 1990; Sagvolden et al 1998, 2000, 2005; Russell et al, 1995, 1998, 2002), dopamine lesioned rat (Luthman et al 1989), dopamine transporter knockout mouse (Gainetdinov and Caron, 2000), poor performers in the 5-choice serial reaction time (5-CSRT) task (Barbelivien et al, 2001), coloboma mutant mouse (SNAP-25 knockout; Jones et al, 2001), and neonatal anoxia (a risk factor for ADHD; Del'anna, 1999).

Of all the animal models of ADHD, SHR have been the most extensively investigated and provide the best model for the combined subtype of ADHD. Sagvolden and colleagues (1990, 1998, 2000) have developed sophisticated behavioural techniques to investigate specific aspects of ADHD behaviour. Using similar multiple fixed interval/extinction schedules of reinforcement but different context and nature of reinforcer (e.g., trinkets to children, water to rats), they showed that SHR behaved just like children with ADHD when compared to controls. Both displayed impaired sustained attention, and hyperactivity/impulsivity that developed gradually over time in a familiar environment (Sagvolden 2000; Sagvolden et al 2005).

Figure 1. Human right brain hemisphere, depicting dopaminergic pathways in blue. (From Baer et al., 2001, *Neuroscience – Exploring the Brain*)



The neurochemistry of ADHD has been extensively investigated and provides convincing evidence that the dopaminergic system is functionally impaired, the noradrenergic system is poorly regulated, and calcium signaling may be impaired (Lehohla et al, 2004; Russell et al, 1995, 1998, 2002). Calcium is an important second messenger and any impairment in calcium signaling would impair neurotransmitter function. It is possible that the observed changes in the neuromodulators, dopamine and norepinephrine, reflect a compensatory response to a more fundamental defect in calcium signaling in SHR. Similarly, compensatory adaptations may occur in the SNAP-25 knockout mouse. Other animal models of ADHD help to provide further insight into specific aspects of ADHD in that they mostly support the findings with SHR. All of the models display impaired learning and memory formation, but rats that have been selected for poor performance in the 5-CSRT task provide a particularly good model for the predominantly inattentive subtype of ADHD, they are selected for impaired sustained attention, and are impulsive, defined as premature responding, but they are not hyperactive. The other models display hyperactivity and reflect disturbances of the dopaminergic system or general interference with neurotransmitter release (SNAP-25) or neonatal oxygen deprivation, affecting development.

All of the animal models of ADHD display decreased function of the dopaminergic system. The dynamic developmental behavioural theory (DDT) of Sagvolden et al (2005) suggests that the dopaminergic system is hypoactive in ADHD and explains how behavioural changes associated with ADHD may result from altered reinforcement and extinction processes (Sagvolden et al, 2005). There are three major dopaminergic systems in the brain, the mesocortical, mesolimbic and nigrostriatal pathways.

Mesolimbic dopamine neurons project from the ventral tegmental area of the midbrain (VTA) to limbic areas of the brain. Activation of the projection to the ventral striatum (nucleus accumbens) is suggested to underlie the reinforcement of appropriate behaviour by signalling errors in the prediction of rewarded outcomes (Fiorillo et al, 2003). The firing rate of dopamine neurons is increased in response to unexpected reward and decreased when a fully predicted reward is omitted (Fiorillo et al, 2003; Schultz, 1998). Deficient reinforcement of appropriate behaviour and/or deficient extinction of previously reinforced behaviour can give rise to ADHD symptoms of delay aversion, hyperactivity in a familiar environment, impulsiveness, deficient sustained attention, increased behavioural variability and failure to extinguish previously acquired behaviour (Sagvolden et al, 2005).

The mesocortical dopamine system originates in the VTA and projects to cortical areas, including the prefrontal, parietal and temporal cortex. These dopamine projections modulate circuits that are known to play an important role in a variety of executive functions, including motor control, behavioural inhibition, attention, and working memory (Goldman-Rakic, 1996). Dopamine activation of D₂ receptors (DRD2) selectively modulates neural activities associated with memory-guided motor activity in delayed response tasks whereas DRD1 are responsible for memory-related persistent activation of prefrontal cortex neurons (Wang et al, 2004). Deficient dopamine-mediated modulation of prefrontal cortical circuits can cause attention response deficiencies

(impaired orienting responses, saccadic eye movements and responses towards a target) and impaired executive functions (poor behavioural planning).

Nigrostriatal dopamine neurons project from the substantia nigra pars compacta to the dorsal striatum (caudate nucleus and putamen). Impaired dopamine modulation of cortico-striato-thalamo-cortical circuits can impair motor function and cause deficient habit learning i.e. impaired nondeclarative memory formation (Sagvolden et al., 2005). These impairments can give rise to apparent developmental delay, clumsiness, neurological “soft signs” (Sagvolden et al., 2005).

Several models also suggest that the noradrenergic system is poorly regulated by hypofunctional α_2 -autoreceptors and may be uncontrollably hyperactive in states of arousal, giving rise to hyperactivity of the noradrenergic system. It is possible that the behavioural characteristics of the animal models result from impaired dopamine modulation of neurotransmission in cortico-striato-thalamo-cortical circuits and in some cases behaviour may be determined by an imbalance between hyperactive noradrenergic and hypoactive dopaminergic systems in the prefrontal cortex.

Drugs that are used to treat children with ADHD, such as the psychostimulants, methylphenidate (Ritalin) and d-amphetamine, ameliorate all three major clusters of symptoms of ADHD but do not correct the underlying disturbance in neural circuits, their effects wear off within a few hours. On the other hand, drugs that target the noradrenergic system, such as atomoxetine, desipramine, and α_2 -adrenoceptor agonists, take much longer to exert their effects (several weeks as opposed to half-an-hour) but their effects are enduring, lasting several months. In normal animals, desipramine causes long-term changes in noradrenergic receptors including persistent downregulation of β -adrenoceptors. Evidence from several animal models of ADHD suggests that, in addition to hypofunction of dopaminergic systems in the brain, the noradrenergic system may be hyperactive in ADHD. This is consistent with the therapeutic effect of noradrenergic drugs being dependent on downregulation of norepinephrine acting on β -adrenoceptors. Further studies using animal models of ADHD are required to determine exactly what the underlying mechanism of noradrenergic drug action is in ADHD. Once this is achieved, better drugs can be developed to target the underlying cause of the disorder.

Several important findings have emerged from studies of animal models of ADHD. Behavioural tests were designed to investigate specific aspects of ADHD behaviour in SHR, and subsequently applied to children with ADHD, enabling direct comparison of behaviour. An important contribution to the understanding of the disorder has been the identification of common neurotransmitter disturbances that are found in the brains of several different animal models, of different origins, suggesting possible fundamental causes of the behavioural disturbances of ADHD. Neurons that use dopamine as a neurotransmitter do not function normally in animal models of ADHD. All three major dopaminergic systems appear to be hypofunctional. Another important finding has been the demonstration across studies that the brains of animal models of ADHD do not react to psychostimulants in the way that brains of normal

animals do. This makes it especially important to distinguish between results obtained with ADHD children and normal controls when interpreting effects of drugs on behaviour.

In addition, animal models have generated hypotheses that can and have been tested in children with ADHD and provided unique insights into the neurophysiology of ADHD. Currently animal models are being used to test new drugs that can be used to alleviate the symptoms of ADHD.

References

- Barbelivien, A., Ruotsalainen, S., & Sirviö, J. (2001). Metabolic alterations in the prefrontal and cingulate cortices are related to behavioral deficits in a rodent model of attention-deficit hyperactivity disorder. *Cerebral Cortex*, 11, 1056-1063.
- Dell'Anna, M. E. (1999). Neonatal anoxia induces transitory hyperactivity, permanent spatial memory deficits and CA1 cell density reduction in developing rats. *Behavioral Brain Research*, 45, 125-134.
- Fiorillo, C. D., Tobler, P. N., & Schultz, W. (2003). Discrete coding of reward probability and uncertainty by dopamine neurons. *Science*, 299, 1898-1902.
- Gainetdinov, R. R. & Caron, M. G. (2000). An animal model of attention deficit hyperactivity disorder. *Molecular Medicine Today*, 6, 43-44.
- Goldman-Rakic, P. S. (1996). Regional and cellular fractionation of working memory. *Proc.Natl.Acad.Sci.U.S.A.*, 93, 13473-13480.
- Jones, M. D., Williams, M. E., & Hess, E. J. (2001). Abnormal presynaptic catecholamine regulation in a hyperactive SNAP-25-deficient mouse mutant. *Pharmacology, Biochemistry and Behavior*, 68, 669-676.
- Lehohla, M., Kellaway, L., & Russell, V. (2004). NMDA receptor function in the prefrontal cortex of a rat model for attention-deficit hyperactivity disorder. *Metab Brain Dis.*, 19, 35-42.
- Luthman J, Fredriksson A, Lewander T, Jonsson G, Archer T (1989): Effects of d-amphetamine and methylphenidate on hyperactivity produced by neonatal 6-hydroxydopamine treatment. *Psychopharmacology (Berl)* 99: 550-557.
- Russell, V. A. (2002). Hypodopaminergic and hypernoradrenergic activity in prefrontal cortex slices of an animal model for attention-deficit hyperactivity disorder — the spontaneously hypertensive rat. *Behavioural Brain Research*, 130, 191-196.
- Russell, V. A., de Villiers, A., Sagvolden, T., Lamm, M., & Taljaard, J. (1998). Differences between electrically-, ritalin- and D-amphetamine-stimulated release of [³H]dopamine from brain slices suggest impaired vesicular storage of dopamine in an animal model of Attention-Deficit Hyperactivity Disorder. *Behavioural Brain Research*, 94, 163-171.
- Russell, V. A., de Villiers, A., Sagvolden, T., Lamm, M., & Taljaard, J. (1995). Altered dopaminergic function in the prefrontal cortex, nucleus accumbens and caudate-putamen of an animal model of Attention- Deficit Hyperactivity Disorder - the spontaneously hypertensive rat. *Brain Research*, 676, 343-351.
- Sagvolden, T. (2000). Behavioral validation of the spontaneously hypertensive rat (SHR) as an animal model of attention-deficit/hyperactivity disorder (AD/HD). *Neuroscience and Biobehavioral Reviews*, 24, 31-39.
- Sagvolden T, Aase H, Zeiner P, Berger D.F (1998): Altered reinforcement mechanisms in Attention-Deficit/Hyperactivity Disorder. *Behav Brain Res* 94: 61-71.
- Sagvolden, T., Johansen, E. B., Aase, H., & Russell, V. A. A dynamic developmental theory of Attention-Deficit/Hyperactivity Disorder (ADHD) predominantly hyperactive/impulsive and combined subtypes. *Behavioral and Brain Sciences*, In press <http://www.bbsonline.org/Preprints/Sagvolden-05152002/>, (in press).
- Sagvolden, T., Russell, V. A., Aase, H., Johansen, E. B., & Farshbaf, M. Rodent models of attention-deficit/hyperactivity disorder. *Biological Psychiatry*, (in press).
- Schultz, W. (1998). Predictive reward signal of dopamine neurons. *Journal of Neurophysiology*, 80, 1-27.
- Wang, M., Vijayraghavan, S., & Goldman-Rakic, P. S. (2004). Selective D2 receptor actions on the functional circuitry of working memory. *Science*, 303, 853-856.
- Wultz, B., Sagvolden, T., Moser, E. I., & Moser, M. B. (1990). The spontaneously hypertensive rat as an animal model of attention-deficit hyperactivity disorder: effects of methylphenidate on exploratory behavior. *Behavioral and Neural Biology*, 53, 88-102.

Problems with Models in Psychiatry

Over the past decade or two, psychiatry has largely adopted scientific ways. Due to intellectual and budgetary pressure, operational diagnoses and randomised trials now prevail. These methods are demonstrably reliable and useful; but often appear far removed from clinical practice, where patients need to be treated as individuals, and idiosyncratic details can be the key to therapeutic success. There are continuing concerns about the failure of research methods to convincingly capture such complexity (Nunn et al. 2000; Szasz 2001; Timimi 2004; reviewed by Kandel 1998; and Midgley 2004). This essay argues that bridging the gap requires researchers not just to incrementally improve models of mental

function, but to become far more rigorous in the ways we create and use such models.

Here we are using the term model as a convenient shorthand for simplifications of reality. In order to focus on science rather than philosophy, we include the related concepts of theory, hypothesis, paradigm, picture, repre-

sentation, and simulation. We exclude models that are not simplifications, such as simulations of every molecule in a synapse, and animal models that are not simplifications in their target area. But all animal models in psychiatry are dramatically simpler than the group of people with a disorder, in homogeneity, cytoarchitecture, upbringing, and cognition (see e.g. Moore 2004).

Every thought and every perception involves at least one model: the world we perceive is constructed from our sensations and our experience. In science, every hypothesis is based on a model. In clinical work, every treatment decision is based on models of the patient and his environment; and the fitting of these to models of disorders and treatments. Thinking is impossible without models.

There are at least twenty reasons why psychiatrists need to simplify (Meehl 1978); and many ways to do this. Some are explicit: Freud's topographical model; neuropsychological models; animal models; computational models (which can mean models of how information is processed, or models implemented on a computer). We add another kind of model, namely the unspoken simplifying assumptions made by all practitioners. The kinds of models differ in many ways, and are usually considered separately but, in the spirit of Synergies we group them together. This approach will frustrate readers concerned with just one class of models, but we hope that the approach will improve the understanding of results



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from models; encourage cross-fertilisation between nosological, psychological, animal, and computational communities; and perhaps clarify the underlying real-world phenomena.

Problems with models themselves

Being too simple

Although an evolutionary drive to simplicity does exist (Azevedo et al. 2005) it does not appear to be a major force (Kirschner and Gerhart 1998). Many real biological mechanisms are much more complicated than might be expected, in genetics and biochemistry, cognition and ecology. “The ‘typical’ behaviour of complex systems is often quite simple, so that a naive view leads to simple models and (wrong) explanations of most phenomena.” (Carlson and Doyle 2001; see Williams and Taylor 2004; and Peterson and Flanders 2002).

Dozens of neuropsychological abnormalities, and at least 7 genes, have been found to make a contribution to some cases of Attention Deficit / Hyperactivity Disorder (ADHD). The true tally must be much greater, given the thousands of interacting genes that govern brain function, versus the small number of named neurodevelopmental disorders. This makes it impossible for a simple computational framework, or a single strain of rats, to capture all facets of a disorder. Current models of ADHD need to be reconceptualized as models of individual processes contributing to ADHD, so the set of all current ADHD models becomes the set of interacting ingredients to be incorporated into a more comprehensive ADHD model.

Endophenotypes are generally defined as genetically determined, fairly hidden traits that underlie disorders. But some definitions require that the endophenotype be specific to a disorder – problematic when many risk factors are shared between disorders. Others have required that endophenotypes be discrete types, rather than graded – which would make them very unusual in psychology, and would in practice largely restrict the term to effects of single alleles. These restrictive definitions are natural by-products of underlying models. A danger is that they result in psychiatric research being over-focussed so that important patterns are missed.

Information has a deep mathematical and computational underpinning, which is incorporated into very few psychiatric models, even though brains clearly process information and psychiatric diagnoses are most often based on what patients say. This omission has three causes: (a) definitions of disorder, which underemphasise learned factors contributing to illness; (b) the vague view that pharmacological treatments normalize chemical imbalances linked to psychiatric disorders; and (c) the difficulty of including information processing concepts (see Dayan and Abbott 2001). The omission probably leads to an undervaluing of the importance of psychological and social interventions. It seems likely to be superseded.

Being too powerful

This problem happens when a model is vague or insufficiently specified, so there is no way to weigh its relevance, or to disprove it.

Nonquantitative, nonbiological models based on verbal reasoning are particularly at risk. In the extreme case, a model can account for any possible finding; obvious examples are belief in God or the Devil. After a

century of development, the wealth of described psychodynamic processes are adequate to describe essentially any clinical situation in several ways (Meehl 1998). This can be useful clinically, but the internal consistency of formulations can also create an illusion of correctness. Psychodynamic theory is difficult to test or to relate to neuroscience, but this may change (Kandel 1998).

Risky predictions (i.e. both unlikely and testable) are an important means of testing models (Popper 1959), and are hardly seen in psychiatry. Of course, predictions only test a model to the extent they were previously unexpected: predicting a new cognitive deficit in a highly deficit-enriched group carries very little risk. As another example, simple feedforward neural net models are able to copy essentially any empirical input-output mapping; therefore, their ability to copy a particular mapping tells us almost nothing about brain structure or function.

Being unidisciplinary

The biggest obstacle to psychiatric progress is its unidisciplinary nature (Kandel 1998), and one of the greatest strengths of explicit models is that they encourage interdisciplinary work. Unfortunately many researchers and clinicians are so focused on their own models that they don't compare them to others, and don't adequately disseminate, or integrate, the results.

Being too complicated

Complexity increases the likelihood of many types of logical errors (Gilovich 1993). Complex interactions between processes can be studied using computer simulation. Such simulation is itself complicated, often producing unexpected emergent properties that need to be understood in order to be published or (much more often) debugged. Simulation has several compensations for the effort involved, though, including repeatability, modifiability, distributability, and the facility to produce graphs that communicate to noncomputational readers. This is important because complex presentations can lead to audience rebellion – or can seduce by distracting from the core issues. When models are too complex to be understood in one sitting or one article, they need to be presented in pieces.

Problems with the ways models are used

Having a model without acknowledging it

Clinicians and researchers often overlook the fact that the disorders they work with are themselves models, constructed by committees of experts. For example, the successive versions of the Diagnostic and Statistical Manual (DSM) are intended eventually to become a comprehensive catalogue of disorders, in which the disorders are “natural kinds” (Zachar 2000) created by carving nature at its joints. This may be an impossible task, because there is no evidence for such joints in mental function, within or near ADHD (Figure 1).

The idea that the most severe cases, being closest to a prototype, have the most in common, is another unspoken model that has been central to clinical and research work. Research has often focused on combined type ADHD, or the even more severe hyperkinetic disorder, for this reason. Similarly, formal diagnostic systems usually include a threshold number of

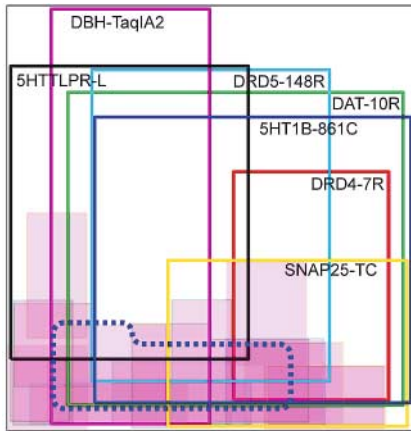


Figure 1. One possible population distribution of genes contributing to ADHD. ADHD individuals are within the dotted outline. The size of named rectangles indicates actual allele frequency; 20 unnamed ones, each conferring 20% increased risk in 5% of the population are hypothesized based on non-replications in genetic studies. Interactions of alleles are unknown so arrangement is derived by optimising individual and combined (additive) odds ratios, together with the normality of the resulting risk distribution.

symptoms. This is completely appropriate if a very damaging “core” problem is often combined with unrelated or ameliorating factors that confuse the picture. However, genetic and behavioural research have not yet revealed a dominant core (Bobb et al. 2004; see Rapport et al. 2000), and it is possible that high thresholds select patients who individually have several smaller problems, rather than the single core that was originally hoped for. Figure 1 illustrates this for risk alleles; a similar diagram could presumably be made for neuropsychological risk factors.

The concept of disorder is itself based on unstated models of humanity, in which people are generally intelligent, predictable, and sociable, and in which deviations from this are

flaws (see Szasz 2001). Society’s reluctance to stigmatise these flaws, and optimism based on past medical progress, have led the deviations to be called disorders, with the implication that it is only a matter of time before they can be “treated”. At CAS, we have made simulations that cast doubt on such a view of impulsivity, showing that in certain conditions, group survival can be enhanced by having a minority of unpredictable individuals. ADHD behaviours may have some value to society simply because they are different from average behaviours.

Using a model for the wrong purpose

Many people expect that there is a single best way to parcel or understand the world, and that since biological measurements are so obviously right, they must be it. However, just as molecules and signals can most obviously be grouped topographically (shown in the left cylinder of Figure 2), they can also be grouped according to other principles (shown in the other cylinders) (Killeen 1999; Dayan and Abbott 2001; Olds 2000). The hierarchies of formal processes and information processing are just as real as the visible brain, but tend to be neglected.

Descriptive models do not link levels, but are often wrongly treated as explanations, which do (Figure 2). For example, fitting equations to data points, which has a rich and productive history from Ptolemy to Herrnstein, is useful for prediction but sheds essentially no light on underlying mechanisms. Most diagnostic systems such as DSM consider a single level (high in the third column of Figure 2). They help to make epidemiology and treatment reliable, but they have come to be used as the basis for almost all research in biological psychiatry, for which they are much

Problems with Models in Psychiatry

less appropriate. Similarly, psychodynamic formulations describe high-level processes, so direct links to biology may be as difficult (and irrelevant) as explaining WORD bugs in terms of computer hardware.

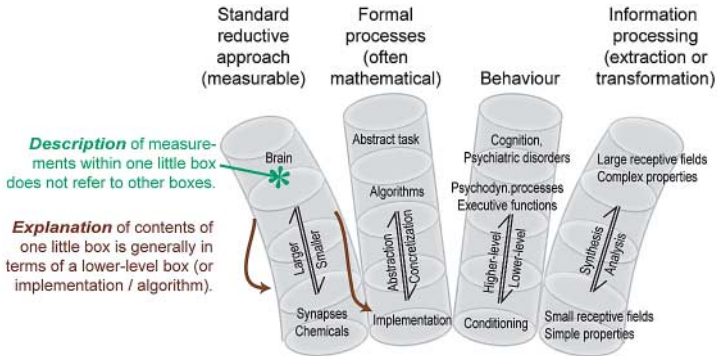


Figure 2. Hierarchies within biological information-processing systems. Models can address any parts of these hierarchies. The lowest levels of the hierarchies are closely bound together; higher up, connections become much more tenuous.

In order for multi-level explanations to be grounded in reality, they need to be based on a painstakingly acquired understanding of low-level connections between the biological and informational worlds. This implies studying genetically identified endophenotypes (e.g. Caspi et al. 2003) rather than high-level concepts such as theory of mind; and single standardizable interventions rather than months of individualised therapy.

Having a model of the wrong thing

Throughout history, treatments have been used as models of disorder, and vice versa. The following line of reasoning has been very influential: ‘Since stimulants are a very effective treatment for ADHD, and stimulants affect dopamine, ADHD is primarily a dopamine disorder.’ The reasoning is much weaker than it appears, because (a) stimulants help human controls who don’t have ADHD; (b) stimulants don’t help all aspects of ADHD; (c) after brain damage, stimulants help both humans and rats; (d) stimulants affect other transmitters beside dopamine.

Not realising how the model affects your reasoning

Having a model, especially a personal one, can influence thinking in many ways (Gilovich 1993). For example, it increases our interest in data that supports the model, but not our interest in whether other models exist that are supported by the data. Being aware of such cognitive biases can help to reduce them.

Requiring inappropriate competition between models

According to Occam’s principle the simplest explanation is the best. But this doesn’t help us choose between the many models of ADHD, for example, which are all similarly simple. Platt suggested that we use “strong inference”, relying on crucial experiments to choose between alternative models (Platt 1964). Alternatively, models can be made to compete quantitatively to find which provides the best balance between simplicity and data-fitting (Burnham and Anderson 2002). But these ideas have limited

applicability to the hyper-multifactorial problems that are common in biology (Kendler 2005; Carlson and Doyle 2001). This is because there is no agreed set of data to fit; and no fully integrated model of ADHD.

Not documenting weaknesses in the model

Like tents, models need well-spaced supports. A model with supportive evidence from behaviour, genetics, and drug effects is far stronger than one with behavioural support alone – such as most psychodynamic or behaviourist models. Compared with the main supports, clear boundaries are much less exciting to establish: the tent pegs of the modelling world. But without them, all models lose credibility, because common sense dictates that models are not all right, all the time. Beyond the pegged area, discrepancies need to be documented, to clarify the relationship between the model and reality.



Conclusions

Progress toward understanding the roots of psychiatric disorder depends on the methodical construction of integrated computational models, which will in turn require close collaboration between clinicians, neuroscientists, psychologists, and computationalists. Only such integrated models can sensibly compete against each other. Real effort is needed to avoid oversimplifications and preconceptions.

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References

- Azevedo, R. B., Lohaus, R., Braun, V., Gumbel, M., Umamaheshwar, M., Agapow, P. M., Houthoofd, W., Platzer, U., Borgonie, G., Meinzer, H. P., and Leroi, A. M. (2005). "The simplicity of metazoan cell lineages." *Nature*, 433(7022), 152–156.
- Bobb, A. J., Castellanos, F. X., Addington, A. M., and Rapoport, J. L. (2004). "Molecular genetic studies of ADHD: 1991 to 2004." *Am. J. Med. Genet. (Neuropsych. Genetics)*.
- Burnham, K. P., and Anderson, D. R. (2002). "Model selection and multimodel inference: A practical information-theoretic approach." Springer-Verlag, New York.
- Carlson, J. M., and Doyle, J. (2001). "Robustness and complexity." *Robustness in Natural, Engineering, and Social Systems*, (RS-2001-017).
- Caspi, A., Sugden, K., Moffitt, T. E., Taylor, A., Craig, I. W., Harrington, H., McClay, J., Mill, J., Martin, J., Braithwaite, A., and Poulton, R. (2003). "Influence of life stress on depression: moderation by a polymorphism in the 5-HTT gene." *Science*, 301(5631), 386–389.
- Dayan, P., and Abbott, L. F. (2001). "Theoretical Neuroscience." MIT Press.
- Gilovich, T. (1993). "How we know what isn't so: the fallibility of human reason in everyday life." Free Press, New York.
- Kandel, E. R. (1998). "A new intellectual framework for psychiatry." *Am. J. Psychiatry*, 155, 457–469.
- Kendler, K. S. (2005). "Toward a philosophical structure for psychiatry." *Am. J. Psychiatry*, 162(3), 433–440.
- Killeen, P. R. (1999). "Modeling modeling." *J. Exp. Anal. Behav.*, 71(2), 275–280.
- Kirschner, M., and Gerhart, J. (1998). "Evolvability." *Proc. Natl. Acad. Sci. U. S. A.*, 95(15), 8420–8427.

Problems with Models in Psychiatry

- Meehl, P. E. (1998). "The Power of Quantitative Thinking." (Speech on receipt of J. M. Cattell Award at Am. Psychol. Society, Washington DC, 23 May).
- Meehl, P. E. (1978). "Theoretical Risks and Tabular Asterisks: Sir Karl, Sir Ronald, and the Slow Progress of Soft Psychology ." *J. Consult Clin. Psychol.*, 46, 806–834.
- Midgley, N. (2004). "Sailing between Scylla and Charybdis: Incorporating qualitative approaches into child psychotherapy research." *J. Child Psychotherapy*, 30(1), 89–111.
- Moore, B. R. (2004). "The evolution of learning." *Biol. Rev. Camb. Philos. Soc.*, 79, 301–335.
- Nunn, K., Nicholls, D., and Lask, B. (2000). "A new taxonomy." *Clin. Child Psychol. Psychiatry*, 5(3), 313–327.
- Olds, D. D. (2000). "A semiotic model of mind." *J. Am. Psychoanal. Assoc.*, 48(2), 497–529.
- Peterson, J. B., and Flanders, J. L. (2002). "Complexity management theory: motivation for ideological rigidity and social conflict." *Cortex*, 38(3), 429–458.
- Platt, J. (1964). "Strong Inference." *Science*, 146(3642), 347–353.
- Popper, K. R. (1959). "Conjectures and Refutations: The growth of scientific knowledge." Routledge, New York.
- Rapport, M. D., Chung, K. M., Shore, G., Denney, C. B., and Isaacs, P. (2000). "Upgrading the science and technology of assessment and diagnosis: laboratory and clinic-based assessment of children with ADHD." *J. Clin. Child Psychol.*, 29(4), 555–568.
- Szasz, T. (2001). "Mental illness: psychiatry's phlogiston." *J. Med. Ethics*, 27(5), 297–301.
- Timimi, S. (2004). "Rethinking childhood depression." *BMJ*, 329(7479), 1394–1396.
- Williams, J., and Taylor, E. (2004). "Dopamine appetite and cognitive impairment in Attention-Deficit / Hyperactivity Disorder." *Neural Plasticity*, 11:1-2.
- Zachar, P. (2000). "Psychological Concepts and Biological Psychiatry: A Philosophical Analysis." *Adv. Consciousness Research, Series A*, 28.

The Hidden Mechanisms of Language Change

Language is both mental and social in nature, involving a language system in the mind of the individual speaker and as well as language norms of the speech community. Although one must assume an innate language faculty which makes the language systems in individual minds possible, it is clear that the words and their meanings in each language are supplied by the specific speech community, and so are the language-specific choices determining the details of the sound system and the grammar of the language in question. As each language is being passed on to the next generation, the child has to construct his own language system based not directly on the actual language system of his models, but indirectly, via the output of that system, namely actual utterances. In trying to replicate the language system of his models, the child acquiring it must rely heavily on the unreliable but very common kind of reasoning called abduction (Andersen 1973). In abduction, a result, in this case the particulars of the language output, is given, and the way that output comes about, here the language system, has to be guessed. In the earliest phase of language acquisition, children take the language of their caregivers as a model, but as they grow older, they try to imitate kids who are a bit older than they are, at least in modern cities of the Western world. At adolescence, crucial core aspects of the language system are frozen. Thus, basic parameters of syntactic structure such as basic word order are fixed, and adult learners cannot learn to speak new languages without accent.

A basic outlook of the kind just sketched, and widely but not universally accepted, allows us to single out crucial social factors of language change, which constitute mechanisms largely hidden from the view of the historical linguist. When analysing the mechanisms of such change, it is crucial to distinguish the two phenomena that I will call *innovation* and *diffusion*. Put in its simplest terms, innovation is the spontaneous emergence of a novel language feature that was absent in the previous generation. Keeping in mind the transitory nature of child language, what is of primary importance to the historical linguist is those novel features which remain in the fully developed language system of an adult speaker. Diffusion, on the other hand, involves speakers imitating a novel language feature (an innovation) from another speaker. With regard to the interaction between innovation and diffusion, one should keep in mind that the same innovation may emerge spontaneously in many speakers at the same time, so that less diffusion is required.

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When taking stock of the potential for language change, it is useful to start by distinguishing between what is constant and what is variable in the language transmission process. The most basic fact is that *change is never necessary for purely system-internal reasons*. Any language that is spoken and has been acquired by children has thus proved that it is functional. Thus, there are certain boundary conditions for the mental language system which all languages must respect. More interestingly, however, the language system also has some inherent preferences, as some features are more “natural” than others. The concept of *naturalness* is a complex and problematic one, but it is commonly assumed that natural features are the most compatible with the general design of the mental language system and that of the articulatory and auditory organs. Many scholars also assume that such features are the ones best suited for actual language use. As a consequence of their naturalness, such language features are supposed to be easier for a child to acquire and thus tend to be acquired early. An additional common assumption is that natural features should be more resistant to change, and changes should tend to increase naturalness in some way. As naturalness must be assumed to be *local* (determined with respect to a limited part of the language system), naturalness conflicts may emerge when increased naturalness in one respect leads to decreased naturalness in other respects. An example of the disappearance of a rather unnatural feature is the merger of the *tje*-sound [ç] (not found in English) and the *sje*-sound [ʃ] (similar to *sh* in *ship*) in post-World War II Norwegian. It is an indication that *tje* is a rather unnatural sound that the contrast *tje* / *sje* is the last one to be mastered by Norwegian children. However, getting rid of the unnatural sound increases homophony, which is commonly assumed to decrease naturalness, as for instance *kitt* ‘putty’ (with the *tje*-sound) and *skitt* ‘shit’ become indistinguishable. Assuming that a clearly unnatural feature of a language is inherently unstable, any slight change in the external conditions of the language, such as the transmission situation, may easily lead to the demise of such a feature. It must be admitted, however, that many linguistic changes are at best neutral with respect to naturalness (Lass 1997), a point that we will return to later.

While the mental, ultimately inherent and biological, basis of language is constant, the social aspects of a language may vary in a number of ways. Language change can be influenced by changes in the social environment of the language, in various indirect ways, but also more directly by social evaluation of specific features of language. On the most general level, one cannot exclude the possibility that general weakening of the language norms as a social institution, in times of cultural and social instability, in itself accelerates language change. In such times, children acquiring the language may be less inclined to follow to the full extent the conventions of the earlier generation. This may be sufficient for an unnatural feature to disappear, without any preceding reduction in the frequency of that feature in the language output available to the child. However, it is probable that the conditions for language acquisition more specifically also tend to change in such periods.

One of the more specific external social factors of change in language transmission (Ottósson 1992:24f) is *a shift in the sample of the target language available to the average child acquiring his language*. Depending on the structure of the society, children may to varying degrees learn their language from their parents’ (and grandparents’) generation or from their peers. In the

normal language acquisition process, children go through several stages, and forms and constructions deviating from the target language constantly arise, as they gradually approximate that target. These deviating variants are usually abandoned as the child gets full command of his language. In situations where children learn their language mostly from other children rather than from speakers with a fully developed language, those language features which are acquired late are particularly endangered.

Linguistically immature peers then spread their deviating variants to younger children, and language change may be faster than in other cases. In the Norwegian case just discussed, one may wonder whether Norwegian children after World War II started learning their language less from their parents than earlier, and more from (older) children whose sound system was not yet fully developed. In cases like this, nothing new arises in child language, and the innovation involves the promotion of an already existing language feature to the fully developed language system.

Under a second scenario for language change, the (type of) sampling of the target language available to the child remains constant, but there is *a marked shift in adult speech and other language models for the learner*. The Primary Linguistic Data on the basis of which the average language learner abduces his language system may be changed so much with respect to a particular language feature, that a different specification of that feature becomes natural. A type of change of this nature which has received some attention in the literature involves the frequency in use of optional elements, in particular what may be called stylistic rules. Such a change in frequency, in turn, may ultimately have sociological causes which call for elucidation. A potential example involves the interaction of basic word order and “Extraposition” of heavy syntactic constituents, leading to a shift from the order Subject – Object – Verb (SOV) to Subject – Verb – Object (SVO). The basic word order of a SOV language is as in (1a), but in (1b), a heavy object has been moved, “extraposed”, from the underlined position to the end of the sentence.

- (1) a John Mary kissed
- b John _ kissed [the young blonde woman with the funny hat]

If such extraposition gains in frequency, it may become natural for the child to reanalyse the SVO order found in such cases as basic rather than derived by movement. In cases of this kind, the innovation happens in the acquisition process, but is triggered by a change in adult language.

A third basic cause of language change is *imperfect learning* with both the target language and the sample of its output available to the child remaining constant. It is important to realise that many more innovations of this origin are retained in the speech of some adults than those that have a breakthrough by diffusion. In addition to physiologically determined speech errors, such as lisping, speakers may retain idiosyncratic features in their vocabulary or grammar from their childhood into their adult life. It has been claimed, however, that the mistakes children make are rather different from language changes (e.g. Croft 2000), but even if only a relatively minor part of children’s mistakes survives this constitutes a significant factor. Crucially, however, if the other two factors just discussed remain constant, one would expect all such deviances to remain

sporadic. An additional factor, however, may lend momentum to the diffusion of such idiosyncratic innovations, namely (positive) social evaluation.

Innovations (as well as pre-existing variants) may acquire some *social value* which motivates people to adopt them more or less by conscious choice. In that case, the social factors are not only a part of the embedding of the language system, but exert their influence in a much more direct and active fashion. Thus, a linguistic feature becomes a marker of prestigious social status or of solidarity within a social group. If these groups are defined by socio-economic factors, we are dealing with sociolects, whereas dialects are defined by a specific geographical area. A well-known example of such social evaluation is the centralisation of (aw), the diphthong in *town*, on Martha's Vineyard, signalling allegiance to the island community. The need to mark oneself off from members of other groups may lead to the exaggeration of already existing differences or active search for variants which might be used for this purpose. Idiolectal variants arising by imperfect learning, as discussed above, may also be used for this purpose, provided their bearers happen to be looked up to for other reasons. It should be obvious that a great number of microscopic social contingencies may be involved in the process by which a linguistic variant acquires such a positive social evaluation, such as the concrete social networks in a particular school or neighbourhood. In spite of the extensive research of Labov and his associates into ongoing change in American cities (e.g. Labov 1994–2001), we know little about the very inception of language change in contemporary settings, where we may in principle have access to all potentially intervening factors. When analysing changes in past centuries, such detailed data about micro-level social factors is simply not available, and much of our limited comparative knowledge from contemporary sources is from societies quite different from earlier ones.

In social evaluation the naturalness of the feature is not crucial. The above-mentioned centralisation of (aw) on Martha's Vineyard, for example, is arguably not a natural change. What is most important for such social markers is their salience. The sounds of the language are quite effective in this respect by virtue of their frequency, not least vowels and diphthongs which in addition are rather easy to manipulate.

The preceding discussion, although sketchy and simplified, hopefully shows how difficult it is for a historical linguist to find the social mechanisms which trigger diffusion of a language feature at a particular point in time. In spite of the limitations of linguistic naturalness as an explanation of change, it is bound to keep its place in historical linguistics, although more attention should be given to the salience of linguistic features.

References

- Andersen, Henning. 1973. Abductive and deductive change. *Language* 49:765–793.
- Croft, William. 2000. *Explaining Language Change. An Evolutionary Approach*. Harlow.
- Labov, William. 1994, 2001. *Principles of Linguistic Change* 1-2. *Language in Society* 20, 29. Oxford.
- Lass, Roger. 1997. *Historical linguistics and language change*. Cambridge studies in linguistics 81. Cambridge.
- Ottósson, Kjartan G. 1992. *The Icelandic Middle Voice*. The morphological and phonological development. Lund.

Cross-Cultural Issues in ADHD Research

Introduction

Attention-Deficit/Hyperactivity Disorder is the most common child psychiatric disorder in Europe and the United States of America, affecting 3 – 10% of primary school children. The disorder consists of a persistent pattern of inattentiveness, impulsiveness and/or hyperactivity that is inconsistent with the child's developmental level. The disorder is generally more prevalent in males (American Psychiatric Association, 2000).

DSM-IV (American Psychiatric Association, 2000) identifies three subtypes of the disorder, namely: ADHD predominantly inattentive type (ADHD-PI) if six (or more) symptoms of inattention (but fewer than six symptoms of hyperactivity-impulsiveness) have persisted for at least 6 months; ADHD predominantly Hyperactive-Impulsive Type (ADHD-HI), if six (or more) symptoms of hyperactivity-impulsiveness (but fewer than six symptoms of inattention) have persisted for at least 6 months; and ADHD combined type (ADHD-C), if at least six symptoms of inattention and at least six symptoms of hyperactivity-impulsiveness have persisted for at least 6 months.

ADHD is found to be as prevalent on the African continent as in Western countries (Meyer, 1998; Meyer, Eilertsen, Sundet, Tshifularo, & Sagvolden, 2004). The predominant Western approach to understanding mental disorders is based on a biomedical perspective that regards primary syndromes as universal and similar across diverse human cultures. A basic question is to what degree behaviour and its disturbances are affected by culture.

The inability to inhibit behavioural responses leads to risk taking behaviour like drug and alcohol abuse, tobacco smoking premarital and promiscuous sex, driving anger and traffic offences, accident proneness, compulsive buying and tattooing and body piercing (Barkley, 2004; Barkley, Fischer, Smallish, & Fletcher, 2004; Carroll, Riffenburgh, Roberts, & Myhre, 2002; Fillmore & Rush, 2002; Kahn, Kaplowitz, Goodman, & Emans, 2002; Lam, 2002; Molina, Bukstein, & Lynch, 2002; Roberts & Tanner, Jr., 2000; Tercyak, Lerman, & Audrain, 2002).

A high incidence of crime, substance abuse, and especially the very high rate of HIV infection in South Africa, and its possible relationship to ADHD, necessitated an investigation into the prevalence and neuro-psychological manifestations of the disorder.

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Ethnic groups of the Limpopo Province

The Republic of South Africa has one of the most complex and diversified population mixes in the world, a rich mosaic of distinctive minorities. This is underscored by the fact that not one of South Africa's major languages is spoken by a majority of all the people. South Africa has eleven official languages, seven of which are spoken in the Limpopo Province: Northern Sotho (Sepedi), Xitsonga, Tshivenda, Setswana, Isindebele, Afrikaans and English.

The Northern Sotho form the largest group (52,7%) they are part of the Sotho group, who are found mainly in Lesotho and Botswana, and are found scattered throughout the Province and include various tribes. The Tsonga, who are also known as Shangaan and are related to the Tsonga of Mozambique, form the second largest group (22,6%) and are found in the eastern part of the province. Their language is known as Xitsonga. The Venda (15,5%) are a largely homogenous people, living in the northern part of the province, bordering Zimbabwe. Their language is Tshivenda and they are related to the Shona of Zimbabwe. The main white groups are the English (0,4%) and Afrikaans (2,2%). The Tswana (1,4%) and North Ndebele (1,5%) are not regarded as indigenous to the province but are resident in considerable numbers. The Tswana are closely related to the Northern Sotho, and are bonded with them in language and customs. The North Ndebele have been identified as one of the Nguni groups, which include the Zulu, Xhosa, and Swazi people. In the Limpopo Province they are mainly concentrated in the districts of Polokwane, Bakenberg, and Mokopane. Their language is known as Isindebele. The Bolobedu are not considered a separate ethnic group, but a tribe under the Rain Queen, Modjadji, which is believed to have rain making powers and is treated with high respect by the political leaders of South Africa. The Bolobedu, a group of about one million people, are found in about 150 villages around Modjadji's Kloof. Their language, Khelovedu, is not recognized as one of South Africa's 11 official languages (Nxumalo, 2000; Rammala, 2003).

The ADHD project

The study consisted of two parts: (a) an epidemiological study and (b) a neuropsychological investigation. The epidemiological survey was conducted among North Sotho, Tsonga, Venda, Tswana, Afrikaans and English primary school children. The Northern Sotho, Tsonga, Venda, Tswana, North Ndebele, Afrikaans and Bolobedu children participated in the neuropsychological investigation. The North Ndebele and Bolobedu were excluded from the epidemiological survey because of lack of reliable translation facilities for the rating scale used.

Epidemiological survey

The aim of the study was to explore the prevalences of ADHD symptoms as measured by the Disruptive Behavior Disorder (DBD) scales as a function of language/ethnic group, gender, and ADHD subtype in the Limpopo Province of South Africa.

Method

The subjects came from the general population of primary school children in the Limpopo Province. The schools were situated in fairly typical

urban, semi-urban and rural parts of the province. The schools that participated were situated in the areas where the selected ethnic groups are indigenous. The teachers of the children spoke the same language as their pupils. The final sample consisted of 6032 children aged 6 – 15 years.

The DBD is based on information obtained from parents and/or teachers, and assesses the presence and degree of ADHD symptoms (inattention and hyperactivity/impulsiveness), plus Oppositional Defiant Disorder (ODD) and Conduct Disorder (CD) as formulated in DSM-IV (Pelham, Gnay, Greenslade, & Milich, 1992; Pillow, Pelham, Jr., Hoza, Molina, & Stultz, 1998) in primary school children. The scale was translated into the various indigenous languages. Norms were established for the population groups of the Limpopo Province. Mean scores on inattentiveness and hyperactivity/impulsiveness showed no significant between-group differences. The cultural differences were therefore, so small that there was no need for separate norms for the different cultural/ethnic groups (Meyer et al., 2004).

Results

Applying cut-offs based on the DBD, the results showed prevalence rates for ADHD, inattentive, hyperactive/impulsive, and combined subtypes very similar to those obtained when applying DSM-IV criteria to US and European research findings (Swanson et al., 1998). This applies to the total prevalence as well as prevalences within gender groups (Table 1).

ADHD Subtypes									
	No ADHD		Inattentive		Hyperactive/ Impulsive		Combined		Total
	N	%	N	%	N	%	N	%	N
Boys	2936	93.1	120	3.8	43	1.4	55	1.7	3154
Girls	2767	96.1	79	2.7	18	0.6	14	0.5	2878
Total	5703	94.5	199	3.3	61	1.0	69	1.1	6032

Table 1. Prevalences of ADHD subtypes by gender (adapted from Meyer et al., 2004)

Neuropsychological investigation

Referral practices and assessment procedures are neither well developed nor standardised in developed countries like South Africa (Meyer & Aase, 2003). Assessment of and research on ADHD, could be improved with standardised tests reliably differentiating between children with and without ADHD symptoms.

Several factors must be taken into account when selecting tests, as most tests are standardised in Western countries. They must be simple, inexpensive, and easy to transport to and to use in remote rural areas without the convenience of Western settings. They also should preferably be non-verbal, or be limited to a minimum of verbal instructions. There should be no cultural bias.

- The problems addressed were:
- Are ADHD symptoms related to neuropsychological deficiencies?
 - Are there gender differences?
 - Are the results obtained the same across cultures?

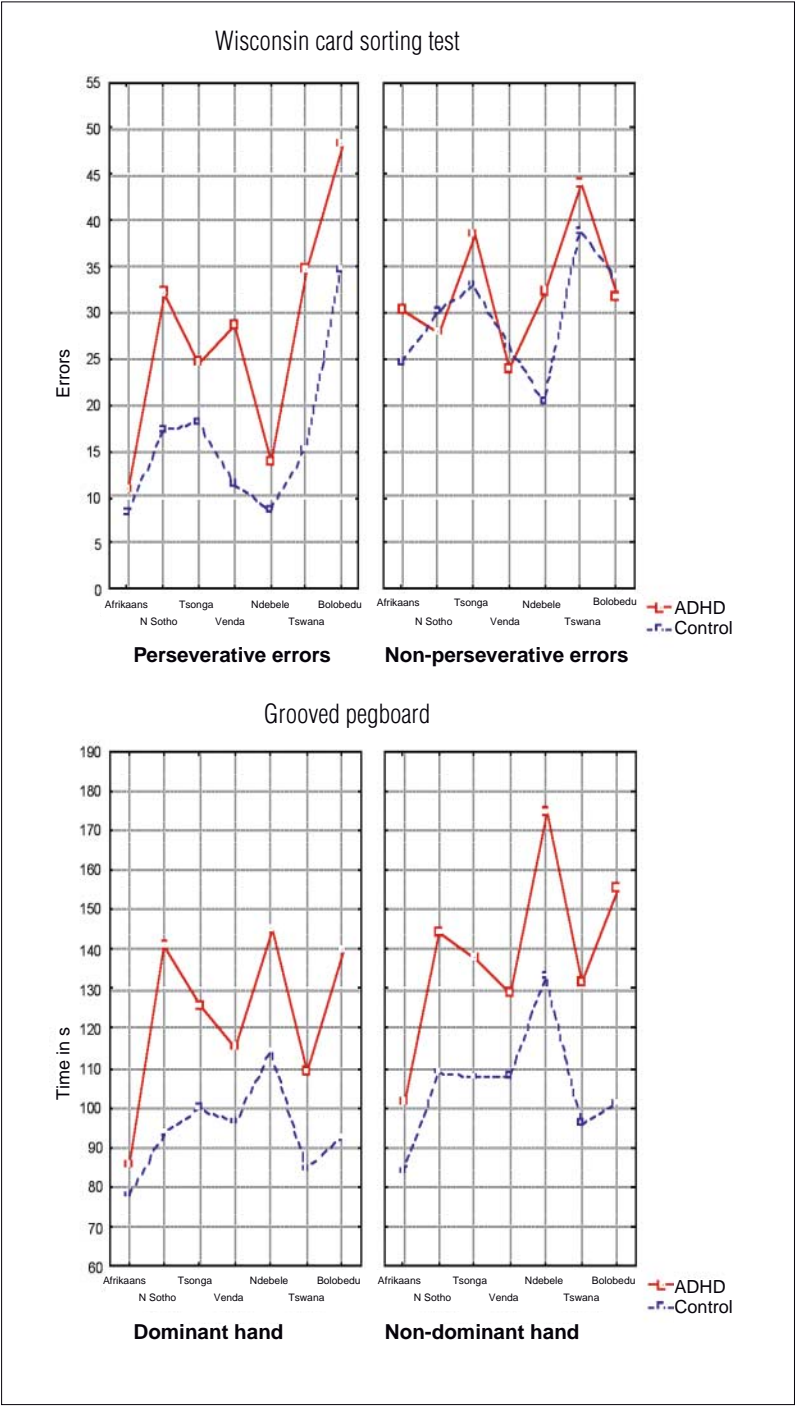


Figure 1. Testresults of the different ethnic groups

Method

Children in the Limpopo Province (Afrikaans, Northern Sotho, Venda, Tsonga, Tswana, North Ndebele and Bolobedu) were recruited from a primary school based population, aged 6 – 13. The 528 children were recruited following screening for ADHD of the general population of primary school children representative of all socio-economic levels. The instrument used for screening was the DBD rating scale, which was standardised for the population groups of the Limpopo Province. Only teachers’ ratings were used for the screening as parents’ ratings could not

be obtained. Teachers' rating are usually regarded as an accurate measure of assessment (American Academy of Pediatrics, 2004). The children meeting the criteria for inclusion into the ADHD group were selected for further testing. They were matched for gender, age, and ethnic group with children who did not meet the inclusion criteria, obtained from the screening process. Children were divided into an ADHD group and a control group without ADHD symptoms.

The tests selected were the Tower of London and the Wisconsin Card Sorting Test (behavioural planning) and two tests to measure manual motor skills, the Grooved Pegboard and the Maze Coordination Task. Group differences on test performance were analysed using analysis of variance. The results were analysed with a 2 x 2 x 7 (clinical x gender x ethnic group) ANOVA for independent samples.

Results

Although all the tests distinguished between children with ADHD and a non-ADHD control group, there was a marked effect of ethnicity. On most tests the Afrikaans group showed the best performance, although this was not always the case. On the tests that measured behavioural planning, the North Ndebeles' performance was on par with that of the Afrikaans group. The Bolobedu performed significantly poorer than the other groups.

The results on the motor tests showed that the performance of the Afrikaans group was again better than the other groups, although their performance did not differ significantly from that of the Tswana. Surprisingly, the North Ndebele, who had significantly higher scores than the other indigenous groups on the behaviour planning tasks, were the poorest performers. Figure 1 shows the results on two of the tasks: The perseverative errors of the WCST and the Grooved Pegboard.

It therefore seems that although the tests were non-verbal, they are sensitive to ethnic and cultural factors, which are difficult to explain. One factor that most certainly plays a role is that of education. The Afrikaans group has benefited in the past from the policy of Apartheid, when more money and resources were spent on white children. After ten years of democracy, the effect is still noticeable. Also, all Afrikaans children had attended pre-primary school, while this is rarely the case with the rural black children. Other possible explanations may be the fact that the Afrikaans children came from urban towns, while most of the indigenous groups came from semi-urban and rural areas. The Bolobedu, who performed poorest on most tests, were only found in remote, rural areas.

Conclusion

From the two studies it follows that the prevalence and sex ratios of ADHD in the Limpopo Province of South Africa are very similar to those reported in Western countries, which suggests that ADHD is caused by the same fundamental neurobiological processes, probably caused by genetic factors expressed independently of cultural differences. However, cultural differences do affect the performance on neuropsychological measures. The reason may be that cultural factors are important determinants of child rearing practices which may affect the brain's organization of cognition. There is therefore a need for assessment methods that are

culturally valid for different ethnic groups. Thus, systematic research to identify and develop and/or adapt the neuropsychological instruments required to assess ADHD symptomatology is greatly needed.

References

- American Academy of Pediatrics (2004). Clinical practice guideline: Diagnosis and evaluation of the child with Attention-Deficit/Hyperactivity Disorder. *Pediatrics*, 105, 1158-1170.
- American Psychiatric Association (2000). *Diagnostic and statistical manual of mental disorders: DSM-IV-TR*. Washington DC: Author.
- Barkley, R. A. (2004). Driving impairments in teens and adults with attention-deficit/hyperactivity disorder. *Psychiatric Clinics of North America*, 27, 233-260.
- Barkley, R. A., Fischer, M., Smallish, L., & Fletcher, K. (2004). Young adult follow-up of hyperactive children: antisocial activities and drug use. *Journal of Child Psychology and Psychiatry*, 45, 195-211.
- Carroll, S. T., Riffenburgh, R. H., Roberts, T. A., & Myhre, E. B. (2002). Tattoos and body piercings as indicators of adolescent risk-taking behaviors. *Pediatrics*, 109, 1021-10217.
- Fillmore, M. T. & Rush, C. R. (2002). Impaired inhibitory control of behavior in chronic cocaine users. *Drug and Alcohol Dependence*, 66, 265-273.
- Kahn, J. A., Kaplowitz, R. A., Goodman, E., & Emans, S. J. (2002). The association between impulsiveness and sexual risk behaviors in adolescent and young adult women. *Journal of Adolescent Health*, 30, 229-232.
- Lam, L. T. (2002). Attention Deficit Disorder and hospitalization due to injury among older adolescents in New South Wales, Australia. *Journal of Attention Disorders*, 6, 77-82.
- Meyer, A. (1998). Attention Deficit/Hyperactivity Disorder among North Sotho speaking primary school children in South Africa: Prevalence and sex ratios. *Journal of Psychology in Africa*, 8, 186-195.
- Meyer, A. & Aase, H. (2003). Assessment and intervention in childhood disruptive behaviour disorders. In N.S.Madu (Ed.), *Contributions to psychotherapy in Africa*. (pp. 164-178). Polokwane (Pietersburg): UNIN Press.
- Meyer, A., Eilertsen, D. E., Sundet, J. M., Tshifularo, J. G., & Sagvolden, T. (2004). Cross-cultural similarities in ADHD-like behaviour amongst South African primary school children. *South African Journal of Psychology*, 34, 123-139.
- Molina, B. S., Bukstein, O. G., & Lynch, K. G. (2002). Attention-deficit/hyperactivity disorder and conduct disorder symptomatology in adolescents with alcohol use disorder. *Psychol.Addict.Behav.*, 16, 161-164.
- Nxumalo, N. E. (2000). *The status and role of minority African Languages in South Africa's new and democratic language policy*. University of the North.
- Pelham, W. E. Jr., Gnay, E. M., Greenslade, K. E., & Milich, R. (1992). Teacher rating of DSM-III-R symptoms for the disruptive behaviour disorders. *Journal of the American Academy of Child and Adolescent Psychiatry*, 31, 210-218.
- Pillow, D. R., Pelham, W. E., Jr., Hoza, B., Molina, B. S., & Stultz, C. H. (1998). Confirmatory factor analyses examining attention deficit hyperactivity disorder symptoms and other childhood disruptive behaviors. *Journal of Abnormal Child Psychology*, 26, 293-309.
- Rammala, J. R. (2003). Draft language policy for the University of the North. Unpublished Work.
- Roberts, J. A. & Tanner, J. F., Jr. (2000). Compulsive buying and risky behavior among adolescents. *Psychological Reports*, 86, 763-770.
- Swanson, J. M., Sergeant, J. A., Taylor, E., Sonuga-Barke, E. J. S., Jensen, P. S., & Cantwell, D. P. (1998). Attention-deficit hyperactivity disorder and hyperkinetic disorder. *Lancet*, 351, 429-433.
- Tercyak, K. P., Lerman, C., & Audrain, J. (2002). Association of attention-deficit/hyperactivity disorder symptoms with levels of cigarette smoking in a community sample of adolescents. *Journal of the American Academy of Child and Adolescent Psychiatry*, 41, 799-805.

Numerical Solutions to Problems in Physics from Model to Model

Hierarchy of models

Models are the cornerstone of any scientific discipline not relying strictly on logic. In physics the present understanding of the world around us is based on a mosaic of models. Some models try to answer basic questions such as what are the governing forces of nature (e. g. general relativity [3]), or what are the building blocks of matter (e.g. the prediction of anti-particles [2]). From the fundamental models many more models are derived. These secondary models are often simplifications to the original models made by imposing additional assumptions (e. g. Newton's laws can be viewed as a simplification of general relativity). Models of this type are potentially well suited for describing smaller sub-sets of problems. A third category consists of models which rely more strongly on observations and where the connection to the underlying physical laws is more uncertain. These descriptive models often represent a first step towards a more fundamental understanding of the problems studied (e. g. stellar evolution models based on the Hertzsprung-Russell diagram [5]). All three classes of models are physical models whose primary task is to provide qualitative understanding of nature.

Having a mathematical formulation of a physical model, we can hope to get quantitative information about processes in nature. Often mathematical models are an integral part of the corresponding physical models. Others are derived through strict manipulation of equations resulting in models which are not so easily tied to physical interpretations. Starting with observations, some mathematical models are established by simple functional fits to data. To be able to make predictions on the basis of a mathematical model, we usually have to solve a set of equations that describes the relation between relevant quantities. In some cases, it is both feasible and useful to solve the equations analytically. However, often the solutions to these equations can be so complicated that solving the equations numerically is the only option. For this we will need a third class of models, namely numerical models. Just as the mathematical models rely on the physical models, the numerical models rely on the mathematical models.

From an analytical to a numerical model

The main issue when designing a numerical model based on a mathematical or more precisely an analytical model, is often how descriptions based

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on continuous variables can be replaced by descriptions based on discrete variables. Assuming we restrict our attention to problems described by a temporal coordinate and a generalized spatial coordinate, we have to choose a method for discretizing time and space. Furthermore, we need to look at how the mathematical operations can be performed on a computer. This can be particularly challenging when dealing with quantities which can become arbitrarily large or which are stochastic. It is important to know what additional assumptions have been applied in order to construct the numerical model and to have a thorough understanding of how the solutions from the numerical model might differ from those of the corresponding analytical model as a result of these assumptions.

A solution at time t_0 can only influence the solution obtained at time t_1 if t_0 is less than t_1 . It is therefore a common approach to solve for time variations somewhat differently than space variations. Information on variation in space is generally stored by a large set of calculation points that cover the spatial domain. In contrast, information on variation in time is typically stored only for a few points in time. In solving for spatial changes, one of two different approaches is common:

(i) Grid solvers discretize space independently of whether the simulated regions contain any mass or not. A solver of this type must keep track of any material entering or leaving each grid cell (see Figure 1). Accurate estimates of higher order derivatives can be made¹. Properties such as stability and accuracy of a particular solver are relatively easy to determine. Techniques for incorporating various boundary conditions are

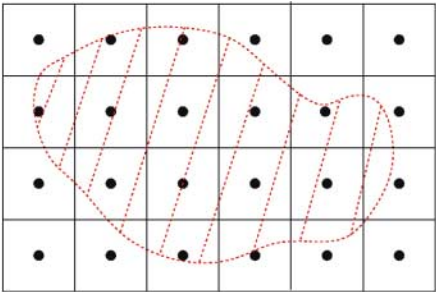


Figure 1. Illustration of the grid solver approach where the filled circles indicate calculation points, the red curve represents an isolated body of material.

also well known. And in general, many different grid methods are available that have been developed and refined for decades.

(ii) Particle solvers discretize the material and neglect areas of vacuum. A solver of this type keeps track of how mass moves around by discretizing the material itself (see Figure 2). It is therefore well suited for describing complicated material flow (called advection), possibly with free surfaces and complex interfaces. Solvers of this kind use a more intuitive

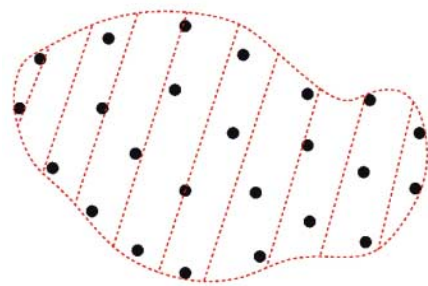


Figure 2. Illustration of the particle solver approach where the filled circles indicate calculation points ("particles"), red curve represents an isolated body of material.

approach since we humans are more used to relating to the material that occupies space rather than space itself. Extensions to higher dimensional descriptions are easily facilitated with the particle approach.

Example: Plasma simulations of meteor ionization

In order to illustrate strengths and weaknesses of the grid and particle solver approach, we will take a look at a simulation of the interaction between the upper atmosphere and a 1m-sized meteor entering the atmosphere at a speed of roughly 40 km/s. In the interaction, atoms boiling off the surface of the meteor collide with the atmospheric gas causing originally neutral atoms to be split into negatively charged electrons and positively charged ions, creating what is known as a plasma around the meteor [4]. The plasma can generate electromagnetic waves, in addition to sound waves which can be generated by neutral gases as well. The simulation focuses on the plasma generated around the meteor, while the neutral particles in the atmosphere are assumed to originate

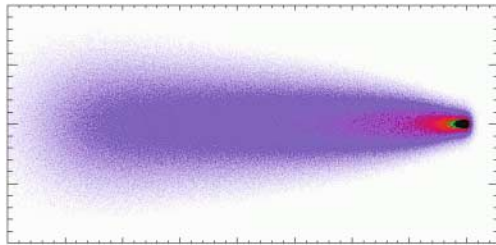


Figure 3. The density profile of the plasma generated around the meteor (Colours in decreasing density order: Black, green, red, purple, and white). The plotted frame has been rotated so that the meteor moves horizontally relative to the frame.

from a uniform, equilibrium background population. Figure 3 illustrates the plasma density profile in a two-dimensional simulation of the meteor. The plasma is generated close to the meteor head but subsequently spread out by elastic collision with the neutral background and by the electric forces.

The plasma density is only non-negligible in a fairly narrow field trailing the meteor head. Also, the generalized spatial coordinates in this simulation are a combination of the physical space coordinates and the velocity coordinates². Free surfaces are therefore important features of this problem. Also, it is crucial to have an accurate treatment of advection. This points towards using particle solvers. However, the electric field generated by the plasma will extend into regions where the plasma density in practice is zero. Furthermore, to calculate the electric field, higher order derivatives must be calculated. This indicates that grid solvers are better suited for the problem. The current numerical model (known as Particle-In-Cell) combines grid and particle solvers [1]. The former approach describes the plasma itself and the advection of plasma. The latter approach describes the electric field resulting from the ever changing distribution of material. The coupling between the two approaches is done by projecting the particles onto a grid, thus achieving a hybrid description that takes advantage of both approaches.

Notes

- 1 As an example, the time derivative of a function f is in itself a function that describes how f varies in time. The second order derivative of f , correspondingly describes how the derivative of f varies in time.

- 2 This is known as a kinetic description where velocity is treated as an independent variable that cannot be expressed as a function of the physical space coordinates and time. This description takes into account that at any point in space and time, particles with widely different velocities can be found.

References

- [1] Birdsall, C. K. & Langdon, A. B. 1985 *Plasma Physics via Computer Simulation*. McGraw-Hill, New York
- [2] Dirac, P. A. M. 1947 *The Principles of Quantum Mechanics*, 3rd ed. Oxford University Press, New York
- [3] Einstein, A. 1915 *Zür allgemeinen Relativitätstheorie*. Preuss. Akad. Wiss. Berlin, Sitzber.
- [4] Jones, W. 1997, *Theoretical and observational determinations of the ionization co-efficient of meteors*. Monthly Notices to the Royal Astronomical Society, 288, 995
- [5] Wuchterl, G & Tscharnuter, W. M. 2003 *From clouds to stars. Protostellar collapse and the evolution to the pre-main sequence I. Equations and evolution in the Hertzsprung-Russell diagram*. Astron. & Astrophys. 398, 1081

DAG HAUG:

Model-Theoretic Semantics and Models of Semantic Change

What is meaning? And how does meaning change? These are long standing questions of synchronic and historical linguistics. And in order to answer them, linguists have come up with semantic models and with models for semantic change.

What is meaning?

The question must at once be made more precise. Languages have words, and words have meanings – this is what we study in lexical semantics. But languages have sentences too, and sentences also have meanings, conceivably of a quite different kind from the kind of meanings that words have. Many nouns refer to things in the world, and their meaning is a concept which defines the sort of things that they refer to. Verbs, on the other hand, often refer to events, a more abstract concept. But what do sentences refer to? According to one theory, sentences refer to truth and falsehood and their meanings are their truth conditions. To know what a sentence means is to know what the world will have to be like for the sentence to be true. In Tarski's famous formulation: "The sentence 'snow is white' is true if and only if snow is white."

All this is well and good, you may say, but even if the meanings of words are different from the meanings of sentences, there must still be a connection. How could we understand sentences if not by putting together the meanings of their parts? And indeed it is a central tenet of modern semantics that, as Frege put it, "the meaning of the whole is a function of the meaning of the parts and their mode of combination".

But what are the parts of a sentence? Words, obviously. But there are also intermediate parts of the sentences which are studied in syntax. Not any two words, even adjacent, form a part of a sentence. For example "Dogs bark" is a possible sentence in English, but it is not a part of the sentence "All dogs bark". Instead "All dogs" is a part of "All dogs bark", and it is the part that we usually call the subject.

So sentences are built up of such parts in a way that can be represented as a binary branching tree (Figure 1). The construction of this tree is governed by the rules of syntax, and for every syntactic rule that allows us to put together two units to form a sentence part or a whole sentence, we need a semantic rule that will tell us how the meaning of the combination is derived from its parts.

To express this meaning, the language of set theory has proven useful: we model things as individuals and predicates as sets of individuals: so

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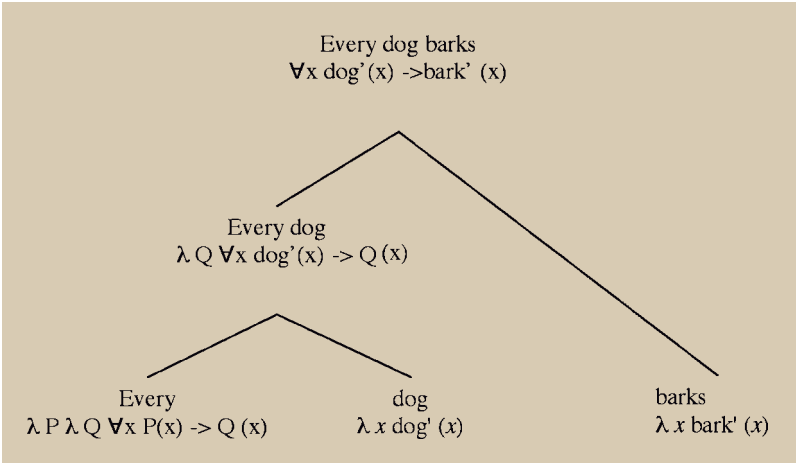


Figure 1. A semantic tree for the sentence ‘Every dog barks’.

‘Snow is white’ is true if and only if the thing that we call snow is in the set of all white things. But how do we know whether the thing that we call snow is in the set of all white things? This is linguistics and not natural science, so we are not going to look out of the window. Actually, we are not interested in whether ‘Snow is white’ is true at all – we only want to know its truth conditions.

Was that all?

Is this all there is to meaning? Not in our ordinary sense of the word. If I say to someone “My glass is empty”, this sentence has a meaning which is derivable from the words ‘my’, ‘glass’, ‘be’ and ‘empty’. But what I really mean could well be something like “Could you get me some water?” – a meaning which is not computable from these four words. This is called the pragmatic force of the sentence.

Pragmatic force is exceedingly important in human communication. Uttered in an English pub shortly before 11 PM, the sentence “The place is closing” is less likely to be a mere statement of fact than an invitation to buy another beer before it is too late; or indeed the opposite, a request to drink up and leave. It all depends on the context.

None of these pragmatic implications are directly linked to the literal meaning of “The place is closing” in the calculable way that the literal meaning of “The place is closing” is linked to the meanings of the term “The place” and the predicate “is closing”. However, the philosopher Paul Grice has suggested that pragmatic implications arise from the assumption common to both parties in a communicative situation that certain maxims underlie the communication. One of these maxims is particularly important for us, namely the maxim of relevance “Make your contribution relevant!” Consider the following exchange:

- A: Can I borrow 50 dollars?
- B: My purse is in the hall.

B’s answer is not immediately relevant to A’s question. So A is led to look for an interpretation that would be relevant, in this case probably something like “Yes, go and get it from my purse which is in the hall”.

Semantic change

We said above that the semantic component of a language could be modelled as a set of rules which are paired to the syntactic rules used in building up sentences. For every time a syntactic rule allows us to put together two words or sentence parts, a semantic rule tells us how to derive the meaning of the whole from that of its parts. However, such a view of (sentence) semantics as a set of rules is essentially ahistoric: at some point in time, the set contains a certain rule. Some 200 years later, we may no longer need the same rule in our model of the semantic change; or perhaps the system will contain a similar but not quite identical rule.

For example, in Latin we find sentences like *habeo litteras scriptas* meaning something like ‘I have a written letter’. In French we find *j’ai écrit une lettre* which corresponds more or less in meaning to ‘I have written a letter’ – a quite different concept. In Latin, the speaker would have to have the letter in his possession for the sentence to be true. This is not necessary in the case of the French sentence. Conversely, the French sentence is only true if the speaker wrote the letter himself, whereas the Latin sentence only entails that the letter was in some way written by someone.

So, we could say, the semantic rule governing the composition of ‘have’ and its object changed from Latin to French. But this is no more than a description. We want to know how and why that happened. And this is where pragmatics enters the scene.

Meaning change through conventionalization of implicatures

In a way, grammar change must be sudden: in the semantic model outlined above, the semantic representation of a certain word is fixed. It may be different at one time from what it is at another, but it does not change gradually from one to another. It may change from A to B, but it is never halfway between A and B. Still we all know that we understand each other across generations: even though I speak differently from my grandmother and though I may have some different semantic representations, we can understand each other. So in a sense, change in linguistic output is gradual.

So change in linguistic output is gradual, but grammar change is sudden. This is so because, as Henning Andersen pointed out more than thirty years ago, learners do not have direct access to the grammar rules of the older generation. They construct their grammar on the basis of the linguistic output they hear.

Let us now look at how this works in semantic change. Take the case of English *will*. This verb is related to German *wollen* ‘want’ and originally expressed desire as the German verb still does. Nowadays, however, English *will* is a marker of futurity. How did this happen?

When we speak about our own desires, the maxim of relevance will often lead the hearer to conclude that we speak of our intentions: it is often more relevant to speak of our desires if we intend to realise them. So if you tell someone “I want to go now”, they will often conclude that you intend to go. This is not, however, the literal meaning of the sentence, and it is an implication that can be cancelled: “I want to go now, but I cannot” is entirely OK.

Pragmatic implications can therefore be cancelled in the context, but if they arise often enough from a certain linguistic construction it is also

possible that they will become conventionalized and actually part of the core semantic meaning of that construction. This is what happened to English *will*: the implication of intention, and later, speaker's prediction became conventionalised and part of the core meaning – which is why you can no longer say “I will go now, but I cannot”. The same thing happened to the verb to have in the Latin example above: What is the relevance of the participle ‘written’ in ‘I have a written letter’ – letters typically *are* written. Well, the hearer may conclude, the verbal form implies an agent and this is likely to be the speaker himself. And so the implication of coreferentiality between the agent of the main verb ‘have’ and the underlying agent of the participle ‘written’ – an essential feature of the perfect construction – arises. And actually this implication arose in a lot of cases, which is why it eventually became conventionalised. On the other hand, the implication “yes” will only arise from the sentence “My purse is in the hall” in very specific conditions – which is why it is not very likely to be conventionalised and why “My purse is in the hall” will probably never become the normal way of saying “yes”.

Exploring Reinforcement Processes using Intra-Cranial Self-Stimulation

Intra-cranial self-stimulation, ICSS

In 1953 the two Canadian scientists, James Olds and Peter Milner, discovered that rats would willingly expose themselves to electric stimulation of the brain (Olds & Milner, 1954). In further studies, Olds and Milner placed a lever in the cage and connected the lever to a stimulator so that each press would result in the delivery of a pulse (Figure 1). They found that rats with the electrode implanted in the lateral hypothalamus rapidly learned to press the lever and would press it up to 7000 times per hour repeating the behavior for hours if allowed, ignoring thirst and hunger. Later research has shown that intra-cranial self-stimulation is general; ICSS has been shown in a variety of species ranging from goldfish to humans (including guinea pig, bottlenose dolphin, cat, dog, goat, and monkey) and several brain areas support responding for ICSS.

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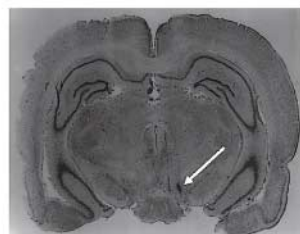
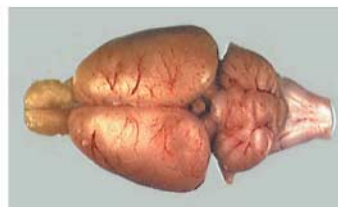
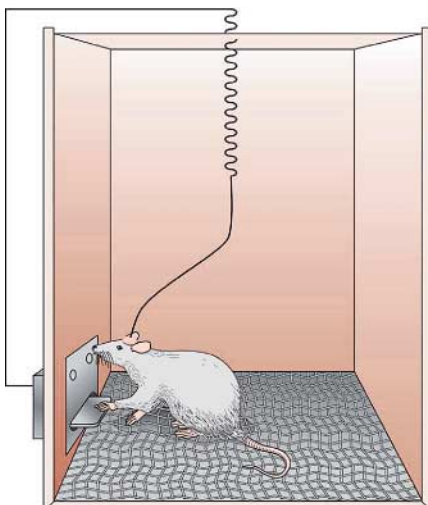
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Figure 1. Rat in self-stimulation chamber (left, from Bear, 2001). Rat brain (upper right, from Synapse Web, Medical College of Georgia, <http://synapses.mcg.edu/>) and section of rat brain from present study showing that the bipolar electrode was positioned in the ventral tegmental area (lower right, from Johansen et al., 2005).



Working mechanism of ICSS

An early interpretation of the mechanisms behind ICSS was that pleasure and displeasure centres were stimulated by the electrical pulses. Early reports from self-stimulation in humans supported the suggestion that responding for electrical brain stimulation produced a feeling of pleasure:

“During these sessions B-19 stimulated himself to a point that he was experiencing an almost overwhelming euphoria and elation, and had to be disconnected despite his vigorous protests”

(Moan, C.E., & Heath, 1972)

However, other studies showed that in some people the site most frequently chosen to stimulate induced an irritable feeling or a feeling of being about to remember something. These and other findings lead to the conclusion that self-stimulation in humans is not synonymous with a feeling of pleasure. Thus, the working mechanisms behind ICSS probably depend upon stimulation site and which brain structures are activated by the stimulation. The rewarding effects of ICSS may work through inducing positive affective experiences, but can also be produced through activation of other brain systems without generating a positive effect.

The mesolimbic dopamine system and ICSS

The mesolimbic dopamine system originates in the ventral tegmental area (VTA) in the brain stem and projects to a collection of neurons in the basal forebrain called nucleus accumbens, NAc. There is overwhelming evidence that the mesolimbic dopamine system is involved in reward and reinforcement processes. Primary reinforcers such as food, sex, and also drugs of abuse are associated with dopamine release in NAc.

In a simplified form, function of the mesolimbic dopamine system may be summarized as follows:

- Respond to novelty in the environment
- Focus behaviour into approach, seeking, and investigation of these novel stimuli, especially if they are related to reinforcers
- Strengthen adaptive behaviour and connections between environmental stimuli and responses that may help sustain survival (Figure 2)
 - however, this system does not mediate affective experiences (pleasure, satisfaction, or hedonic aspect)

Studies have shown that positioning the electrode in VTA or its dopamine projection to NAc produces the highest and most reliable ICSS response rate (Wise, 1996). The reinforcing effects of ICSS in VTA and NAc are mediated by dopamine neuron activity, but the effects appear not to be mediated by a feeling of pleasure. ICSS in VTA might be described as a short-circuiting of the brain's reinforcement system by stimulating the neurons directly, thereby bypassing the sensory systems and other systems normally important for initiating behaviour (Figure 2).

Investigating reinforcement mechanisms in an animal model of ADHD

Attention-Deficit/Hyperactivity Disorder (ADHD) is a disorder affecting 3–5 % of children, and is characterized by a persistent pattern of inattention, impulsivity, and hyperactivity. Findings from several research areas

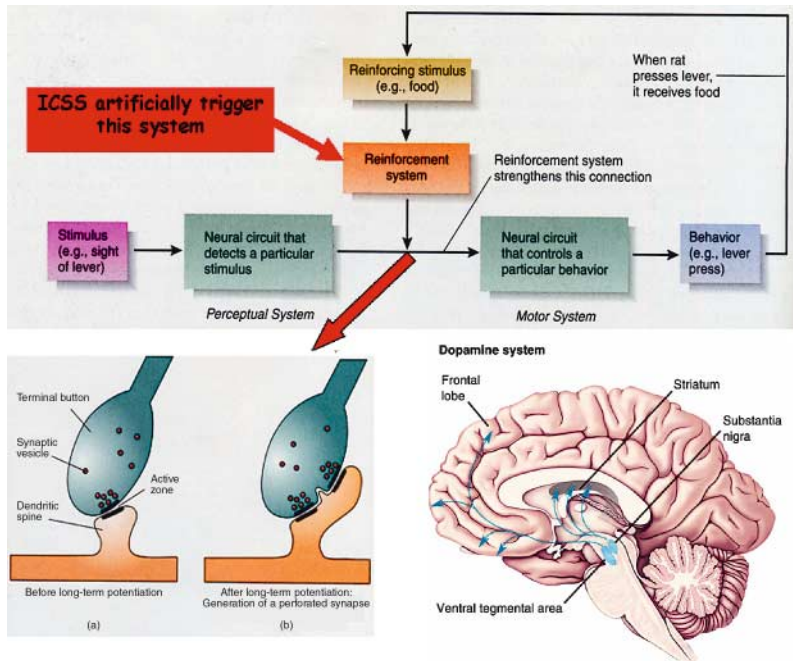


Figure 2. External stimuli are detected by neural circuits acting on motor circuits and may lead to initiation of behaviour (upper, from Carlson, 2004). Behaviour that has a favourable outcome (food) produces dopamine release in nucleus accumbens (lower right, from Bear, 2001). ICSS reinforcement can lead to synaptic long-term potentiation (LTP) (Reynolds, Hyland, & Wickens, 2001), the neuronal correlate to learning (lower left, from Carlson, 2004). The reinforcing effects of ICSS in the ventral tegmental area (lower right, from Bear, 2001) may be an artificial triggering of the reinforcement system and the strengthening of behaviour that produces electrical stimulation.

strongly suggest that dopamine dysfunction is at the core of ADHD etiology. Further, children with ADHD react abnormally to reinforcers and reinforcement contingencies. The known association between reinforcement and dopamine neuron activity further points to a dopamine dysfunction in ADHD.

Based on behavioural studies of children with ADHD and spontaneously hypertensive rats (SHR) which is possibly the best-validated animal model of ADHD (Sagvolden, 2000; Sagvolden, Russell, Aase, Johansen, & Farshbaf, 2005), we have presented a behavioural theory of ADHD suggesting that symptoms are produced by dopamine dysfunction leading to altered effects of reinforcers (Sagvolden, Johansen, Aase, & Russell, 2005).

Using ICSS reinforcement in VTA, we have investigated how reinforcement processes may be different in SHR compared to normal controls by varying important reinforcement parameters: Current intensity, reinforcer frequency, and reinforcer delay (Johansen & Sagvolden, 2005). The method of ICSS was chosen due to its many advantages: Reinforcers can be delivered with millisecond accuracy, consummation of every reinforcer produced is ensured and no or little time is spent on consummation (e.g. drinking), reinforcer value can be studied by varying ICSS current, and satiation effects are to a large extent avoided.

Varying current intensity (reinforcer value)

The most commonly used ICSS paradigm is the curve shift paradigm (Miliaressis, Rompre, Laviolette, Philippe, & Coulombe, 1986). By varying ICSS current, the resulting current-response rate curves resemble the traditional logarithmic dose-response curves commonly obtained in pharmacology (Figure 3). The drug's effects on reinforcement can be estimated by comparing curves from saline and drug sessions. Dopamine agonists will increase the effects of the ICSS reinforcers and produce the same response rate with lower ICSS current values (left-shift) while dopamine antagonists will have the opposite effect (Miliaressis et al., 1986).

The results from varying current during frequent and infrequent reinforcement show that the current-response curve-shift in SHR compared to controls is two-dimensional (Johansen et al., 2005). During frequent reinforcement (fixed interval 0.5 s), maximal response rate in SHR was found at a lower current than in the controls (Figure 3, right, A, Johansen et al., 2005), while infrequent reinforcement (variable interval 60 s) caused a shift towards higher response rates in SHR (Figure 3, right, B, Johansen et al., 2005). These findings support the suggestion that reinforcers act differently on responding in SHR compared to controls and indicate that strain differences may be linked to frequency of dopamine release (Johansen et al., 2005).

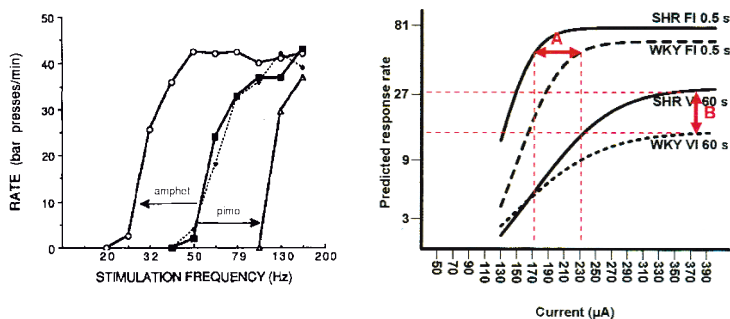


Figure 3. Shifts in relation between response rate and ICSS current frequency produced by dopamine agonists and antagonists (left, from Wise, 1996). Current-response curves in SHR and controls (right, adapted from Johansen et al., 2005) as functions of reinforcement frequency: a significant shift towards lower currents (A) was found in SHR during frequent reinforcement (fixed interval 0.5 s), while a significant shift towards higher response rates (B) was found in SHR during infrequent reinforcement (variable interval 60 s).

Varying reinforcement frequency and reinforcer delay

Our study (Johansen et al., 2005) included testing effects of varying reinforcement frequency on response rates in SHR and controls using variable interval schedules with different lengths (Figure 4). The relation between response rate and reinforcement frequency is described by the VI input-output relation, also referred to as the Matching law: $B = k * r / (r+c)$, where B represents response rate; k is a constant representing the asymptotic response rate during high reinforcer frequency; r represents the reinforcer frequency ($r = 1/t$, t = time); and c is a constant describing the rate of reinforcement maintaining half of the asymptotic k (Catania, 1973; Herrnstein, 1970).

Included was also a condition imposing a specified delay interval between the response and reinforcer delivery (Johansen et al., 2005). Theoretically, the relation between response rate and reinforcement delay is described by the hyperbolic decay function

$V = A / (1 + k \cdot \text{delay})$, where V is the reinforcer value when the reinforcer is delivered after a delay, D ; A is the reinforcer value when there is no delay; and k describes the rate of decay of the reinforcing effect (Mazur, 1995).

Our results show that the ICSS reinforcement contingencies rapidly change the behaviour and produce systematic responding even after only a few sessions on each condition. ICSS produced response rates that were highly consistent with the equations. Fitting the equations to response rates, explained variance in individual response rates were in excess of 90% showing high correspondence between theoretical models and behavioural observations during ICSS reinforcement (Figure 4).

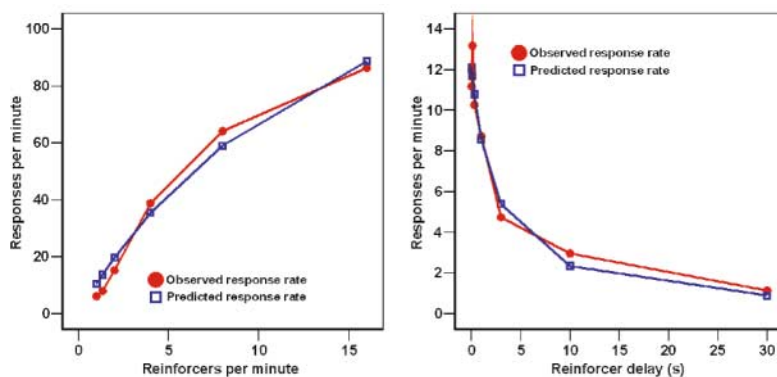


Figure 4. The figure illustrates the correspondence between theoretical models and behavioural observations during ICSS reinforcement in one individual rat. The VI input-output equation was fitted to the observed response rates across six rates of reinforcement and parameter estimates were used to plot predicted response rates (left). The hyperbolic decay function was fitted to observed response rates during reinforcement delay and predicted response rates are plotted based on parameter estimates (right).

In general, the findings from investigating reinforcement processes in SHR are consistent with results from previous studies using water reinforcers and support the suggestion that reinforcers work differently on responding in SHR compared to controls (Johansen, Sagvolden, & Kvande, 2005; Johansen et al., 2005). Further, due to the excellent experimental control and the possibility of experimental manipulations not easily performed with water or food reinforcers, the results suggest that ICSS reinforcement may be a valuable method for further investigating reinforcement processes in SHR. Future studies should investigate effects of dopamine agonists and antagonists on current-response rate curves, thereby examining the association between the suggested altered reinforcement processes in SHR and a possible dopamine dysfunction.

References

- Bear, M. (2001). *Neuroscience: exploring the brain* / Mark F. Bear, Barry W. Connors, Michael A. Paradiso.
- Carlson, N. (2004). *Physiology of behavior* / Neil R. Carlson.
- Catania, A. C. (1973). Self-inhibiting effects of reinforcement. *Journal of the Experimental Analysis of Behavior*, 19, 517–526.
- Herrnstein, R. J. (1970). On the law of effect. *Journal of the Experimental Analysis of Behavior*, 13, 243–266.
- Johansen, E. B. & Sagvolden, T. (2005). Behavioral effects of intra-cranial self-stimulation in an animal model of attention-deficit/hyperactivity disorder (ADHD). *Behavioural Brain Research*, 162, 32–46.
- Johansen, E. B., Sagvolden, T., & Kvande, G. (2005). Effects of delayed reinforcers on the behavior of an animal model of attention-deficit/hyperactivity disorder (ADHD). *Behavioural Brain Research*, 162, 47–61.
- Mazur, J. E. (1995). Conditioned reinforcement and choice with delayed and uncertain primary reinforcers. *J Exp. Anal. Behav.*, 63, 139–150.
- Miliaressis, E., Rompre, P. P., Laviolette, P., Philippe, L., & Coulombe, D. (1986). The curve-shift paradigm in self-stimulation. *Physiol Behav.*, 37, 85–91.
- Moan, C.E., & Heath, R. G. (1972). Septal stimulation for the initiation of heterosexual behavior in a homosexual male. *Journal of Behavior Therapy and Experimental Psychiatry*, 3, 23–30.
- Olds, J. & Milner, P. (1954). Positive reinforcement produced by electrical stimulation of septal area and other regions of rat brain. *Journal of Comparative and Physiological Psychology*, 47, 419–427.
- Reynolds, J. N., Hyland, B. I., & Wickens, J. R. (2001). A cellular mechanism of reward-related learning. *Nature*, 413, 67–70.
- Sagvolden, T. (2000). Behavioral validation of the spontaneously hypertensive rat (SHR) as an animal model of attention-deficit/hyperactivity disorder (AD/HD). *Neuroscience and Biobehavioral Reviews*, 24, 31–39.
- Sagvolden, T., Johansen, E. B., Aase, H., & Russell, V. A. (2005). (in press). A dynamic developmental theory of Attention-Deficit /Hyperactivity Disorder (ADHD) predominantly hyperactive/impulsive subtype. *Behavioral and Brain Sciences*.
- Sagvolden, T., Russell, V. A., Aase, H., Johansen, E. B., & Farshbaf, M. (2005). Rodent Models of Attention-Deficit/Hyperactivity Disorder. *Biological Psychiatry*, 57, 1239–1247.
- Wise, R. A. (1996). Addictive drugs and brain stimulation reward. *Annual Review of Neuroscience*, 19, 319–340.

Turbulence in Plasmas: What is different from Turbulence in Neutral Fluids?

In old Democrit's mind the world consisted of four elements: earth, water, air and fire. The modern view is not much different, we have four aggregate states of matter: solids, liquids, gases and plasmas. We may view these as four steps on a temperature ladder. Starting with ice, it produces water when melting, which again produces vapour – that is a gas – when boiling. Finally, the gas, if passed through a flame, is transformed into a plasma where a certain fraction of the atoms or molecules of the gas has been broken up into positively charged ions and free negatively charged electrons. The plasma is thus an ionized gas. The charged particle species on the one hand interact with any electric or magnetic field present, on the other hand they are themselves sources for such fields. This fact is responsible for a vastly different physics of plasmas compared with that of the neutral gas.

In fact, the new properties are so dominating that a gas where only one atom for every 10,000 atoms is ionized is commonly denoted as a strongly ionized gas. We sometimes refer to liquids, gases or plasmas as fluids.

The complexity of the physics increases significantly when going from a neutral fluid to a plasma. This comes as a result of the importance of the long range effects of electric and magnetic fields. Thus a local disturbance in the plasma that produces an unbalance in the charge density at some point will generate fields that will be felt by charged particles at large distance. This gives the possibility for coherent oscillations in plasmas with no counterparts in neutral fluids. With this larger selection of possible wave modes in plasmas, some of these may go unstable in the presence of a proper free energy source, leading to the generation of a turbulent state.

The free energy source may be of different types. In a neutral fluid a velocity shear is a common free energy source. The corresponding instability produced is named after Kelvin and Helmholtz, two of the giants in the history of physics. A velocity shear means that the mean flow velocity of the fluid varies in space in the span-wise direction, that is, in the direction perpendicular to the flow itself. This means that neighbouring layers of the fluid are moving with different velocities. This situation arises if a fluid is forced through a circular tube and where the flow velocity near the centre line is larger than that near the wall. A similar situation results if a fluid jet is forced into an otherwise stationary fluid. Instabilities and turbu-

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lence will result if the forcing is strong enough. The typical turbulent plumes from industrial smokestacks are common examples of this situation.

The Kelvin-Helmholtz mechanism will be acting also in an electrically conducting fluid like a plasma. In this medium, however, a large selection of alternative free energy sources are available. One example is the presence of a drift of electrons relative that of the ions. This will produce a net transport of charge in the plasma, and therefore an electric current. It is a well-known fact that at plasma carrying a threadlike current will go unstable if special precautions are not taken. This fact was one of the first stumbling blocks met with in the research toward the controlled nuclear fusion reactor.

But even a relative drift of two parts of the same particle population will do as a suitable free energy source. This situation will arise for instance when an ion beam is penetrating a stationary ion background population. To give a mathematical description of this situation it is no longer enough to represent the ion specie in terms of its mean density, its mean velocity and temperature as is commonly done with other fluids. To describe the properties and dynamics of this system it is necessary to introduce the time varying particle probability distribution function $f(\mathbf{r}, \mathbf{v}, t)$ in the six-dimensional phase space. The phase space (\mathbf{r}, \mathbf{v}) consists of the combination of the three-dimensional configuration space with the three-dimensional velocity space. The distribution function f expresses the probability of finding particles of the given species at a given position \mathbf{r} and velocity \mathbf{v} per unit phase space volume at the given time t . From the distribution function the particle density $n(\mathbf{r}, t)$ and mean drift velocity $\mathbf{V}(\mathbf{r}, t)$ of a given particle species can be found by an integration over velocity space,

Equation 1:

$$n(\mathbf{r}, t) = \int f(\mathbf{r}, \mathbf{v}, t) d^3\mathbf{v}$$

$$n(\mathbf{r}, t) \mathbf{V}(\mathbf{r}, t) = \int \mathbf{v} f(\mathbf{r}, \mathbf{v}, t) d^3\mathbf{v}.$$

For a quantitative description of the plasma dynamics we will thus need an equation telling how the distribution function f evolves in phase space as a function of time. The relevant equation is conceptually and intuitively simple. The distribution function should remain constant if we move along particle trajectories in phase space. A particle at position \mathbf{r} with velocity \mathbf{v} at time t will at time $t + dt$ have position $\mathbf{r} + \mathbf{v} dt$ with velocity $\mathbf{v} + q\mathbf{E}(\mathbf{r}, t) dt / m$. Here q and m are the charge and mass of the chosen particle species and \mathbf{E} is the electric field present. In the last term $q\mathbf{E}(\mathbf{r}, t) / m$ represents the acceleration, that is, the instantaneous change in velocity that a particle at position \mathbf{r} at time t will suffer per unit time due to the presence of the electric field. For simplicity we here neglected the corresponding effect due to magnetic fields. The constancy of the distribution function along particle trajectories is now conveniently expressed through the partial differential

Equation 2:

$$\partial f / \partial t + \mathbf{v} \cdot \partial f / \partial \mathbf{r} + q/m \mathbf{E} \cdot \partial f / \partial \mathbf{v} = 0.$$

This equation is, however, not quite as simple as it may look. The electric field \mathbf{E} is again determined by the net charge density produced by all particle species present, that is, determined by velocity integrals of all evolving distribution functions. In the proper terminology, the field \mathbf{E} to be substituted in (1) is the self-consistent electric field produced by the plasma itself in addition to possible external fields present. This fact turns (1) into a non-linear differential-integral equation in f . In addition the equation as it stands does not include effects produced by close encounters between the particles in the plasma, including possible ionization and recombination processes. These additional effects can be included by adding rather complicated non-linear collision terms to the right hand side of (Equation 1).

Convenient mathematical tools are available for the analysis of linear systems. For non-linear systems the situation is different, each case requiring its special tricks, if at all within our present analytical capability. For the present problem some progress can be made by studying a simplified linearized version of (Equation 1). The very early stage of an unstable situation may be analyzed this way. For the later saturated and turbulent state this approach is, however, not sufficient. The full effect of non-linear terms has to be included.

For this reason numerical simulation techniques have become a very important tool for advancing our understanding of plasma dynamics. We will illustrate this by considering one example in the following, an example that we are presently actively studying. In this example a plasma beam, consisting of co-moving ions and electrons, is penetrating a neutral gas. For the illustration we again simplify the problem, this time not by removing any non-linearity, but by assuming that certain aspects of the problem can be described in a simplified one-dimensional model, that is, by assuming that the distribution function only depends on one spatial variable x and that the dynamics can be limited by including only one velocity component v . We will in our example take account of effects due to one particular type of collisions between ions and neutral atoms, namely collisions in which the ion and the atom are exchanging electric charge. That is, a fast ion and a slow atom before the collision are transformed into a fast neutral atom and a slow ion after the collision.

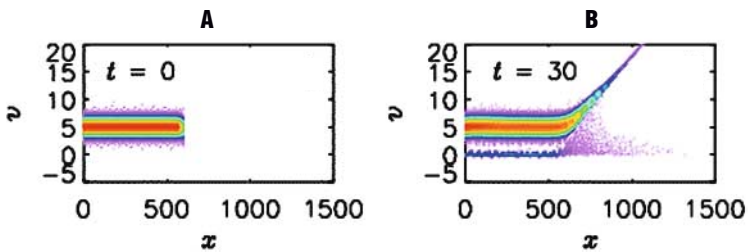


Figure 1. Phase-space snapshots of ion distribution function

Results from the simulation are plotted as phase-space plots in Figure 1a) and 1b), the former displaying the initial state at time $t = 0$, the latter the development at a later stage. In figure a) the plasma beam with a mean velocity of 5 velocity units has been allowed to penetrate a cold background neutral gas a distance of 600 length units. The distribution function f of the ions as a function of position x and velocity v are plotted

using a color code, increasing values as the color changes from violet, through blue, green, yellow to red. The effects of the charge-exchange collisions are turned on at time $t=0$.

Figure 1b illustrates several typical effects. First, due to the existence of unavoidable net charge densities near the beam head, and therefore the generation of localized electric fields in this region, ions near the beam head are accelerated to higher velocities and are therefore speeding away. This is seen as the upward pointing nose in the figure. Secondly, due to the effect of the charge-exchange collisions between the beam ions and the background neutral atoms, a population of slow ions are growing at the expense of the original ion beam. This is seen as the thick blue line at $v = 0$ in the figure and the more yellowish central part of the beam ion distribution function. This will, however, produce a double humped velocity distribution function for the total ion population. Under suitable conditions this situation will go unstable. Evidence of this is seen as a growing almost periodic spatial modulation of the double humped distribution function in the figure (ragged violet envelope of the blue line and increasing fuzziness of the low velocity part of the beam ion distribution function). In the end the phase space between the beam and the cold ion population will be filled with ions until the growth rate of the instability is saturated.

The result of this study is somewhat atypical in that it is a dissipative (collisional) process that is responsible for generating a free energy source (a double humped distribution function) that eventually leads to an instability and a turbulent state. We expect the results of the above and related examples to be of relevance for instance in chemical engineering, for the understanding of meteor dynamics and for the interaction of the solar wind with the interstellar medium.

Using the Ionosphere as a Laboratory for Plasma Turbulence

A plasma is the state of matter when it is ionized, that is, it consists of free electrons which carry a single negative electric charge, and ions, which usually carry one or more positive charges, and are much heavier than the electrons. For most purposes, plasmas are theoretically described in terms of classical physics, which means Newtonian mechanics fused with classical electromagnetism, i. e., Maxwell's equations. Mechanics is the principles of what motion results from given forces. Electromagnetism is about what force fields result from given charge and current distributions. In plasma dynamics, the electromagnetic force fields put the charged particles into motion, and thereby change the local charge and current distributions, leading in turn to modifications of the electromagnetic force fields. So, plasma dynamics is the interplay resulting from this fusion of the two basic theories of classical physics.

From the point of view of basic research, there were good reasons to expect that a broad range of new phenomena would reveal themselves through this fusion. From the point of view of practical applications, plasma physics has to a large extent been driven forth by the perspective of confining a plasma to create conditions for thermonuclear fusion. This has so far not been successful. On the other hand, the study of plasma processes has been very important in space research during the last 4–5 decades. Recently there have also been some developments towards various industrial applications.

Even if the basic theoretical framework of plasma dynamics is clear and uncontroversial, a sound development requires a good interaction between experiment and theory. However, to build good plasma experiments has not been an easy task, and so, creative experimental setups have been crucial for the development of plasma physics. This contribution aims at describing a particular, fairly non-standard, experimental setup, which in the author's opinion has been quite successful in establishing contact between theory and experiment in the case of a fairly complex plasma process.

The setup has the following ingredients: (i) The plasma of the *ionosphere*, which is the ionized layers of our atmosphere from approx. 60 to several 100 km altitude. (ii) A *radar system* which is used for studies of the ionosphere. Such a radar system, EISCAT (European Incoherent SCATter radar system), operates in northern Scandinavia, with transmitters in Tromsø, and receivers in Tromsø, Kiruna, and Sodankylä. (iii) A powerful radio transmitter, *Heating*, which is used for active drive of plasma processes in the ionosphere. Such a powerful radio transmitter is located

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next to the EISCAT transmitters. A similar setup exists at the Arecibo observatory in Puerto Rico, but at the moment, that combined facility is not operating.

The Heating facility at Tromsø operates at frequencies in the range 4–8 MHz. In this frequency range, the radio wave is strongly modified by the ionospheric plasma. In the present case, where it is also very powerful, it also has a potential for driving processes in the plasma, as we shall describe in slightly more detail below. The EISCAT radars, in comparison, operate at 224 MHz (the VHF radar) and 929 MHz (the UHF radar). In this frequency range the propagation of the radio wave is not affected by the plasma. However, a tiny fraction of the incident energy flux is *scattered* back by *fluctuations* in the plasma. It is this backscattered signal that is received and analyzed by the receiving system of the radars.

The process: “Radio driven Langmuir turbulence”.

In order to describe the theory of the actual process, as well as the theory of the measurements, from first principles, one would probably have to write a whole book, with much heavy mathematical derivation. Here, we shall be content with indicating a few concepts of general classical physics.

(i) *Oscillations*. In a simple mechanical system containing *inertia* and a *restoring force*, oscillations will result. Examples: a) A spring where the restoring force is proportional to the displacement (“Hooke’s law”), and a mass point attached to the spring. A straightforward text book analysis of this system leads to the formula $\omega = \sqrt{k/m}$ for the frequency ω , in terms of the spring constant k and the mass m . b) A pendulum. Here the frequency turns out to be $\omega = \sqrt{g/l}$, where g is the acceleration of gravity (approximately 9.8 m/sec²) and l is the length of the pendulum. c) *Space charge oscillations of a plasma*: If an excess or a deficit of electric charge arises somewhere in the plasma, electric forces arise, since similar charges expel each other and opposite charges attract each other. This will set the lightest elements of the plasma, which are the electrons, into motion. But since the electrons also have inertia, oscillations result. The frequency of these space charge oscillations, or *Langmuir oscillations* (after the American physicist and chemist Irving Langmuir 1881–1957, Nobel Prize in

Chemistry 1932) is called the plasma frequency $\omega_{pe} = \sqrt{4\pi e^2 n_e / m_e}$,

where n_e is the electron density, m_e the mass of the electron, and e is the charge of the electron (in suitable units! This version is in old-fashioned Gaussian units.)

(ii) *Equilibrium; stationary state*. Equilibrium refers to a state where everything is at rest, or not changing, meaning that all forces are in balance. Stationary state refers loosely to a state where the system is changing in some regular way. In fluid dynamics, the term *laminar flow* may be seen as an example.

(iii) *Stability, instability*. Some equilibria or stationary states are *unstable*, which means that some small disturbance of the state grows. We know examples of this from everyday life: e.g. the instability of the inverted pendulum (with stiff support). Everybody has tried to balance an upside-down rake. Another example is waves coming up on the surface of water as a result of wind blowing over it. The latter is an example of an insta-

bility in a system with infinite degrees of freedom. Equilibrium and stability/instability can be defined in purely mathematical terms, within the discipline called *dynamic systems*.

(iv) *Saturation* refers to the ultimate state developed from an instability. We are very far from any general mathematical theory of the “saturation” of an instability. In physics, the principle of conservation of energy gives an overall point of view: Energy delivered *into* the system, feeding the instability, must be *dissipated* by the turbulent process.

(v) *Turbulence*. We shall not put any effort into defining this term, but merely state that one possible (but not the only!) point of view on turbulence could be as the saturation of an instability, provided that this state is complex enough. There are many examples where an instability results in a fairly regular motion; then it is not turbulence.

(vi) *Resonance*. When a system which has an internal mode of oscillation, such as the examples above, is exposed to an external periodic forcing with frequency near the internal frequency of oscillation, we have a situation of resonance. Strong oscillation at the forcing frequency may result. This is, for example, the principle of antennas.

(vii) *Langmuir turbulence*. A system with an electron beam being shot into a plasma, is unstable, and it is Langmuir oscillations which in that case grow up. Therefore, it is called Langmuir turbulence. A saturation theory from the 1960s assumed that Langmuir turbulence is saturated by

(viii) *cascades*, which roughly means that the wave originally growing up, by a resonant process gives rise to new waves at other (lower) frequencies. These waves can in turn cascade to even new waves and so on.

(ix) *Cavitation*. Zakharov [1] demonstrated theoretically that a phenomenon called *collapse* can occur in the Langmuir system. This means that the plasma fields contract to a point (similar to a black hole?). Another, indeed different, phenomenon, is the self cavity resonance. Both of these processes occur in what we call cavitation.

(x) *Parametric instability*. An example is a pendulum for which the point of

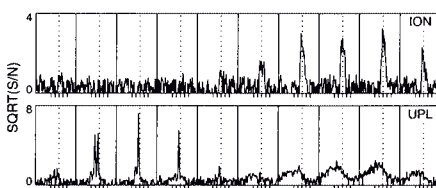


Figure 1. Example of results from experiment on radio-driven Langmuir turbulence in the ionosphere, from [6], using the EISCAT VHF radar and the Heating facility. The vertical lines in each panel separate height bins, where each height bin is 300 m. The data within each height bin are spectra, where the tick marks on the axis represent 5 kHz. The spectra in the lower panel to the left are typical cascade spectra. (“UPL”=“Upshifted Plasma Line”; the spectra are shifts to the radar frequency + the Heating frequency.) Those to the right (both panels) resemble those predicted from cavitation cases. The upper panel is “Ion line”, in those data the frequencies are shifts from the radar frequency.

support makes vertical oscillations. This is a permissible movement (a stationary state), but it turns out to be *unstable* when the frequency is nearly twice the pendulum’s internal frequency, leading to growing pendulum motion. A related example is the swing. Another example is a cup of water (or coffee) oscillating vertically. At certain frequencies, one can see standing concentric water (or coffee) waves in the cup.

(xi) *Radio driven Langmuir turbulence*. It was theoretically predicted in the 1960s that an incident radio wave could drive up Langmuir oscillations by a parametric insta-

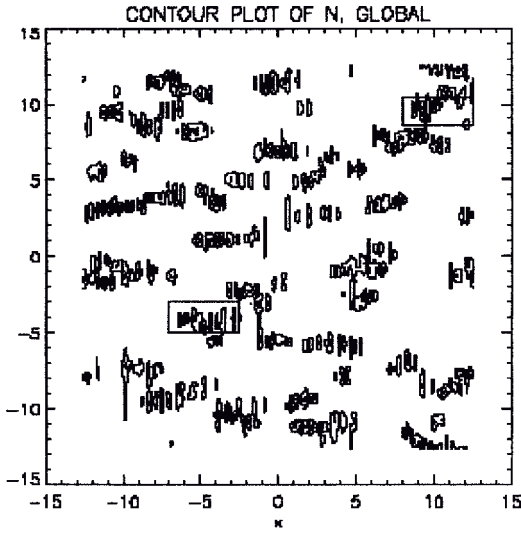


Figure 2. Contour plots of the state at a fixed time for a numerical run of the driven and damped Zakharov model, from [10]. N : dimensionless (relative) plasma density perturbation. Dotted (whole) contours represent positive (negative) values. $\nabla\psi$: electric field of the Langmuir turbulence. The upper part shows the whole numerical cell, while the lower part is magnifications of the regions indicated. The horizontal

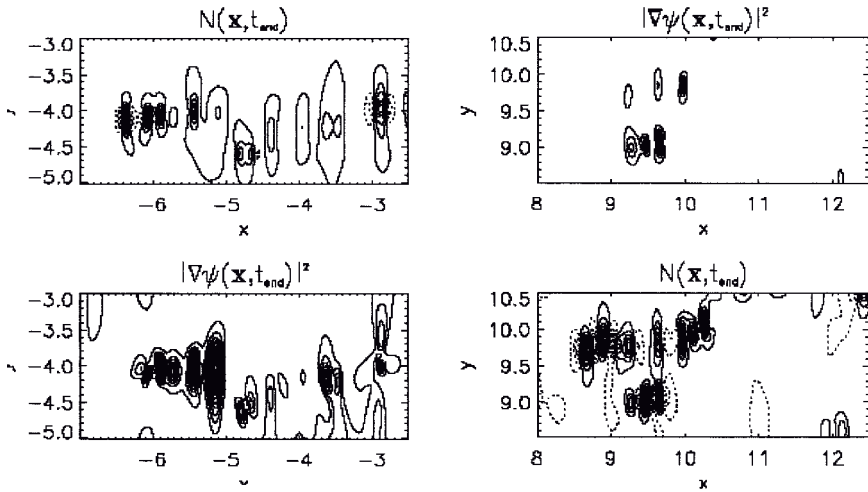
direction is along the ambient magnetic field, and the driving electric field polarization is along the magnetic field. Three features may be noticed: (i) The anisotropy of the cavitations (predicted in Russian works in the 1970s, but to my knowledge not noticed in such a numerical

bility in a plasma. The process takes place near the locus where the plasma frequency is equal to the radio wave frequency. The theory of its saturation resembles the Langmuir turbulence, and this justifies its name.

The experiments

Experiments of the kind described in sect. 1 above at Arecibo [2] around 1970, demonstrated the existence of this parametric instability. Experiments continued in the 1970s and 1980s. A saturation theory based on cascades occurred [3], but was not without problems when compared with experiments. Alternatives based on cavitation and the so-called Zakharov model occurred during the 1980s. In my opinion, the correct picture of this process was described by DuBois and co-workers from 1985 [4] and onwards. Around 1990 there was a state of confusion and controversy. In theoretical work initiated at Tromsø [5], it was demonstrated that cavitation was to be expected in the upper part of the excited plasma volume (or: highest density), while cascade was to be expected further down. But the cascading process is not necessarily observable by the radars. These predictions were demonstrated in some nice experiments at Arecibo [6], and later at Tromsø [7], from which Figure 1 is taken. A particularly nice study at Arecibo was published in [8], and finally we mention the very thorough experimental study [9] from the Tromsø facilities. The paper [10] contains an overview of the theory based on the damped and driven Zakharov model, and a series of 2-dimensional numerical runs of that model. Figure 2 shows one example.

Much of the work using the kind of radar installations that exist at EISCAT and at Arecibo, is “geophysics”. This means that one is interested in what *is there*, and the activity should be described as *observations*. The study described above, differs in many respects from that kind of work. In many ways one *designed* the experiments to test hypotheses. For that purpose, one needed as pure and controlled conditions as possible. Nice “ionospheric weather” (at Arecibo, the experiments were done



context), (ii) the tendency that the cavities come in “streets” along the magnetic field; so far unexplained; and (iii) a tendency of upstew at each side of the cavity along the magnetic field (dotted lines in the n plots); this supports the trapping, and makes the cavitation dynamics more similar to the 1D picture.

during night time); “cold start”, meaning that one turned on the heater for a very short time and then turned it off for a long time, and made many repetitions, in order to secure undisturbed conditions; but most of all: very clever experimental procedures (which we cannot describe in detail here) to obtain simultaneous *height* and *spectral* resolution. For these reasons, this work really deserves the name *plasma experiments*.

References

- [1] V. E. Zakharov, Collapse of Langmuir waves, Sov. Phys. JETP, Engl. Transl., 35, 908–914, 1972.
- [2] H. C. Carlson, W. E. Gordon, and R. L. Showen, High-frequency induced enhancements of the incoherent scatter spectrum at Arecibo, J. Geophys. Res. 77A, 1242–1250, 1972.
- [3] F. W. Perkins, C. Oberman, and E. J. Valeo, Parametric instabilities and ionospheric modifications, J. Geophys. Res. 79A, 1478–1496, 1974.
- [4] G. D. Doolen, D. F. DuBois, and H. A. Rose, Nucleation of cavitons in strong Langmuir turbulence, Phys. Rev. Lett. 54, 804–807, 1985.
- [5] A. Hanssen, E. Mjølhus, D. F. DuBois, and H. A. Rose, Numerical test of the weak turbulence approximation to ionospheric Langmuir turbulence, J. Geophys. Res. 97A, 12073–12091, 1992.
- [6] M. P. Sulzer and J. A. Fejer, Radar spectral observations of HF-induced ionospheric Langmuir turbulence with improved range and time resolution, J. Geophys. Res. 99A, 15035–15050, 1994.
- [7] M. T. Rietveld, B. Isham, H. Kohl, C. LaHoz, and T. Hagfors, Measurements of HF-enhanced plasma and ion lines at EISCAT with high altitude resolution, J. Geophys. Res. 105A, 7429–7439, 2000.
- [8] P. Y. Cheung, M. P. Sulzer, D. F. DuBois, and D. A. Russel, High-power HF-induced Langmuir turbulence in the smooth ionosphere at Arecibo: II. Low duty cycle, altitude-resolved, observations, Phys. Plasmas 8, 802–812, 2001.
- [9] F. T. Djuth, B. Isham, M. T. Rietveld, T. Hagfors, and C. LaHoz, First 100 ms of HF modification at Tromsø, Norway, J. Geophys. Res. 109A, 11307–11331, 2004.
- [10] E. Mjølhus, E. Helmersen, and D. F. DuBois, Geometric aspects of HF driven Langmuir turbulence in the ionosphere, Nonl. Proc. in Geophysics 10, 151–177, 2003.

ADHD – From Basic Research to Therapy

Basic research in psychology usually means the study of the central nervous system and basic brain functions, typically by using animal or computational models. We should not expect it to have instant clinical relevance, as its aim is to understand more about basic mechanisms that, in time, may help us understand more about behaviour and how disorders come about. There seems to be a general opinion that the ultimate causes of behaviour should be looked for in the brain. However, the brain is an organ that *serves* behaviour; it is changed by the individual's interaction with the environment to the same extent as it contributes to those interactions. So, in order to understand how the brain works, we need to under-



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stand behaviour (Catania, 2000). Also, knowledge of basic *behavioural* processes may contribute to bridging the gap between knowledge about brain functions and how individuals function in their environment. Basic behavioural research on Attention-Deficit/Hyperactivity Disorder (ADHD; American Psychiatric Association, 1994) has been shown to be of direct clinical relevance.

Reinforcement and the acquisition of behaviour

Within the lifetime of the individual organism, behaviour is selected by its consequences, much as organisms are selected over generations by evolutionary contingencies (Catania, 2000). The emission of behaviour provides the variations upon which operant selection operates. The most important mechanism in operant selection is reinforcement. A stimulus is acting as a reinforcer when the probability of repeating a response is increased by presenting the stimulus. Reinforcers are imperative during acquisition of behaviour, and they contribute to the maintenance of acquired behaviour.

Skills represent an important category of acquired behaviour. Skills involve units of behaviour and each high level unit (like typing or writing your signature) can be subdivided into lower-level units that involve smaller and more explicitly defined units, until at the lowest level, limbs or muscles are specified (Rhodes, Bullock, Verwey, Averbeck, & Page, 2004). The higher levels are controlled by longer term consequences, and lower levels are controlled by short-term outcomes of individual movements. Thus, as behaviour becomes successively more skilled, smaller units are integrated into larger units, and the consequences for carrying out the sequence are postponed. A unit is defined functionally by what it brings about in terms of behaviour, not by the way specific neurones interact.

Reinforcement as a process operates within a limited time window from the occurrence of the behaviour to the perception of the consequences of this behaviour. Reinforcers' effect on behaviour can be depicted theoretically by the delay of

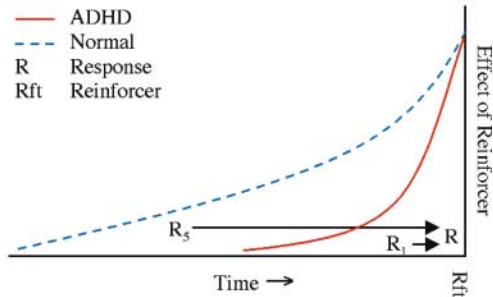


Figure 1. *Theoretical delay-of-reinforcement gradients*

The shorter and steeper delay gradient for ADHD (solid red line) implies that the relation between the response R_5 and R will not be reinforced, while this relation will be reinforced with a normal delay gradient (broken blue line). The relation between R_1 and R is close enough to be reinforced both when the delay gradient is short and when it is normal. A reinforcer will have almost the same effect on responses occurring immediately before reinforcer delivery with both a short and a long delay gradient, increasing the probability of repeating R with almost the same amount irrespective of the shape of the gradient. (Modified after (Sagvolden et al., 2005).

ically by the delay of reinforcement gradient (Figure 1). A reinforcer not only affects the response that produced it, it may also affect prior behaviour, although to a lesser degree. In addition, the relation between responses may be reinforced, as when a rhythm in button presses leads to the delivery of a reinforcer, the same rhythm tends to be repeated. With a normal delay gradient, lots of different time relations between responses may be reinforced.

Additionally, it will be easy to establish the relation between a stimulus that signals that a certain behaviour will be reinforced, the actual behaviour, and the reinforcer.

Reinforcement mechanisms in ADHD

ADHD is a disorder characterized by developmentally inappropriate levels of hyperactivity, impulsivity, and inattention. Impulsivity is increasingly seen as the main symptom, leading to inattention, hyperactivity, and increased variability of all behaviour.

ADHD may be a consequence of altered reinforcement mechanisms (Sagvolden, Johansen, Aase, & Russell, 2005). Altered reinforcement processes in ADHD can be described as a narrower time window than normal for associating behaviour with its consequences, or theoretically by a shorter and steeper delay gradient (Figure 1). This means that in ADHD, a reinforcer will affect rather few responses, only short time relations between responses will be selected, and a stimulus signalling what behaviour will be appropriate in a given situation will not work as discriminative stimulus if its onset is outside the reach of the delay gradient. In addition to resulting in increased variability in behaviour, reduced sustained attention, and hyperactivity, this implies that the establishment of behavioural units and the integration of units into longer sequences will be hampered. Thus, the ADHD behaviour will be characterized by short, disorganized, and undirected sequences of behaviour, or behaviour frequently characterized as impulsive.

Normally, impulsiveness will decrease with age (Panzer & Viljoen, 2005), as behaviour develops into increasingly larger units, behavioural

sequences with more and more distal consequences. During practice, response time is normally reduced and responding is chunked into larger units that reinforcers will work on (Domenger & Schwarting, 2005). This process will be slowed in ADHD, may never catch up with normal development, and the behaviour may be characterized as immature.

Investigating learning and behavioural sequences in children with ADHD

Although self-control and the organization of behaviour over time have been described as the major problem of ADHD (Barkley, 1997), few studies have focused on the ordering and predictability of behaviour in ADHD. There are indications that development of functional units of behaviour, or performance of integrated behavioural sequences, is hampered in children with ADHD when the task gets increasingly complicated or demands higher-level processing (Sheppard, Bradshaw, Georgiou, Bradshaw, & Lee, 2000; Kalff et al., 2003; Siklos & Kerns, 2004).

Only one study has directly investigated acquisition of response sequences in the behaviour of children with and without ADHD (Aase & Sagvolden, 2005b). Here, the children completed a computerized task presented as a game with two squares on the screen, where mouse clicks on one of the squares resulted in a reinforcer. Reinforcers were cartoon pictures and small trinkets that were delivered after unpredictable time intervals contingent on responses. The spatial and temporal behavioural dimensions were analyzed by autocorrelating consecutive responses across five response lags. Acquired response sequences will then show up as predictable

responding, where a substantial amount of variance was explained. In addition, the degree of learning was defined as the percentage of all responses that were correct (placed in the square associated with reinforcement).

As predicted, the results showed that children with ADHD developed significantly shorter sequences of responses compared

to children without ADHD on the spatial response dimensions. Figure 2 shows to what degree a response on one (of two) sides predicted the placement of the next response, the response after that one, and so on up to the sixth response in a sequence. The children without ADHD developed predictable response sequences of up to six responses in a row, while only

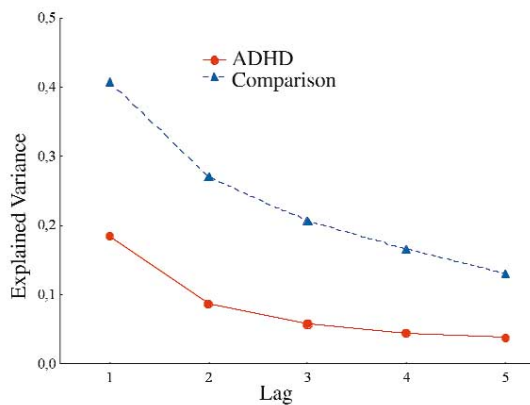


Figure 2. Predictability of responding according to side of the screen

Predictability of on which side of the screen consecutive responses were placed is depicted as mean explained variance (autocorrelations squared) from one response to the next ($n+1$, first lag) up to the sixth response ($n+5$, fifth lag). The graphs show means of the performance of the ADHD group and the comparison group across all segments (Aase et al., 2005b).

two responses in a sequence could be predicted in children with ADHD. In addition, children with ADHD showed problems in learning the task; they performed marginally above chance level (Figure 3).

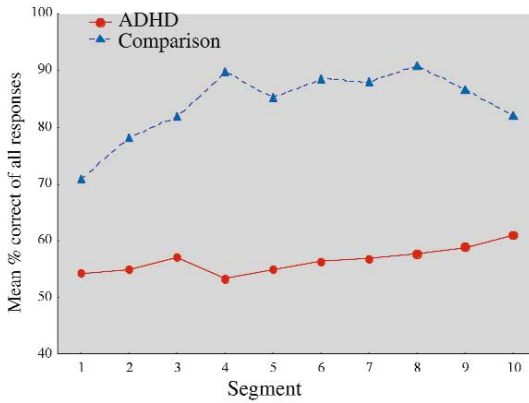


Figure 3. Mean percent of all responses allocated to correct square

Mean % correct responses for each group is depicted as means per segment (1 – 10) as a learning curve (Aase & Sagvolden, 2005a).

The findings suggest that children with ADHD have problems in learning long sequences of behaviour, particularly related to response location. Problems in learning long behavioural sequences may ultimately lead to deficient development of verbally governed (rule-governed) behaviour and self

control. The study represents a new approach to analyzing the moment-to-moment dynamics of behaviour, and provides support for the theory that reinforcement processes are altered in ADHD (Sagvolden et al., 2005).

Implications for basic research

Acquisition of behavioural sequences may be related to habit learning, characterized by a transition from response-consequence associations that are flexible and sensitive to reinforcement devaluation, to stimulus-response associations that are less flexible and sensitive (e.g., Yin, Knowlton, & Balleine, 2004). These processes seem to involve separate brain areas (Lehericy et al., 2005). We think that our way of analyzing the dynamics of behaviour may be used during brain imaging in order to investigate which are the brain areas that show deviant activity in ADHD. The dynamic developmental theory of ADHD suggests that both the mesolimbic dopamine branch, involved in reinforcement and learning, and the nigrostriatal dopamine branch, involved in habit formation and motor control, may be dysfunctioning in ADHD (Sagvolden et al., 2005).

Clinical implications of hampered learning of behavioural sequences in ADHD

So – by analyzing behaviour on a very fine-grained level, we hope to find out which are the behavioural mechanisms that are the basis for a development that may include increasing problems and problem complexity in daily life. By a dynamic analysis of the details in behaviour, we hope to identify how a learning style characterized by acquisition of only very short units of behaviour may generalize into behavioural patterns described as disruptive behaviour, learning problems, and poor social skills.

The identification of micro-dynamic changes in the behaviour of children with ADHD may ultimately lead to the development of better assessment tools and early identification of dysfunctions. Better diagnostic tests may be used across age groups and in cultures completely different from Western ones. These improvements will in turn both provide opportunities for early intervention, and a basis for the development of improved medical and behavioural intervention programs.

References

- Aase, H. & Sagvolden, T. (2005a). Infrequent, but not frequent, reinforcers produce more variable responding and deficient sustained attention in young children with attention-deficit/hyperactivity disorder (ADHD). *Journal of Child Psychology and Psychiatry*, 0.
- Aase, H. & Sagvolden, T. (2005b). Moment-to-Moment Dynamics of ADHD Behaviour. *Behavior and Brain Functions*, 1, 12.
- American Psychiatric Association (1994). *Diagnostic and statistical manual of mental disorders: DSM-IV*. (4 ed.) Washington, D.C.: Author.
- Barkley, R. A. (1997). Behavioral inhibition, sustained attention, and executive functions: constructing a unifying theory of ADHD. *Psychological Bulletin*, 121, 65–94.
- Catania, A. C. (2000). From behavior to brain and back again. *HyperPSYCOLOGY* 11(027) [On-line].
- Domenger, D. & Schwarting, R. K. (2005). Sequential behavior in the rat: a new model using food-reinforced instrumental behavior. *Behavioural Brain Research*, 160, 197–207.
- Kalff, A. C., de Sonnevile, L. M., Hurks, P. P., Hendriksen, J. G., Kroes, M., Feron, F. J. et al. (2003). Low- and high-level controlled processing in executive motor control tasks in 5–6-year-old children at risk of ADHD. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, 44, 1049–1057.
- Lehericy, S., Benali, H., Van de Moortele, P. F., Pelegriani-Issac, M., Waechter, T., Ugurbil, K. et al. (2005). Distinct basal ganglia territories are engaged in early and advanced motor sequence learning. *Proceedings of the National Academy of Sciences of the USA (PNAS)*.
- Panzer, A. & Viljoen, M. (2005). Supportive neurodevelopmental evidence for ADHD as a developmental disorder. *Medical Hypotheses*, 64, 755–758.
- Rhodes, B. J., Bullock, D., Verwey, W. B., Averbeck, B. B., & Page, M. P. (2004). Learning and production of movement sequences: behavioral, neurophysiological, and modeling perspectives. *Human Movement Science*, 23, 699–746.
- Sagvolden, T., Johansen, E. B., Aase, H., & Russell, V. A. (2005). A dynamic developmental theory of Attention-Deficit/Hyperactivity Disorder (ADHD) predominantly hyperactive/impulsive and combined subtypes. *Behavioral and Brain Sciences*, In press <http://www.bbsonline.org/Preprints/Sagvolden-05152002/>.
- Sheppard, D. M., Bradshaw, J. L., Georgiou, N., Bradshaw, J. A., & Lee, P. (2000). Movement sequencing in children with Tourette's syndrome and attention deficit hyperactivity disorder. *Movement Disorders*, 15, 1184–1193.
- Siklos, S. & Kerns, K. A. (2004). Assessing multitasking in children with ADHD using a modified Six Elements Test. *Archives of Clinical Neuropsychology*, 19, 347–361.
- Yin, H. H., Knowlton, B. J., & Balleine, B. W. (2004). Lesions of dorsolateral striatum preserve outcome expectancy but disrupt habit formation in instrumental learning. *European Journal of Neuroscience*, 19, 181–189.

Using Plasma Turbulence to understand the Global Impact of Billions of Daily Meteors

Every day billions of meteoroids impact and disintegrate in the Earth's atmosphere. Current estimates for this global meteor flux vary from 2000–200,000 tons per year, and estimates for the average velocity range between 10 km/s to 70 km/s [Cziczo *et al.*, 2001; Janches *et al.*, 2000; Taylor, 1995; Ceplecha *et al.*, 1998; Mathews *et al.*, 2001]. Understanding this meteor flux is important for several fields of study from solar system evolution, upper atmospheric physics to manned and unmanned space flight. Yet, the basic properties of this global meteor flux, such as the average mass, velocity, and chemical composition remain poorly understood [Mathews *et al.*, 2001]. The research outlined in this report aims to improve our understanding of these meteors, by improving our capabilities to observe and interpret observations of these small (sand grain and dust size) meteor impacts. We begin with a brief description of the physical processes of interest to provide a context for the reader.

For decades, meteor observations were typically made with photographic and TV cameras and small meteor radars, and much was learned about the continuous impact of meteors ranging in size from sand grains to large boulder sized meteoroids. Yet, over the past decade, large radars such as the European Incoherent Scatter (EISCAT) Radar and the Arecibo Observatory in Puerto Rico have been pointed towards the sky to measure meteor impacts. These radars have observed two types of radar meteor reflections that have become known and now widely studied. These reflections are known as meteor head echoes and non-specular trails. An example of these types of observations is shown in Figure 1. This figure shows a meteor head echo followed by trail reflections, called non-specular trails. While the head echo is believed to be a cloud of electrons moving at the speed of the meteoroid, the non-specular trail echoes result from radio scatter from plasma turbulence. Both of these reflections occur to plasma phenomena and turbulence, and to understand them and what they are telling us, we need to understand the plasma turbulence occurring during reflection. Additionally, because these observations produce such detailed signatures, they show great promise as tools for deriving more complex parameters about meteoroids and the atmosphere they interact with. Already, it has become clear that these reflections largely result from the very frequent impact of small dust sized meteors,

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that were too small for conventional observation. For example the Arecibo radar observes a region of sky approximately 300 meters in diameter, and in the morning counts over 2000 meteors per hour [Dyrud et al., 2005; Janches et al., 2000].

Our current understanding of the physical processes occurring during the early stages of a small meteor atmospheric entry remains somewhat anecdotal and can be summarized as follows. As a meteor enters the Earth's atmosphere near 100 km altitude, the particle heats up and atoms begin boiling off the surface in a process known as ablation.

Depending on energy, the ablated meteor atoms are ionized (freeing an electron from the atom, producing a positively charged ion and negatively charged electron) upon collision with an air molecule. These newly produced meteor ions cool after approximately 10 collisions, which takes between a fraction of a millisecond at 80 km and as long as one millisecond at 110 km [Jones, 1995]. During this thermalization process, the plasma density near the meteoroid could be very high, allowing for the scattering radar reflections. In order to understand the large radar observations of this stage the researchers at CAS have developed a computer simulation, the results of which are shown in Figure 2. This figure plots the density of plasma (gas composed of ions and electrons) as a function of distance from the mete-

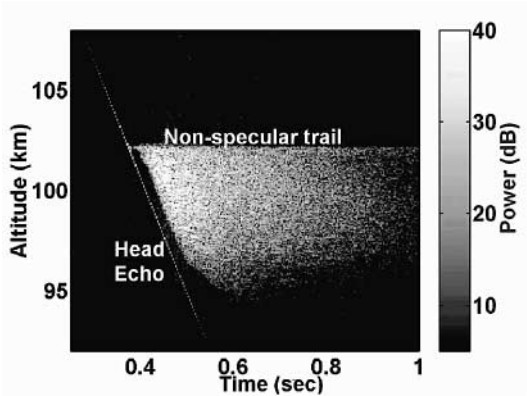
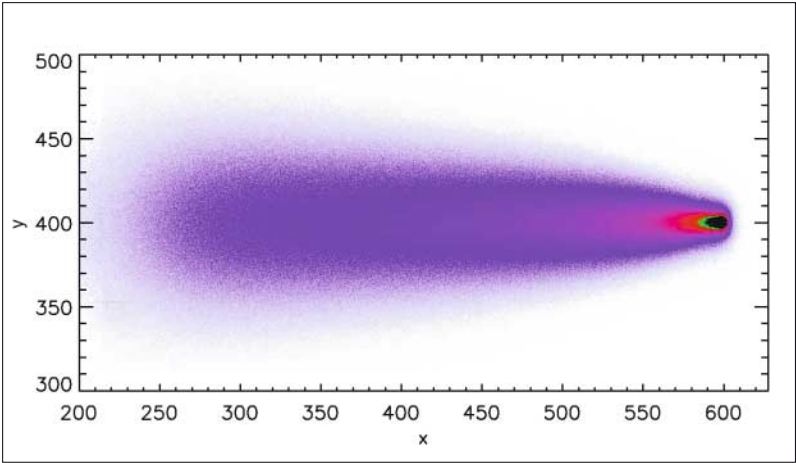


Figure 1. Altitude-time-intensity image of a head and subsequent non-specular echoes over extended range from ALTAIR VHF Radar. The diagonal line to the left is called a head echo, while the echoes spread in range and time to the right are the non-specular trail. Figure reproduced from Close et al. [2002].

Figure 2. Results from a meteor plasma simulation. This figure shows the color representation of the plasma density surrounding a meteor. The meteor simulated here was producing 10^{12} ions per meter traveled, and was moving against the surrounding atmosphere at a rate of 40 km/s.



oroid body. The meteoroid in this simulation was traversing to the right at a velocity 40 km/s. This work shows that the meteor generated plasma should be observable with a large radar, but that care must be taken when interpreting the results. We expect simulations such as these to greatly enhance our capabilities to interpret the radar reflections from meteors, and assess their speed and size with improved accuracy.

The evolution of a meteor trail continues in the following manner, and the effects of plasma turbulence become all the more obvious. Once the meteor plasma has cooled, the result is a large trail or column of enhanced ionization near 100 km altitude, which may extend between 10 and 20 km in length. Our understanding of next stages of evolution result directly from super computer simulations of plasma instability and turbulence within meteor trails published in [Dyrud *et al.*, 2005; Dyrud *et al.*, 2002, 2001]. These stages can be described by best with reference to these simulations, and example of which is shown in Figure 3. This figure shows

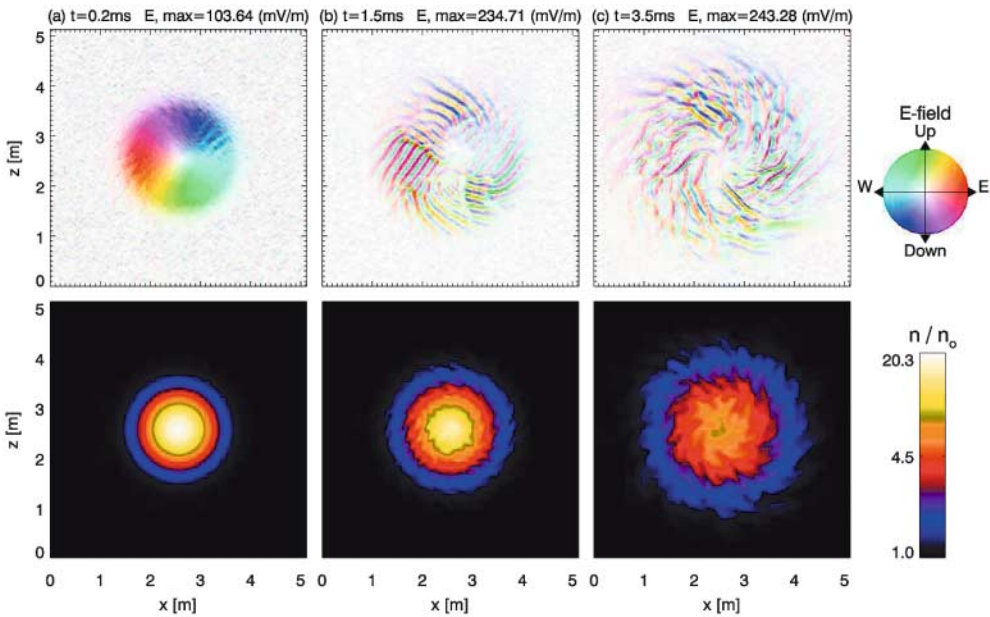


Figure 3. Simulation of a meteor trail electric field, E(top panels) and density ratio of the trail plasma to the background ionospheric density, (bottom panels) at three different times.

a cross-section of meteor trail plasma and the electric fields that develop within the trail. The simulation shows that the meteor plasma is highly unstable to the development of waves shown in the second column of panels. These waves are a cousin of naturally occurring waves in the ionosphere near the aurora [Farley and Balsley, 1973]. The third column shows that these waves become turbulent, generating a flower-like pattern in the density. It is this turbulent structuring that is highly reflective to radars, and accounts for the observations shown Figure 1.

Further modeling, the details of which are beyond the scope of this report, has shown that the development of turbulence upon meteor trails is highly dependent on the specific conditions of the meteor trail. This is allowing researchers to use these large radar observations of meteors to derive a tremendous amount of information about the meteor that generated the trail and the atmosphere where the trail resides. Work continues,

but we are already using plasma turbulence theory combined with observations to calculate meteor velocities, masses and estimates of composition. As these data become refined, new estimates for the source size and speed of the this global meteor flux should be dramatically improved.

References

- Cepilecha, Z., J. Borovicka, W. G. Elford, D. O. Revelle, R. L. Hawkes, V. Porubcan, and M. Simek, Meteor phenomena and bodies, *Space Science Reviews*, 84, 327–471, 1998.
- Close, S., M. Oppenheim, S. Hunt, and L. Dyrud, Scattering characteristics of high-resolution meteor head echoes detected at multiple frequencies, *Journal of Geophysical Research (Space Physics)*, 107, 9–1, 2002.
- Cziczo, D. J., D. S. Thomson, and D. M. Murphy, Ablation, flux, and atmospheric implications of meteors inferred from stratospheric aerosol, *Science*, 291, 1772–1775, 2001.
- Dyrud, L. P., M. M. Oppenheim, and A. F. vom Endt, The anomalous diffusion of meteor trails, *Geophysical Research Letters*, 28, 2775–2778, 2001.
- Dyrud, L. P., M. M. Oppenheim, and A. F. vom Endt, Interpretation of nonspecular radar meteor trails, *Geophysical Research Letters*, 29, 2002.
- Dyrud, L. P., L. Ray, M. Oppenheim, S. Close, and K. Denney, Modelling highpower large-aperture radar meteor trails, *Journal of Atmospheric and Terrestrial Physics*, In Press, 2005.
- Farley, D. T., and B. B. Balsley, Instabilities in the equatorial electrojet, *Journal of Geophysical Research*, 78, 227, 1973.
- Janches, D., J. D. Mathews, D. D. Meisel, and Q.-H. Zhou, Micrometeor Observations Using the Arecibo 430 MHz Radar, *Icarus*, 145, 53–63, 2000.
- Jones, W., Theory of the initial radius of meteor trains, *Monthly Notices to The Royal Astronomical Society*, 275, 812–818, 1995.
- Mathews, J. D., D. Janches, D. D. Meisel, and Q.-H. Zhou, The micrometeoroid mass flux into the upper atmosphere: Arecibo results and a comparison with prior estimates, *Geophysical Research Letters*, 28, 1929, 2001.
- Taylor, A. D., The Harvard Radio Meteor Project velocity distribution reappraised., *Icarus*, 116, 154–158, 1995.

Establishing and Maintaining Morpheme Order

Words are composed of meaningful parts that linguists call **morphemes**. For example, *cat-s* contains two morphemes – one meaning something like ‘feline’ and the other ‘plural’; *cantaloup* contains only one morpheme. Thus the notion of morpheme has nothing to do with length.

Some languages have words that contain many morphemes; a short example from the language Abxaz is given in (1), where hyphens separate morphemes. The first morpheme tells us that the subject is second person (‘you’) and masculine, the second that the object is third person neuter (‘it’), and the third that the base meaning is ‘read’.

- (1) *w-a-px~oɟʔ*Abkhaz
2M.SU-3N.OBJ-read
‘you (masculine) are reading it’

Specific kinds of morphemes most often occur in certain positions relative to others. These may be thought of as their universally preferred or expected positions, as indicated in Table 1, where SU represents the person and number of the subject, OBJ the person and number of the (indirect or direct) object, TNS the tense, ASP the aspect, and DERIV derivational morphemes. (The meaning of the latter is discussed below.)

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SU	OBJ	MOOD	TNS	ASP	DERIV	ROOT	DERIV	ASP	TNS	MOOD	OBJ	SU
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Table 1. Universally preferred linear order of morphemes in the verb.

We notice immediately that the morphemes in Table 1 are in mirror-image linear order on either side of the root, and that some morphemes are usually “inside” or “outside” certain others. The suffix *-en* is an example of a derivational morpheme, which builds a new word, and Table 2 shows how the parts of the word *dark-en-s* fit with the order of Table 1.

						dark	en					s
SU	OBJ	MOOD	TNS	ASP	DERIV	ROOT	DERIV	ASP	TNS	MOOD	OBJ	SU

Table 2. Example of linear order of morphemes in the verb in English

Table 3 gives the preferred universal order for nouns and pronouns, but not in mirror-image; and Table 4 shows how the morphemes of the word *comput-ation-s* fit this order.

ROOT	DERIV	NUMBER	CASE
------	-------	--------	------

Table 3. Preferred order in the noun or pronoun

compute	ation	s	
ROOT	DERIV	NUMBER	CASE

Table 4. Example of order in the noun in English

Tables 1 and 3 raise various questions: Why are morphemes (usually) in these orders, instead of some other orders? How do morphemes get into these orders historically? Given that all languages are constantly changing, how do languages maintain the preferred orders?

The answer to the first question is, at least in part, that morphemes are in this order because it represents semantic scope. If one part of a word is within the semantic scope of another, the meaning of the latter applies to the former. Thus, the order of elements in *((dark)en)s* indicates iconically that the final *-s*, which means a third person singular subject, applies not just to *-en*, and not just to *dark*, but to the whole of *dark-en*. Similarly the final *-s* in *((comput)ation)s*, which means now plural, applies not just to part of what precedes it, but to the whole, *computation*.

However, it is the other questions above that appeal especially to a historical linguist. Complex words are built up historically, step by step, usually one morpheme at a time. It has been hypothesized that the order of morphemes reflects the order in which they are added. While there is certainly some truth in this, it does not seem to be the whole story.

Sometimes, though rarely, morphemes change their position after they have been added to a word. Usually this kind of change puts them more in line with the ideal in Table 1. An example is given in (2). The examples are from Georgian, spoken in the Republic of Georgia. When the former word *me* meaning ‘indefinite’ was added to the word for ‘what’ it became a derivational morpheme and was not in the preferred position indicated in Table 3. The change in order shown in (2b) brought it in line with Table 3, as shown in Table 5.

- (2)

(a)

ra-s'me

what-DAT'INDEF

ROOT-CASE'DERIV

'something'

(b)

ra-me-s

what-INDEF-DAT

ROOT-DERIV-CASE

'something'

Old Georgian

Modern Georgian

ra	me		s
ROOT	DERIV	NUMBER	CASE

Table 5. Preferred order established in Modern Georgian

A second way languages maintain morpheme order even through a variety of kinds of change is by assigning a new function to a morpheme in keeping with its order. An example of this comes from Laz, a language

related to Georgian. (The examples on the left have asterisks to indicate, as is conventional, that the forms are reconstructed, that is, inferred or hypothetical.) In the older, inherited pattern, which we can be relatively sure of because of the structure of nouns in its sister languages, several suffixes began with *i*. On this basis, speakers began to use *i* before all suffixes in the singular, so that, in effect its function changed. It became a marker of the singular number. This is summarized as the change from the system in Table 6 to that in Table 7.

(3)

	(a) Inherited pattern		(b) Attested pattern		
Nom	*k'oč-i	*k'oč-ep-i	k'oč-i	k'oč-epe	'man'
Nar	*k'oč-k	*k'oč-ep-k	k'oč-i-k	k'oč-epe-k	
Dat	*k'oč-s	*k'oč-ep-s	k'oč-i-s	k'oč-epe-s	
Gen	*k'oč-iš(i)	*k'oč-ep-iš(i)	k'oč-i-š(i)	k'oč-epe-š(i)	
All	*k'oč-iša	*k'oč-ep-iša	k'oč-i-ša	k'oč-epe-ša	
Abl	*k'oč-iše(n)	*k'oč-ep-iše(n)	k'oč-i-še(n)	k'oč-epe-še(n)	
Inst	*k'oč-it	*k'oč-ep-it	k'oč-i-te	k'oč-epe-te	

k'oč			i
ROOT	DERIV	NUMBER	CASE

Table 6. Morpheme order in nominative case, inherited pattern

k'oč		i	ø
ROOT	DERIV	NUMBER	CASE

Table 7. Morpheme order in nominative case, attested pattern

A third way of maintaining preferred morpheme order is through loss of a trapped morpheme. The example here is again taken from Georgian, and it illustrates the common change of an auxiliary becoming part of a main verb. In eighth century (and earlier) Georgian the first person subject form of the intransitive pluperfect had the form (for example) *damalul v̑iq'av* 'I had hidden', where *damalul* corresponds to 'hidden', and *v̑iq'av* is the past tense of the auxiliary 'be'. The underlined *v* in *v̑iq'av* indicates that the subject is first person singular, 'I'. The first person subject marker is always a prefix this way in the verb, though it is not always the first prefix. The problem arises when the two words merge into one, **damalulv̑iq'av*, maintaining the same meaning. Here *v* is not in its accustomed place, at or near the beginning of the verb. The solution that speakers found was to remove it from its earlier position and insert it near the beginning of the word, in keeping with other verb forms in Georgian: *daṽmaluliq'av(i)*. (The final *i* is an irrelevant addition that happened about the same time.) Although this appears to be movement, evidence from other examples suggests that it is rather loss in one position and insertion in the other.

Thus, we find that languages have at least three ways of establishing and maintaining something close to the universally preferred orders shown in Tables 1 and 3. As we saw in example (2), languages occasionally move a morpheme, changing its order relative to others. They may assign

Establishing and Maintaining Morpheme Order

a new function to part of a word, in keeping with its position in the word, as illustrated in (3). A morpheme that occurs in a position not in keeping with the preferred orders of Tables 1 and 3 may be lost, as we saw in the Georgian pluperfect.

Working on Language Change by using Historical Corpora: Problems and Methods

Linguists working on language change work in many different ways and on very different material bases. Some are working on languages which have been attested for a long period of their history, others work on languages which are oral, and have never been recorded, implying that earlier stages of these languages can only be reconstructed. In still other cases, only modern periods of the language have been attested.

I am working on Romance languages, in particular on French. These languages are all very well attested, as we have written texts covering more than two thousand years. One might think that it is easier to work on attested languages than to do reconstruction and this may be true, but in a way it is easier to reconstruct hypothetical stages than to work on heterogeneous data – and heterogeneous data are indeed what you find when working on what we call “text languages”, i.e. languages that we can only grasp through written texts. In the following, I will first present the heterogeneity of historical corpora, i.e. collection of historical texts, and problems about hypothesis-testing on these corpora.

We know that copyists of the Middle Ages were working on one or more original (as seen in the illustration taken from a manuscript).

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Let us just consider the simple case of one copyist working on one original and copying for a public speaking his own dialect. The text of the original may be written in a dialect that is identical to or different from the copyist's dialect and it may have been written recently or it may be old. If the text was written recently in the same dialect or in a very close variety, the copyist has an easy task of transmission. But if, on the other hand, the text of the original is written in a different dialect, or stems from an earlier stage of the same dialect, the copyist will have to decide whether he is going to modify his text or not, as these texts are normally in rhymed verse.

He may decide to copy the text as accurately as possible – and in that case he is a so-called “mirror-copyist”. Or he may decide to adapt his original to his own dialect or to the dialect of whoever has ordered the copy. In the case of adaptation, the copyist will have predictable problems stemming first and foremost from the fact that dialects have different vowel developments of the same word. Another source of adaptation may be special wishes from the person who has ordered the copy to be made. We know of cases where the future owner wants references to be inserted on the noble origin of his family, for example or more importance shown to courtly love, to religion, etc. But let me exemplify the case of adaptation due to language change.

If the language of the copyist has undergone vowel change, the copyist may decide to respect the original verse-final rhyme by replacing the unfamiliar dialect form of a given word by a regular form in his dialect which fits into the assonance or the rhyme. This can often be done without seriously affecting the sense of the passage, but in other cases we can see that the text has been seriously modified. Consider a simple case of well known vowel change from [o] to [u], spelled *ou*, and further to [ø], spelled *eu*, which took place in French during the 13th century. If we take an Old French text from the 12th century, e.g. *Charroi de Nîmes*, its manuscripts are all later, and they show that the vowel change is well on its way. Some copyists just discard the original rhyme by adapting the original unfamiliar form to the corresponding normal form of their dialects, this holds for the copyist of A1, A2, A3, A4, and C, adopting a spelling that reveals the [u] or the [ø] pronunciation of the word ‘neck’ that was originally *gole*, pronounced with an [o]. But the copyists of B1 and B2 respect the original verse-final rhyme by replacing the original word by another word, having the same vowel, meaning a piece of clothing. Such an adaptation might seem innocent, but if you want to study e.g. the system of punishment in medieval times, it makes quite a difference to have a death sentence or to have your clothes damaged!

Charroi de Nîmes verse 963, O / U / Ø assonance

ms. A1 *perdi les eulz et pendi par la **goule*** [u]

'His eyes were torn out and [he] was hung by his neck'

ms. A2 *perdi les eulz et pendi par la **goule*** [u]

ms. A3 *perdi les eulz et pendi par la **goule*** [u]

ms. A4 *perdi les euz et pendi par la **gueule*** [ø]

ms. F lacuna

ms. B1 *batus en fu, deschirée ot sa **gonne*** [o]

'[He] was hit and his clothes were damaged'

ms. B2 *batu en fu, s'ot desciré sa **gonne*** [o]

ms. C *les iels perdi et pendi par la **goule*** [u]

ms. D lacuna

Now, considering that the transmission of texts is either mirror copying or adaptation of different stages of different dialects, the language of the extant manuscript will probably come out as a chronological and dialectal mixture of features. The traditional policy of edition has followed two well known main directions : either to look for the original, by means of the method of the common error (Lachmann) or to publish one single manuscript, as it is supposed impossible to reconstruct the original (Bédier). I want to call attention to the fact that for most literary vernacular texts, both editorial policies (and especially the first one) are wrong, as they do not provide the scholar with the relevant material basis. What the scholar needs is a trustworthy version of the text tradition she or he wants to study. A Lachmanian critical edition is a construct, something that never existed. It is based on the wrong assumption, typical of the nineteenth century, that a copy is a deterioration of a (perfect) original that needs to be repaired. In bad cases the result is a fictitious text, a result of emendations and regularisations. Even Bédierien editions often correct texts, in order to provide homogeneity. But heterogeneity is inherent in Old French texts. In sum, text languages, i.e. written texts reflecting older stages of languages, are heterogeneous for two reasons: firstly because of the text transmission itself, and secondly because of the absence of a language norm.

Traditional philology from the 19th century and in the early 20th century based its editorial policy on a different, a romantic conception of the author, and they accordingly modified the texts that they published, many of which are still used in teaching and for research. This illustrates in an interesting way, I think, of how our material basis can be altered on the basis of previous scientific theories that we now believe to be wrong.

Let me briefly illustrate the difference it makes to a scholar to work on the basis of manuscripts instead of a traditional critical edition. In my study of the case system of Old French, I made two parallel studies of the declension of proper nouns in *Le Charroi de Nîmes*, one according to a critical edition and another according to the manuscripts. The study based on the edition showed that the declension system was well preserved, 82,7 % of all proper names having the expected nominative form in the functions of subject, subject predicate, apposition etc. with the exception of a few names that were mostly used in the accusative form. The study based on manuscripts showed a quite different pattern. Firstly, proper names tend to be abbreviated in a form without declension markers. Secondly, proper names of *Le Charroi* divide themselves into three

types: (1) those that are almost never spelled out and which are consequently without declension, (2) those that sometimes are found spelled out and that have a tendency to be in a fixed case, irrespective of their function, and (3) those – in fact only five proper names – that sometimes are found spelled out and that have a genuine case marking when spelled out. Let me add that this is only one case among many others where problems arise from choosing editions as the basis of research. Similar problems arise each time a hypothesis is tested on historical data. Things being like this, how can we proceed in research on text languages? We have to choose between two possibilities: either to work exclusively on manuscripts – which would of course be the best thing, but it is not possible, as mss are not immediately available, and certainly not in electronic format, or to work on editions – well knowing their weaknesses – and consulting mss whenever possible. Moreover, we must constantly bear in mind that text languages are of an inherent heterogeneous nature, due to the absence of a standard and due to the particular transmission of these texts. This implies that it is difficult to describe these languages and in particular it is difficult to test non-trivial hypotheses concerning these languages. There is simply too much noise! If you just look for an isolated form or construction, you can find almost everything. It is very important to have accurate documentation and accurate description for each type of variation i.e. for each diasystem.

What I propose is to combine micro- and macro investigations and in particular to draw upon the results of modern corpus linguistics and variational linguistics concerning e.g. medium, register, text type, social variation, and other sources of variation, when we test hypothesis concerning language change. This implies that we should propose hypotheses for e.g. language change in such a way that they can be appropriately tested on a well defined sub-corpus, in order to avoid irrelevant variation. The difficult task, then, is of course to identify the relevant parameters for testing – but this is a task common to all branches of science.

References

- Schösler, L. “Historical corpora. Problems and methods”. *Linguistica computazionale XX-XXI, Digital technology and philological disciplines* pp. 455–472. Andrea Bozzi, Laura Cignoni, Jean-Louis Lebrave (eds.). Istituti editoriale e poligrafici internazionali, Pisa, Roma 2004.
- Schösler, L. “Scribal variations: When are they genealogically relevant – and when are they to be considered as instances of ‘mouvance’?” *Studies in Stemmatology* 2 pp. 207–226.
- Pieter van Reenen, August den Hollander & Margot van Mulken, with the assistance of Annelies Roeleveld (eds.). John Benjamins Publishing Company, Amsterdam/Philadelphia 2004.

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Brain Maturation – It covers three decades: Considerations of the Development of ADHD

As children grow, parents and teachers alike wonder at the skills the young develop – physical and cognitive abilities alike. By the age of 5 years the child's brain is packed with far more neurons (grey matter) that make far more connections than in the adult brain. Over the next 10 years these walking, talking interactive wonders must then cope with conflicting stimuli and signs from the events around them. They must learn, fast and well. They must also be capable of switching and maintaining attention, able to plan behaviour, develop goals, construct, hold and recall concepts – put them in to effect and be able to communicate about them.

Is it really not surprising that the hugely complex biology underlying this development sometimes takes an inefficient course? Delays may occur and inappropriate connections be made. Precisely over this long haul from the first to the second decade of

life the process of reducing grey matter for efficiency and establishing the right pattern of neuronal connections can take an anomalous course. One such case gives rise to the neurodevelopmental condition known as attention-deficit/hyperactivity disorder (ADHD). Here, the maturation of those abilities I have listed above follows a different course from 5 to 15 years of age – and we are now in a position to show that this developmental course in the biological bases for behaviour and what may go wrong with it, may even go on quite some time after the age of 25 years.

We can illustrate this by taking a biological marker of a fundamental cognitive ability, – that of detecting a deviant sound in a series of otherwise similar auditory stimuli. A recording of electrical brain activity from the skull (electroencephalogram, EEG) after a few hundred tones – when averaged with respect to the sound's onset – shows a distinctive negative-going, excitatory event-related potential (the ERP). A subtraction of the ERP following a common repeated standard tone from that after a rare, perhaps deeper deviant sound gives us the mismatch negativity (MMN). We all develop deviance detection as infants: it is automatic and occurs without the need to consciously listen. But, note that if this early stage of information processing goes wrong, one can hardly expect successive 'higher' abilities that build on it to be accurate.

There is no need to worry. Children with ADHD develop a similar and a normally sized MMN as rapidly as those without ADHD. Curiously, if we record from an array of sites over the skull of 10 year-olds, we note from the topography that this ability develops first over the right

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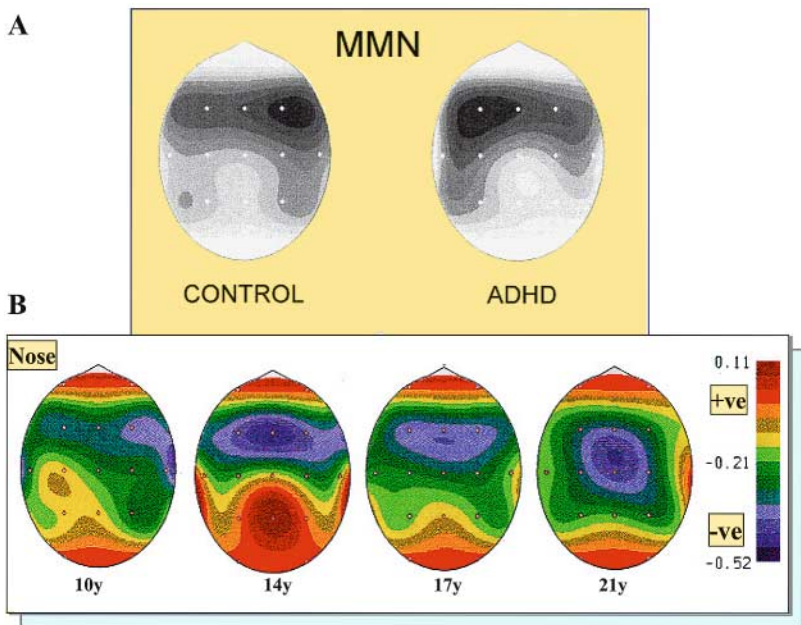


Figure 1. Both parts A and B show the topographical distribution of negative potentials (MMN) representing the detection of deviant sounds on a model of the skull with the nose pointing up the diagram. Part A shows normal right hemispheric development in 10 year-old children side by side with anomalous left hemisphere development in 10 year-old children with ADHD (Oades et al., 1996). Part B shows the normal development of MMN topography (blue colour) over the skull for groups of 10, 14, 17 and 21 year-olds (Oades et al., 1997). Bilateral representations typical of young adults are achieved post-pubertally, and their latencies mature at about 17 years of age (not shown).

hemisphere, before it becomes bilaterally distributed after puberty. But in those with ADHD it is first evident on the left side (Oades et al., 1996, Figure 1). This appears to reflect a right frontal impairment. Its compensation, however, may also compromise abilities that would normally otherwise develop in an uncomplicated way on the left (e.g., language related functions). More recent neuroimaging studies confirm impaired patterns of brain activation in the right hemisphere while children with ADHD meet more demanding cognitive challenges (e.g. stop- and delay-tasks, Rubia et al., 1999). Thus, there is evidence for a major ‘dislocation’ in the pre-pubertal development of the anatomical bases underlying selective information processing: it is one that affects the efficient division of labour between right hemisphere function in sensory, spatial, holistic processing and the left hemisphere involvement in fine detailed analyses, working memories and language.

After puberty the wave of development, cutting down on excess grey-matter and pruning back of the number of synaptic connections, progresses forward over the ever more frontal parts of the brain (Gogtay et al., 2004). These parts, among other functions, harbour the ability to switch the direction of processing (should the deviant sound be interesting, threatening or aversive). MMN latencies that reflect the speed and efficiency of processing, mature in the late teens (Oades et al., 1997). Is development then all over?

We have been using an algorithm known as “brain electrical source analysis” (BESA) to calculate where the sources must be in the brain to

account for the activity we record. It is not surprising that two such sources are located in the left and right auditory cortices – the highest centres receiving sensory perceptual information. More intriguing is the location of others in the posterior end of the anterior cingulate cortex near the midline, and in the anterior inferior frontal cortex on the right (Jemel et al., 2002). A comparison of 30 year olds with 17 year olds showed that the sources in the auditory cortices (temporal lobe) moved 10–15 mm sideways and down during the third decade of life. Those in the frontal lobes travelled by a similar amount further posterior at the back end of the forebrain (the cingulate) or further anterior at the front end of the forebrain (the inferior-frontal: Wild-Wall et al., 2005). It now seems that the brain is going on developing way past the age of consent and achievement of majority (Figure 2). Indeed, the achievement of adulthood is not so fixed as popular law and lore would have it.

There are several reasons why this has significance for studying what underlies ADHD. The first is methodological. To study what happens differently for ADHD subjects from mid-adolescence to “30 year-old adulthood” researchers must precisely match their healthy comparison subjects for age. It is no longer sufficient to contrast, say, a comparison group of 30 healthy subjects with a mean age of 25 years when the individuals’ age range from 19 to 32 years, with a study group whose mean age of 25 years was made up of subjects aged 24–26 years. The second reason is that we now have grounds to predict that the ‘maturation lag’, previously postulated to account for some of the problems in childhood ADHD, may indeed emerge in the more recently recognised adult form of ADHD. About a third of 8–12 year-old children with ADHD show a ‘maturation lag’ in the pattern of EEG oscillations recorded: (this includes

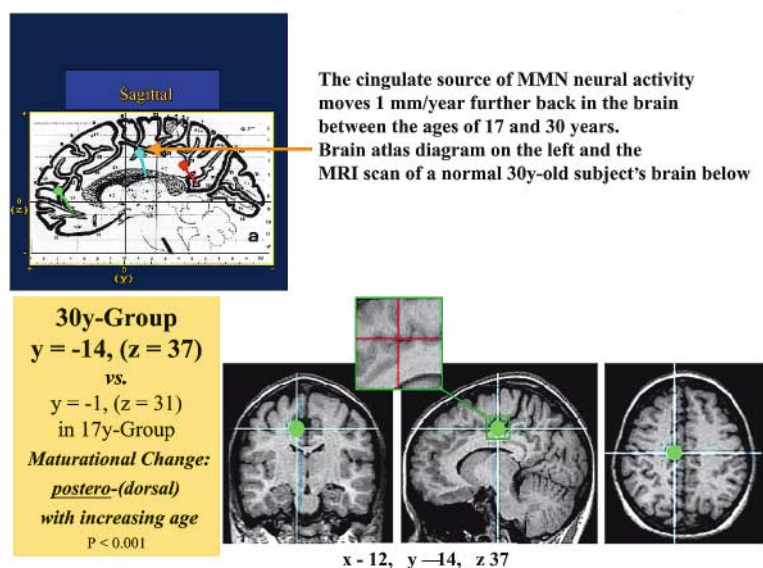


Figure 2. The top part shows 3 of the 4 dipole sources of activity generating MMN placed on a diagram taken from a neurological atlas of brain structures as viewed from the left hand side (the front end is on the left). (Green = inferior/mid frontal, turquoise = midline cingulate, red = auditory cortex in the temporal lobe: Jemel et al., 2002). The bottom part shows the cingulate source (mean solution for a group of normal 30 year-olds) placed on an MR image of one of these subjects, which lies 1.3 cm, on average, further back along the anterior-posterior y-axis than in a group of normal 17 year-olds (Wild-Wall et al., 2005). [The z-axis represents the more vertical, dorso-ventral axis.]

an increased frontal and decreased posterior total power in the recording, Clarke et al., 2002). Remarkably, at least a third of those with a childhood diagnosis of ADHD retain some of their difficulties into adulthood (Faraone et al., 2000). We do not yet know if these data refer to the same type of subject. However, a recent study of 28 year-olds who had and have such difficulties described cingulate dipoles for the mismatch between ‘go’ (respond) and ‘no-go’ (withhold response) stimuli (Fallgatter et al., 2005). These sources of activity also differed on the anterior-posterior Y-axis in comparison with other people without ADHD problems. Their patients’ dipole-sources were further anterior – like those we have also shown to reflect earlier stages of maturation.

In summary, we can calculate and illustrate the location of sources of activity of the brain underlying a fundamental cognitive activity (auditory deviance detection, MMN) in two and three dimensions. This marker shows that (at least) two sorts of anomaly in normal brain development occur as a child with ADHD grows up. The first is specific to pre-pubertal development and reflects the differential roles of the two hemispheres of the forebrain. The second is the maturational lag in brain expansion (rostr-caudally in the frontal and laterally in the temporal lobes) that may become evident from puberty, but potentially dominates in the adult forms of ADHD. As a precautionary note, it should be remarked that this latter feature relates to neurodevelopment – it may not be specific to ADHD, but be a feature accompanying some (but not all) other neurodevelopmental disorders. We have indications that some lag may also be evident in psychoses with an early onset in adolescence (Oknina et al., 2005).

The jury is still out on whether these features reflect the expression/non-expression of certain genes at certain stages of growing up, or on the extent to which these processes may prove sensitive to drug or other treatments. The indications are that currently typical medication directed towards catecholaminergic transmission may not interfere with the development I have described, although the expression of the source activity may be modestly facilitated. Such questions demand and are receiving close attention.

References

- Clarke, A.R., Barry, R.J., McCarthy, R., Selikowitz, M., 2002. EEG-defined subtypes of children with attention-deficit/hyperactivity disorder. *Clinical Neurophysiology*, 112, 2098–2105.
- Faraone, S.V., Biederman, J., Spencer, T., Wilens, T.E., Seidman, L.J., Mick, E., Doyle, A.E., 2000. Attention-deficit/hyperactivity disorder in adults: an overview. *Biological Psychiatry*, 48, 9–20.
- Fallgatter, A.J., Ehlis, A.-C., Rösler, M., Strik, W.K., Blocher, D., Herrmann, M.J., 2005. Diminished prefrontal brain function in adults with psychopathology in childhood related to attention deficit hyperactivity disorder. *Psychiatry Research Neuroimaging*, 138, 157–169.
- Gogtay, N., Giedd, J.N., Lusk, L., Hayashi, K.M., Greenstein, D., Vaituzis, A.C., Nugent, T.F., Herman, D.H., Clasen, L.S., Toga, A.W., Rapoport, J.L., Thompson, P.M., 2004. Dynamic mapping of human cortical development during childhood through early adulthood. *Proceedings of the National Academy of Sciences (U.S.A.)*, 101, 8174–8179.
- Jemel, B., Achenbach, C., Müller, B., Röpcke, B., Oades, R.D., 2002. Mismatch negativity results from bilateral asymmetric dipole sources in the frontal and temporal lobes. *Brain Topography*, 15, 13–27.
- Oades, R.D., Dittmann-Balcar, A., Schepker, R., Eggers, C., 1996. Auditory event-related potentials and mismatch negativity in healthy children and those with attention-deficit or Tourette-like symptoms. *Biological Psychology*, 43, 163–185.

- Oades, R.D., Dittmann-Balcar, A., Zerbin, D., 1997. Development and topography of auditory event-related potentials, mismatch and processing negativity from 8 to 22 years of age. *Psychophysiology*, 34, 677–693.
- Oknina, L.B., Wild-Wall, N., Oades, R.D., Juran, S.A., Röpcke, B., Pfueller, U., Weisbrod, M., Chan, E., Chen, E.Y.H., 2005. Frontal and temporal sources of mismatch negativity in healthy controls, patients at onset of schizophrenia in adolescence and others at 15 years after onset. *Schizophrenia Research*, 76, 25–41.
- Rubia, K., Overmeyer, S., Taylor, E.A., Brammer, M.J., Williams, S.C.R., Simmons, A., Bullmore, E.T., 1999. Hypofrontality in attention deficit hyperactivity disorder during higher-order motor control: a study with functional MRI. *American Journal of Psychiatry*, 156, 891–896.
- Wild-Wall, N., Oades, R.D., Juran, S.A., 2005. Maturation processes in automatic change detection as revealed by event-related brain potentials and dipole source localization: significance for adult AD/HD. *International Journal of Psychophysiology*, in press.

Genes and Parenting: Risk Factors in the Development of Attention-Deficit-Hyperactivity Disorder

The delineation of developmental pathways to psychiatric disorders of childhood and adulthood is a major challenge in the field of developmental psychopathology. A powerful means of identifying these pathways and the organismic and contextual factors that contribute to the onset and severity of psychopathology is through the use of prospective longitudinal designs. A longitudinal design that incorporates a high risk research strategy is most appropriate for the investigations of psychiatric disorders in which there is evidence of familial transmission (Garmezy & Streitman, 1974). Using this



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strategy, sample selection is based on the presence of symptoms of the disorder in a family member thereby increasing the probability that a higher percentage of the research cohort will eventually develop the disorder. This strategy is the one my colleagues and I have used to identify infants at risk for attention deficit hyperactivity disorder

(ADHD) based on paternal symptoms of ADHD.

ADHD is one of the most common disorders of childhood with a prevalence of 3–5% (American Psychiatric Association, 1994). Surprisingly, possible early developmental precursors of this disorder have been relatively uninvestigated. ADHD is a developmental disorder with both genetic and environmental underpinnings making it an ideal candidate for a comprehensive longitudinal investigation of its developmental trajectory.

The evidence that ADHD is a familial disorder is compelling (Barkley, 1990). Children of parents or siblings with ADHD are at increased risk of receiving a childhood diagnosis of ADHD (Biederman et al., 1995a). Twin studies support a strong genetic contribution to ADHD with heritability estimates ranging from 75% to 91% (Levy, Hay, McStephen, Wood, & Waldman, 1997). Recent evidence from molecular genetics also attests to a genetic basis for the disorder with the focus primarily being on genes associated with the dopamine system, for example, the dopamine D4 receptor gene (DRD4) (Faraone et al., 2001).

Nonoptimal parent-child interaction seems to antedate the disorder with coercive, overstimulating, intrusive, and restrictive parenting in the first years of life being predictive of later hyperactivity and impulsivity (Campbell, 2002). Family adversity, in the form of parental psychopathology, marital stress, and other stressful life events, is also associated with ADHD, with the risk of ADHD being particularly high in families with three or more risk factors (Biederman et al., 1995b).

One of the first tasks in our research was to link the symptoms and behaviors characteristic of children with ADHD to behaviors characteristic of the first years of life. Two approaches to the conceptualization of ADHD were particularly relevant for this task. The first approach conceptualizes the behaviors defining ADHD as falling at the extreme edge on a continuum of temperament traits seen throughout the population (Taylor, 1999). Emotionality, activity, and attention/orienting are included under the rubric of temperament and individual differences in their expression can be seen early in life (Rothbart, 1989). The second approach conceptualizes ADHD symptomatology as reflecting neurodevelopmental immaturity. Kinsbourne (1973) suggests that children with ADHD suffer from a delay in neurological maturation resulting in behaviors considered deviant for their chronological age. Making use of these two approaches, our research protocol in the first years of life includes measures which tap the expression of temperament and neurodevelopmental maturity. The effects of the environment are assessed by observations of parent-infant interaction and parenting questionnaires.

The sample is composed of boys only because the ratio of boys to girls with ADHD ranges from 3:1 to 9:1 (American Psychiatric Association, 1994). Families were recruited into the study at the birth of their sons. Two groups were formed based on ADHD symptomatology in fathers. Infants in the ADHD risk group have fathers with 7 or more ADHD symptoms while those in the comparison (low risk) group have 3 or less symptoms. The boys were assessed at one month of age with a standard neonatal behavioral assessment scale and at seven months, they were observed in standard episodes tapping different domains of temperament, such as interest, fear, activity, anger, pleasure, and in interaction with their parents. The episodes are designed to be similar to those encountered by infants in everyday situations. At both assessment periods, parents

completed questionnaires on infant temperament and at one year, a questionnaire on parenting competence. This is an ongoing study and the boys and their families are seen at the following ages: 1, 12, 24, 36, and 54 months.

The figure above presents a summary of the association between ADHD risk and infant behavior at one and seven months and for ADHD risk and parenting behavior and competence at seven months and one year. The associations between the measures are also presented. All lines between boxes indicate a significant finding of $p < .05$. The arrows in the boxes indicate the direction (more or less) of the behavior. For full details of the

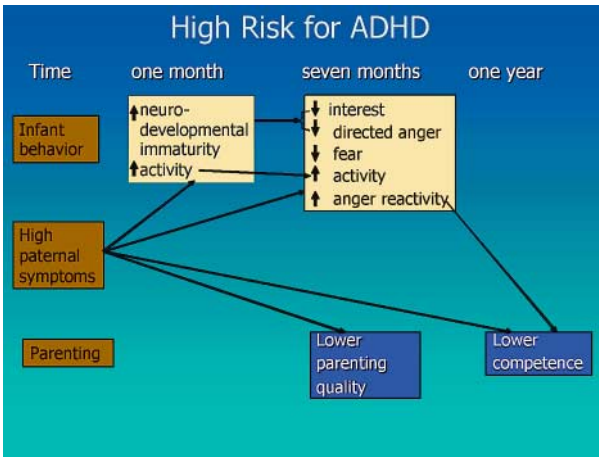


Figure 1. Summary of infant behavior and parenting indicative of high risk for ADHD.

infant behavior results, see Auerbach et al. (2004, 2005). With the exception of the one-month data and the seven-month infant-parent interaction data, all other data are based on partial data sets since not all the seven-month and one-year data have been coded.

The infant behavior results are compatible with ADHD literature conceptualizing ADHD as falling on a continuum of temperamental characteristics and also reflecting neurodevelopmental immaturity. In addition, the importance of including measures of parenting behavior is demonstrated by the less optimal parenting seen in the parents of the risk infants at seven-months of age.

References

- American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders*. (4th edition). Washington, DC: American Psychiatric Association.
- Auerbach, J.G., Atzaba-Poria, N., Berger, A., & Landau, R. (2004). Emerging developmental pathways to ADHD: Possible path markers in early infancy. *Neural Plasticity*, 11, 29–44.
- Auerbach, J.G., Landau, R., Berger, A., Arbelle, S., Faroy, M., & Karplus, M. (2005). Neonatal behavior of infants at familial risk for ADHD. *Infant Behavior and Development*, 28, 220–224.
- Barkley, R. A. (1990). *Attention-deficit hyperactivity disorder: A handbook for diagnosis and treatment*. New York: Guilford Press.
- Biederman, J., Faraone, S. V., Mick, E., Spencer, T., Wilens, T., Kiely, K., Guite, J., Ablon, J. S., Reed, E., & Warburton, R. (1995a). High risk for attention deficit hyperactivity disorder among children of parents with childhood onset of the disorder: A pilot study. *American Journal of Psychiatry*, 152, 431–435.
- Biederman, J., Milberger, S., Faraone, S.V., Kiely, K., Guite, J., Mick, E., Ablon, S., Warburton, R. & Reed, E. (1995b). Family-environment risk factors for attention-deficit hyperactivity disorder: A test of Rutter's indicators of adversity. *Archives of General Psychiatry*, 52, 464–470.
- Campbell, S. B. (2002). *Behavior problems in preschool children*. (2nd edition). New York: The Guilford Press.
- Faraone, S.V., Doyle, A.E., Mick, E., & Biederman, J. (2001). Meta-analysis of the association between the 7-repeat allele of the dopamine D₄ receptor gene and attention deficit hyperactivity disorder. *American Journal of Psychiatry*, 158, 1052–1057.
- Garmezy, N., & Streiptman, N. (1974)). Children at risk: The search for antecedents of schizophrenia. Part I. Conceptual models and research methods. *Schizophrenia Bulletin*, 8, 14–90.
- Kinsbourne, M. (1973). Minimal brain dysfunction as a neurodevelopmental lag. *Annals of the New York Academy of Sciences*, 205, 268–273.
- Levy, F., Hay, D., McStephen, M., Wood, C., & Waldman, I. (1997). Attention deficit hyperactivity disorder: A category or a continuum? Genetic analysis of a large-scale twin study. *Journal of the American Academy of Child and Adolescent Psychiatry*, 36, 737–744.
- Rothbart, M. K. (1989). Temperament in childhood: A framework. In G. A. Kohnstamm, J. E. Bates, & M. K. Rothbart (Eds.), *Temperament in childhood* (pp. 59–73). NY: John Wiley.
- Taylor, E. (1999). Developmental neuropsychopathology of attention deficit and impulsiveness. *Development and Psychopathology*, 11, 607–628.

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Section II:

The Theory of Turbulence in Physics, Linguistics and Psychology

Limits to Predictability and Understanding, seen from a Physicist's Perspective

As an introduction, we may consider an infinitely many times differentiable function F of some variable ξ . Presuming we have complete information of this function in a narrow interval at a reference ξ_0 , we can predict the values of this function at any $\xi > \xi_0$ by a MacLaurin series expansion

$$F(\xi) = F(\xi_0) + \frac{F^{(1)}(\xi_0)}{1!} (\xi - \xi_0) + \frac{F^{(2)}(\xi_0)}{2!} (\xi - \xi_0)^2 + \dots + \frac{F^{(n)}(\xi_0)}{n!} (\xi - \xi_0)^n + \dots$$



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where we by $F^{(n)}(\xi_0)$ understand the n -th derivative, $d^n F(\xi)/d\xi^n$, taken at the position ξ_0 . It can thus be argued that given the a-priori knowledge of infinitely many times differentiable functions, we have complete knowledge of F for all ξ , provided we have been able to obtain the knowledge of all $F^{(n)}$ in just one position ξ_0 . If we

take ξ to represent a time variable t , and $F(t)$ to be the output signal from a signal transmission line, we can then argue that the signal does not contain any information for $t > t_0$ since we have complete knowledge of it already at $t = t_0$. In this sense, information is associated with discontinuities in either the signal $F(t)$, or some of its derivatives, and indeed most methods of signal transmission use pulsed signals of various forms.

The use of the MacLaurin series is, unfortunately, not quite as simple as it may seem: in the vicinity of a reference variable we may in reality be given the function either as a long, but finite, list of numbers or alternatively in the form of a graphical representation. Assume that in the former case we have, say, N points at our disposition: we are then able to estimate $N-1$ derivatives, i.e. up to $F^{(N-1)}$, unfortunately with an error increasing with the order of the derivative, in part also because we will only have a finite number of digits available, and the numerical differentiations become uncertain also because of round-off errors. If the function is given graphically as a curve in an interval, the finite width of the line and other practical problems make the derivative estimates even more uncertain. In *reality*, we will benefit from the MacLaurin series only for some time, and when the errors due to our uncertainty on $F^{(n)}$ and ignorance of higher derivatives accumulate, our predictions will become increasingly uncertain and ultimately simply wrong, in spite of the formal possibility of ideal predictability. In addition we might of course encounter cases where

the function may not be differentiable at a possibly infinite set of ξ -values, in which case our efforts to achieve long time predictions would be in vain anyhow. Such cases have practical importance as already mentioned.

The discussion outlined here made reference to one variable only, but applies equally well for functions of many variables, in particular also for cases where the independent variables are time and spatial positions, i.e. $F = F(x, y, z, t)$. A relevant case could be where F represents the space-time varying smoke concentration emerging from a smokestack which is transported and mixed by the turbulent flow in the atmosphere (e.g. Tennekes & Lumley 1972). Turbulence in nature as well as laboratory experiments represents great challenges for our understanding of phenomena with many degrees of freedom, but in addition it is of great practical importance for pollution transport in the environment. It is important also for certain aspects of the biological food chain as discussed in a different context. It is safe to argue that turbulence is of great importance for everyday life, and significant efforts have been made to understand and describe turbulent flows.

When considering turbulent fluids, as visualized for instance by a smoke plume from a smokestack, it seems inconceivable that such conditions are amenable for analytical studies. Nonetheless it was demonstrated first by Kolmogorov that given some reasonable simplifying assumptions, certain statistical averages can be predicted to a high degree of accuracy, such as the second order structure function, which is defined as the mean square of the velocity difference between two positions in the fluid. The idea was in a sense familiar to physicists already: for example the kinetic theory of gases is a study of statistical averages of measurable quantities associated with many interacting particles. In the early days of classical statistical mechanics, scientists were confident that, at least in principle, any problem involving many interacting particles could be solved in a certain sense, and statistical mechanics was at least to some extent seen as a means of reducing the relevant information to a manageable level. In our imagination, we might consider a situation where a very large number of different springs carrying particles with different masses and all of them interconnected. The problem could in principle be analyzed completely within classical mechanics, but any attempt to do so would be made impossible by the immense number of degrees of freedom that has to be accounted for in the analysis. In particularly simple cases we are actually able to provide an exact solution even for realistic cases, but even if this were possible for a general case, such a result would contain too much information to be manageable in practice.

Classical turbulence models are to some extent related to these problems from statistical mechanics: in models of fluid turbulence we consider the medium as a continuum and ignore its particle properties, but nonetheless turbulence is understood and described as a physical condition where many structures interact, see Figure 1. The basic description in terms of a partial differential equation of incompressible fluids is well established (the Navier-Stokes equation), but its solution for general flows is close to impossible, and even if such a solution were available, it would be of little practical use by containing much more information than is

manageable for an actual application. The Navier-Stokes equation is stated as,

$$\frac{\partial}{\partial t} \mathbf{u}(\mathbf{r}, t) + \mathbf{u}(\mathbf{r}, t) \cdot \nabla \mathbf{u}(\mathbf{r}, t) = -\frac{1}{\rho} \nabla p + \nu \nabla^2 \mathbf{u}(\mathbf{r}, t)$$

where $\mathbf{u}(\mathbf{r}, t)$ is the space-time varying fluid velocity vector, p is the pressure, ρ is the mass density of the fluid (usually assumed to be a constant) and ν is the kinematic viscosity, which accounts for the energy dissipation in the medium as heat. Viscosity is effective predominantly for small scales. (It is important to note that the mathematical structure of the equation becomes significantly different if dissipation as given by the last term in the Navier-Stokes equation is omitted, since the equation then only contains first order spatial derivatives.) The equation is completed by an expression for incompressibility, $\nabla \cdot \mathbf{u}(\mathbf{r}, t) = 0$, which is appropriate for motions with small Mach numbers, i.e. much slower than the velocity of sound. Many relevant turbulence conditions in the oceans or in the atmosphere fulfill this condition. As outlined in the introduction, the idea of predictability of function (here the space-time varying velocity vector field) requires that the function is infinitely many times differentiable at all spatial positions at all times. We can of course ensure that the initial condition in a computer simulation, for instance, has this property, but there is no a-priori guarantee that such singularities can not develop spontaneously at later times. The problem is not completely resolved, but there seems to be a consensus that a statistically homogeneous and isotropic turbulent velocity field remains infinitely many times differentiable as long as the Navier-Stokes equation applies as a model. The Navier-Stokes equation is mathematically relatively simple, but has very complicated solutions, which only recently have been explored numerically by powerful computers, and even then only for cases limited to weakly developed turbulence.

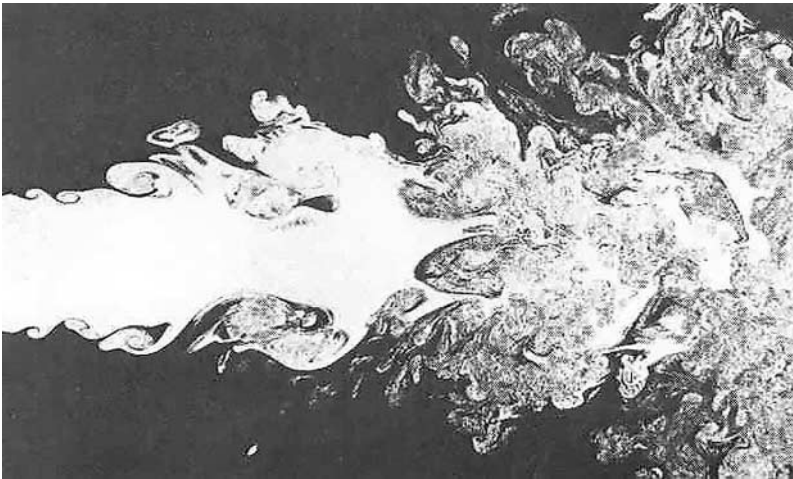


Figure 1. The figure shows a "jet" of high velocity being injected from the left side into a background fluid at rest. Note the evolutions of small coherent structures, which subsequently mix into a turbulent flow to the right of the figure.

The standard and mathematically strict way of describing structures in turbulence is by means of a Fourier transform of the velocity field, but for the present purpose some qualitative ideas will suffice. The most important point is the basic statement that under statistically steady state condi-

tions, turbulence can be seen as a competition of energy input and energy dissipation. Energy is injected into the system by some external force, in laboratory experiments for instance by rotating propellers, moving grids or similar. The energy is assumed to be injected at large scales, for most relevant cases. With the scales interacting, the energy will be fed on to smaller and smaller scales, until it is ultimately dissipated at the smallest scales by the fluid viscosity. In turbulence studies the notion of “energy cascade” is invoked for the process. If we arrest the energy input, the turbulence will decay, and the motions in the fluid will eventually crank to a halt, the largest scales surviving the longest.

The visual impression of turbulent flows is associated with chaos, implying unpredictability. It could be tempting to assume that chaos was uniquely associated with systems having many degrees of freedom. One important observation which dates back to the 19th Century is that chaos, in the sense of unpredictability, can be found also in systems with few degrees of freedom: it can be demonstrated that three suffice (e.g. Schuster 1988). As strange as it may sound, it can be demonstrated that, for instance, three planets interacting by gravitational forces can exhibit regular motion for extended periods of time, until one of them suddenly tears loose and can leave the system. Any prediction made on past observations suggesting regular motion for all future times will be in error. For systems like these, chaos is manifested by lacking predictability. We can observe and describe the system at any instant, but we can only do so with a finite accuracy. If we compare two initial conditions which are both compatible within a certain accuracy, the system can develop into very different later states. Even the slightest error or inaccuracy of our description of a state of the system at a given reference time can result in a prediction of future states which is in grave error, even though we purport to know the basic laws of motion exactly. Unfortunately, meteorological models for weather prediction have such properties: even the simplest reasonable model we might imagine, consisting of only three coupled partial differential equations (related to the Lorenz model), has such a property. The term “butterfly effect” has been coined to describe the great uncertainty in the predictions that we as laymen have observed so often when comparing weather forecasts with actual observations. “The flapping of the wings of a butterfly can give rise to perturbations in our predictions and give results which are completely different from what we find when these perturbation are absent.” If we attempt to make weather predictions using a reasonably accurate numerical model, our results will be extremely sensitive to the input data, sensitive even to the “flapping of the wings of a butterfly”. If we, for instance, specify our initial conditions to, say, 8 digits accuracy, we will find a substantial difference in the predicted evolution if we change the last digit. For a while, the two solutions are likely to follow each other, but the difference will slowly increase, eventually becoming very large. The time it takes for substantial deviations to develop will be one of the characteristics of the problem. In spite of this chaotic feature, the basic model equations will still ensure that identical conditions lead to identical results.

The basic idea of making predictions and models for average quantities in many-body systems has been widely used in natural sciences. The well known Ohm's law, relating electric currents to potential differences is one example, and the diffusion equation or the slightly simpler Fick's law, are

examples of cases where such a model has proved to be valuable. These laws describe in a simple way immensely complicated underlying physical phenomena. Their success relies on the fluctuations around these averages being small. Heuristic model equations are often used also in social sciences for predicting the behaviour of societies, which after all can also be seen as systems of many interacting bodies. The limitations of such models have been made conspicuous by noting that many of these model equations have chaotic solutions.

It seems appropriate here to add some comments relating to “modern physics” or quantum mechanics, which also deals with uncertainties of predictions, albeit, as argued in the following, by completely different reasoning. First of all, it might be stated quite trivially, that uncertainties in measurements were, of course, recognized in classical physics. The uncertainties dealt with in quantum mechanics are concerned with limitations in our basic understanding, and should be seen as something quite different. It might be appropriate first to insert a few ideas concerning the meaning of the word “understanding”. Here it should be emphasized that the discussion will be somewhat restrictive: we might claim to understand a piece of music or a painting, for instance, but these aspects of the word will not be covered here. Rather, we might start with the first human encounter with the word “understanding”: a child experiencing the first causal relationships. Assume that it knocks over an ugly, old vase you hated anyway, so you take it in quite a relaxed way with a few words like “never mind, it was not really your fault, etc...”. Next time, however, it is a precious gift that goes, and this time your reaction becomes much more angry. The child sees no difference in its actions (and indeed with some right), but the consequences are dramatically different. The poor child becomes all confused, it *does not understand*: the causal relations (and the related social relations) it tries to build get all messed up. When seen in this light, we might argue that we *understand* a phenomenon, when we are able to predict the consequences of a given initial condition, or alternatively, given an effect, we can be certain of its cause. The virtue of this formulation is that “understanding” in the present sense can be communicated, and understanding enters also as an element in social or in human relations. We can explain a cause by words or other ways and predict its consequences for somebody else. Many other experiences, no matter how emotionally deep or profound, may remain “private” because we lack words or other means of communicating this experience.

Within classical mechanics, or rather classical physics in general, the possibility of a complete understanding in the sense illustrated before seemed within reach around the year 1900, or so. For sure, scientists were fully aware that any cause, or its effect, could be measured and determined with a finite accuracy only. However, physicists had for centuries seen the accuracy of their measurements increase almost unbelievably. On the distant horizon a nearly perfect accuracy could be imagined, one which allowed measurement of a given state of matter to arbitrary high (though finite) precision, with a subsequent prediction of future states with correspondingly high precision: what we could claim to be a *complete understanding* of nature. The emergence of quantum mechanics reduced this ideal to a shambles (e.g. Davydov 1969). As may best be illustrated by the model experiment known as “Heisenberg’s microscope”, we learned that a state of matter, let this be constituted by just a single electron, can be

measured with finite accuracy only. Basic laws of physics set the limit to this accuracy as expressed in terms of Planck's constant, and not human limitations in experimental accuracy. We might, for instance, claim to know the position of a particle to any precision, but only at the expense of a corresponding ignorance on its velocity. The product of the two uncertainties is larger than a certain minimum value, the relation known as *Heisenberg's uncertainty principle*, stated here as

$$\Delta x \Delta p > h ,$$

where Δx is the uncertainty in the determination of the position of a particle (here for a one dimensional model) and Δp is the corresponding uncertainty in the particle momentum (*mass* \times *velocity*), while h is Planck's constant, where we in classical mechanics would set Planck's constant to zero, thus allowing, at least in principle, $\Delta x = 0$ and $\Delta p = 0$ simultaneously. The consequences of the uncertainty relation for our ideas of "understanding" are profound: we will never be able to define a causal relationship accurately, since the input data will always be undetermined by the uncertainty principle, and consequently we will never be able to reach a complete understanding of a physical problem, at least not in the sense of the word as argued above. There is a profound epistemological difference between limitations of predictability caused by fundamental laws of nature, and those caused by practical problems like round-off errors. These realizations lead to a complete reformulation of physics, known as quantum mechanics. This is still an exact science, but its predictions do not concern individual states of matter or events but rather probabilities of states, where the probability density can now be predicted with accuracy. These predicted probability densities can be estimated experimentally, but no longer on the basis of a single set of observations obtained from just one realization of the experiment.

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References

- Davydov, A. S. (1969) *Quantum Mechanics*. Pergamon Press.
Schuster, H. G. (1988) *Deterministic Chaos, an Introduction*. 2nd ed. VCH Verlagsgesellschaft.
Tennekes, H. & Lumley, J. L. (1972) *A First Course in Turbulence*. MIT press.

Regulated Turbulence in Information

“That which is static and repetitive is boring. That which is dynamic and random is confusing. In between lies art.”

John Locke (1632–1704)

Introduction

This essay has four parts. The first briefly shows ways in which the physical concepts of turbulence (randomness or entropy, without the hidden simplicity that has recently come to be associated with the word *chaos*) apply to information as well. The second argues that it is worthwhile looking for evidence that turbulence is not simply present, but *regulated* in

real systems. The third gives examples of well understood systems and the ways that they regulate turbulence. The fourth contains speculations about the applicability of these ideas to human brain function.



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Turbulence in information flow

Physical turbulence is characterised by

unpredictability at many scales, caused by interactions that are strong, long-distance, and varied. It may seem odd to relate this to the world of *information*, with its precise rules and often perfect solutions in many problem domains. However, many information-processing tasks can be solved in disorganised ways (Introna and Whitley 1996). These tasks generally have no single correct outcome, and can be solved using bottom-up collaborative approaches. Disorganised problem-solving works by generating vast numbers of possible solutions, and then judging them in some way, or making them compete with one another (Figure 1). Such methods optimise the *fits* between species and environment, antibodies and epitope, theories and data (Campbell 1974).

Surowiecki (2004) suggests that the *Wisdom of Crowds* arises from sharing of information, cooperation, and coordination of activity. Selection theories, and standard approaches to “wicked problems” (e.g. van Bueren and Koppenjan 2003), all are more general, in that they include the potential usefulness of distortion or of outcomes being novel rather than right. In such cases, B, D, and E tend to be important; whereas in more pre-planned systems, A and C usually predominate.

Such consideration of a wide variety of systems together can shed light on underlying principles: “some scientific theories are representative of types of theories that solve types of problems.” (Darden and Cain 1989). More specifically, biological theories based on *selection* have been very successful, particularly in evolution and immunology. However, selection requires the fuel of *diversity*, which has not received the same degree of

Regulated Turbulence in Information

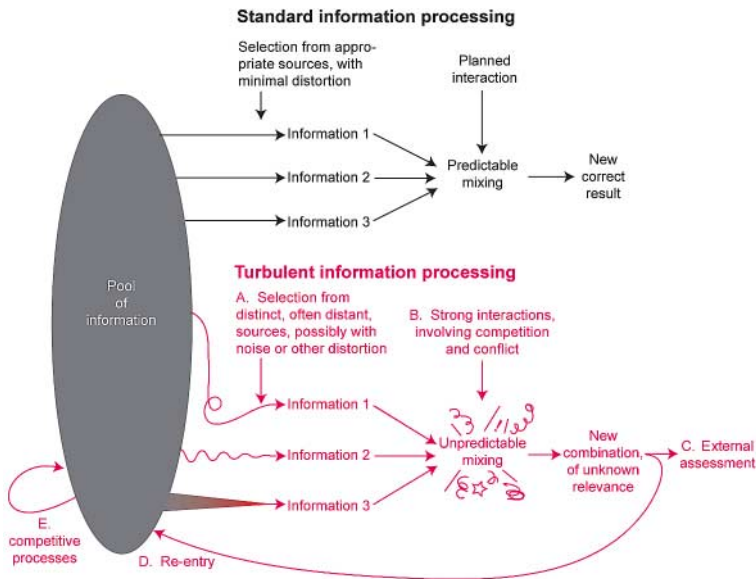


Figure 1. Standard versus turbulent information processing.

attention as selection itself. The same authors assert that “as long as preexisting diversity exists, the details of the mechanism of its production can be omitted from a selection type theory.” Similarly disinterested, Campbell (1960; 1974) described “blind variation” as the root of creativity and made a strong case that it is the root of all knowledge. The current essay attempts to address the omission, and show that variation is not completely blind.

Regulation of turbulence

A computer program that prints bank statements cannot cope with unpredictability. If a single bit of information is altered, the statement will probably be useless. The program can be extended to check its data in various ways, and even correct itself, but it will work best if there is no unpredictability at all. It will certainly not be designed to *introduce* unpredictability.

If we find systems in which unpredictability arises, how can we know whether this is an accident or a useful part of the design? In general, one of the best pieces of evidence for the usefulness of a characteristic is a demonstration that aspects of it would not be expected had it arisen for other reasons such as chance (Andrews et al. 2002). So if randomness occurs in rather specific ways, or is precisely *regulated*, that would constitute evidence that a degree of randomness is useful. The hallmarks of *regulation* are mechanisms to increase and decrease turbulence, and to control the balance between them. These would be quite different from the bank program or, at the other end of the spectrum, from unevolved nature, such as the weather, which produces the maximum entropy possible for the available energy (Whitfield 2005) – a limitation that does not apply directly to information.

When looking for mechanisms that regulate turbulence of *information*, we can be heuristically guided by our understanding of turbulence in *fluids*. Turbulence helps when mixing fluids (Chen 2001), and study of this process has revealed ways of keeping the amount of turbulence within

useful limits. The simplest of these involve changing the *strength* and *variety* of interactions, and the *scales* over which they occur (for others see Chen 2001). These factors all have counterparts in information systems that appear to be used to regulate turbulence, i.e. for both increasing and decreasing turbulence (Yang et al. 1995; Chen 2001).

Well-understood examples of regulated information turbulence

Examples 1 & 2 illustrate random *selection*; then 3 to 6 illustrate random *mixing*.

Example 1: Random search methods

Monte Carlo methods involve unpredictable information selection (Fig. 1A). They are brute force methods that do not rely on intelligent planning. Self-avoiding walks are one method used to force exploration. The degree of randomness can be gradually reduced as in simulated annealing.

Example 2: The Oxford English Dictionary

Creation of this massive work, “on historical principles”, involved enormous logistical effort. Thousands of volunteers, many with no specialist training, wrote down “unregistered words” and illustrative quotations which they felt illustrated usage, and posted these to Oxford (Winchester 1998). In Oxford, the examples were methodically organised into sub-categories and chronological order. It turned out that some of the most useful of the volunteer contributors were also the most unique (Fig. 1A) – i.e. with unusual obsessions, methods, or reading matter – because their contributions overlapped so little with others’. However, their submissions were systematically checked (C).

Example 3: Immune response

Our immune system has evolved to scramble genes randomly on an immense scale (Fig. 1, A,B). This prepares us for challenge by pathogens which select (C) a much smaller number, still in the thousands, of antibodies for proliferation (see Silverstein 2003). Evolution in this case has selected mechanisms for scrambling and amplifying, but not specific sequences of antibody molecule.

Example 4: Evolution

Evolution is the example par excellence of positive change achieved through the selection, mixing, and re-selection (Fig. 1,A,B,D,E) of information – in this case encoded in sequences of DNA. Life has evolved relentlessly in the direction of increased complexity (Szathmary and Smith 1995) except for the simplest creatures (Azevedo et al. 2005). It is clear that evolvability has evolved, increased through the introduction of gene-mixing mechanisms, uncoupling of processes, versatility, compartmentation, redundancy, and long-distance travel – in general, deconstraining effects (Kirschner and Gerhart 1998). A range of genetic mechanisms are used to increase mutations at appropriate times and places (Metzgar and Wills 2000) Constraints on the speed of evolution are the difficulty (cost) of improving on current designs, and the group fitness benefits of long lives. Cultural units (memes) evolve analogously to biological units (Dawkins 1976; though Andersen 2005), but propagate by imitation, and potentially without dilution or regulation.

Example 5: Academic research

In the academic world it is clearly important both to encourage new ideas and to check them rigorously. Selection and mixing of ideas (Fig. 1,A,B) take place in individual staff, whereas peer review for publication (C,D) takes place separately and is required for entry into the pool of published information. Within this pool, ideas compete (E) for readers and citations.

The organisation of education, finance, and above all peer-review, encourage constancy of interests, i.e. low turbulence. Acting in the opposite direction are seminars, sabbaticals, centres for advanced study, and boredom. Some of these are regulated by political perceptions of need; others by social forces intrinsic to science (Hull 1990; see Fig. 2).

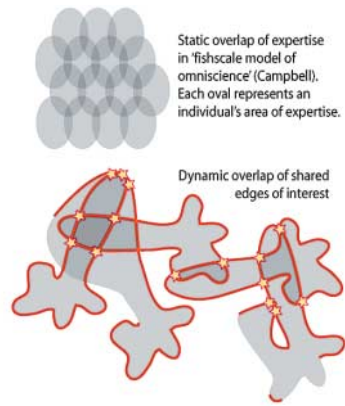


Figure 2. Overlaps between academics.

a: Donald Campbell (1969) viewed interdisciplinarity as the overlap of individuals' static areas of knowledge.

b: Individuals' current interests (red) are often at the borders of their expertise (grey). Current interests have small, dynamic areas of overlap (stars) which may be more important than overlap of expertise in allowing innovation.

Example 6: Wikipedia

Wikipedia is an online encyclopedia which can be freely updated by the public. This is a great novelty, and produces a lot of information mixing. There are 670,000 articles in the English language edition, viewed by 10 million people each day. It was hoped that erroneous contributions would be rapidly corrected by the many people making corrections, inexorably improving Wikipedia until it far surpassed any printed encyclopedia. Hence one of its slogans is "Out of mediocrity excellence."

Wikipedia turns out to be ideal for collecting simple, objective, noncontentious, voluminous information, e.g. soap opera plotlines, or towns in Alabama. The many viewers rapidly correct mistakes in such lists. However, Wikipedia may be fundamentally unsuited to academic subjects, most of which have different vocabularies, mindsets or values from the public: Wikipedia cannot instruct at all levels of understanding simultaneously. It also struggles in fields with strong divergent minority views (e.g. sex or religion), because the content of articles either oscillates or becomes an average of views, weighted by enthusiasm for making the change. Other problems are vandalism, and the gradual degradation of organisation or balance within expertly written articles. There are proposals to reduce this turbulence by introducing voting; or encouraging multiple strong viewpoints to be represented; or using more citations; or making it more difficult to delete (revert) other people's contributions, unless they are lower in a hierarchy of reliability.

Is regulated information turbulence found in human brains?

Like previous selectionist accounts, this has "plausibility by analogy", but must remain vague given our limited knowledge of brain function (Darden & Cain 1989).

It is well known that the initial wiring of the brain contains a great deal of randomness, and that this becomes organised, first topographically and later by learning. At the level of overall brain organisation, though, the idea of randomness is less accepted, because neurophysiologists' success in assigning functions to some of the cells in some brain areas (e.g. sensory and motor cortices) has seemed to suggest that Lashley's equipotentiality (Lashley 1950) was relevant only in lower animals – and also because of a predisposition to believe that we are organised.

But EEGs certainly look random, and their synchronisation in states such as sleep appears regulated. In broad outline the brain's structure is well suited to perform all the functions shown in Figure 1 (A-E). Cortical areas produce different assessments or associations (A); these then interact, or compete, via association fibres (B) and further association takes place (D,E). The basal ganglia sample the resulting patterns, selecting (C) those which have produced the best outcomes in the past (Schultz et al. 1997; Redgrave et al. 1999).

It may not be obvious that random processing can play a useful part in solving complicated problems in practical amounts of time. However, many problems (e.g. face-recognition, visual search, categorisation, and motor planning) can be reframed as *optimisations*, for which random solution methods are well-understood (Example 1). The study of optimal solutions, or fits, is important in many areas of learning (Campbell 1974) including machine learning and simple, phylogenetically old, forms of learning. A recent example is the linking of temporal difference (TD) learning to dopamine (Schultz et al. 1997). TD learning is ideally suited to guide the optimal selection of actions from a large, diverse, set of predictors (Wolpert and Tumer 1999).

Our thinking may be more turbulent than is commonly supposed. For example, magical ideas are much more common after childhood than is usually supposed (Bolton et al. 2002). As another example, people tend to be intrigued by contradictions, surprises, or problems that they partially understand. A *drive for turbulence* (similar to *novelty drive*, *curiosity drive*, *dopamine appetite*) offers one explanation for this (see Hebb 1955; Williams and Taylor 2004). High or low drive is a lifelong trait of some people. The drive is increased temporarily by strongly positive events (causing excitement) and reduced by tiredness, stimulants, or in times of stress (McReynolds 1971), when a reduction in associations can usefully improve reliability (Hanoch and Vitouch 2004).

Variability of behaviour appears to be trainable (Neuringer 2004) but is also increased by low reward probability (Gharib et al. 2004). This suggests there are at least two mechanisms regulating the variability of behaviour (see Williams and Taylor 2004). Serotonin may have a role in these: it has intra-cortical connections that appear capable of gating long-range connections between cortical areas (Park 1998). The fluid analogy suggests that these will modulate turbulence, and indeed serotonin appears to regulate cognitive flexibility (Clarke et al. 2004).

Symbol processing

Problems that cannot be treated as optimisations (such as language or mathematics) appear to be learned by symbolic rule-following mechanisms that have become learned by initially disorganised networks (Omori et al. 1999; Chalup and Blair 2003), perhaps located in prefrontal cortex

(Rougier et al. 2005). This is consistent with what we know of the evolutionary accumulation of learning methods (Moore 2004) and the centrality of symbols in our thinking (Olds 2000). Long-distance interactions between cortical areas, and the “small-world” property, appear to have increased during evolution, in parallel with cognitive ability (Johansson and Rehn 2005). Adding even a few of these long-distance connections to a network radically increases the number of different associations that can be made (Ball 2004). This may have been an important contributor to our ability to use symbols and then language (see Jackendoff 1999). Support for this comes from the finding that language is encoded in connections between the speech area of cortex and distant cortical areas, rather than being in the speech area itself (Pulvermüller 2005).

Brains are equipped with several features that increase the power of random search. These include the use of learned and unlearned heuristics; the pre-processing of sensory information; and the use of multiple, semantically distant, metrics in cortex (e.g. Wood and Grafman 2003). The distinct metrics also increase the likelihood of disagreement between brain areas (Freeman 1991) or between predictions.

The proposal – that information mixing needs regulation – suggests that this relatively recently evolved symbolic system will also have such regulation. One candidate is the phenomenon of cognitive dissonance, i.e.



conflict between ideas in a person (Festinger 1957), which is a key psychological function increasing our willingness to change existing ideas, hence reducing *intrapersonal* conflict. Our drive to reduce the *experience of internal disagreement* – and our ability to *remember* conflicting views – are both demonstrated by our difficulty, even with some effort, in perceiving the picture at right as partly an old woman and partly a young one.

Mental disorders

Most attempts to link psychiatry to turbulence or chaos have been psychodynamic; this section addresses the information processing that is taking place. The premise of regulated turbulence suggests the possibility of dividing disorders into hyper- and hypo- turbulent, and those that have nothing to do with turbulence. This is not to underestimate the impairment and suffering caused by psychiatric disorders.

Hebephrenic thought disorder in schizophrenia produces an incomprehensible jumble of words and sentences (Sims 2003) which may turn out to be caused by *excessive* turbulence. Delusional *systems* in schizophrenia are quite different, growing like islands of certainty, perhaps because disordered thought prevents their being properly monitored and discarded. People with attention-deficit hyperactivity disorder (ADHD) have highly variable behaviour, and Figure 1 suggests that this may be caused by increased variability in either data selection or mixing. Supportive evidence comes from functional brain scans showing that they use more widespread areas of their brains to solve problems (Durston et al. 2003).

Depression, and anxiety-related disorders such as post-traumatic stress disorder and obsessive-compulsive disorder, involve repetitive or stuck thinking, and it may be that underlying this is an *inadequacy* of turbulence

of ideas (see Yang et al. 1995). Negative emotion focuses attention on single, simple factors (Luce et al. 1997), contributing to the persistence of these illnesses; this over-focus may be one target of antidepressant medication.

Anorexia and dissociative disorders are even more persistent; more culturally determined; and show poor response to medication. This is consistent with the possibility that a component of these disorders is embedded as information within the categorising system mentioned above. Hence Multiple Personality Disorder has been described as “forged by an artisan rather than by nature” (McHugh and Putnam 1995). This suggestion receives some support from taxonomic findings (based on symptom scores) that, unlike depression and anxiety, these symptoms are not on a continuum in the population (Haslam 2003).

The value of unpredictable behaviour to the group.

Is it possible that erratic behaviour, in a minority, helps the group as a whole? Information uncovered by an individual, even by his errors, can be useful to other people who learn from it. So in some cases his errors and risk-taking may have the effect of unintentional altruism. (Fig. 3; see Williams and Taylor 2005 for more detailed discussion). This is similar to Example 2.

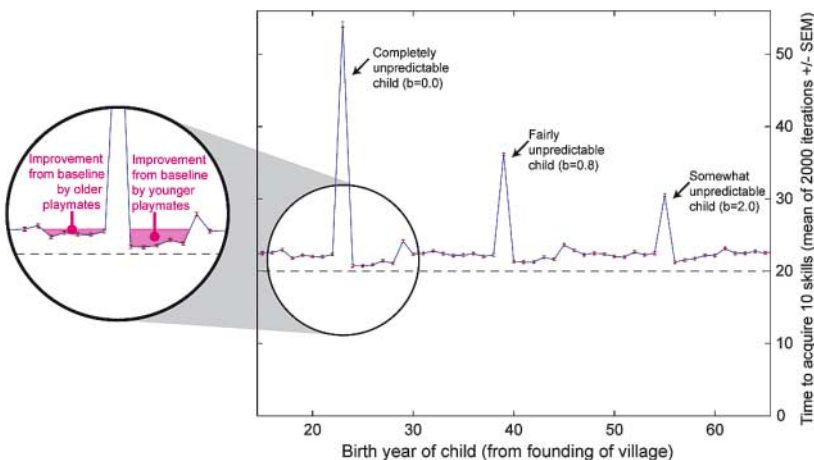


Figure 3. Simulation of maturing individuals in a village: Social skills acquisition during development. Each point represents a simulated child, with the first-born at the left. All the simulated children are identical apart from their level of predictability (brittleness, b). All but 3 of the children are highly predictable, with brittleness $b=8$. The three high peaks in the graph represent the slow maturation of three unpredictable children who take extra time to acquire skills (brittleness values b shown next to their peaks). These three children’s unpredictability produces some useful vicarious lessons for their playmates, particularly the younger ones. The benefit to playmates increases as the individual’s unpredictability increases.

Conclusions

Evolution, working in a haphazard, brute force way, using conflict and adaptability, in contexts of staggering parallelism and diversity, equipped us to solve many problems in similarly *disorganised* ways. This is because large-scale unpredictability can help organisms that are seeking *relatively good* answers (i.e. useful or better than others; satisficing) rather than a special case of this, *the right* answer. The distinction between large-scale unpredictable populations, and predictable populations of any scale, is not

in predictability, since sufficiently large populations of turbulent processors can produce any required degree of predictability (Frost and Stirling 2003). Instead, the difference is that unplanned information mixing produces a “richness of flexibility, and a cornucopia of new opportunities” (Chen 2001; see also Dietterich 1997).

	A. Selection of information	B. Mixing of information	C. External assessment	D. Re-entry into pool	E.Competition
Random search	random selection by algorithm	rule-based (e.g maximum wins)	rule-based	(typically no re-entry)	(typically no reentry)
Evolution	mating	random assortment of genes	fitness in environment	offspring reproduce	survival
Immune (molecular)	random selection of V,J,D genes	splicing	by presentation of pathogens	(no re-entry)	(no re-entry)
Cognition; Mental illness	various sources & metrics; excess control by turbulence drive?	turbulence drive; failure or misregulation of drive	primary reinforcers	immediate	best predictors, cognitive dissonance
Informational altruism	unpredictable behaviour reveals information	information is shared within social group	?	simple updating of previous information	(none)
Wikipedia	self-selection of contributors	from assorted contributors	limited – by administrators	immediate reeditability	by persuasion

Table 1. Characteristics of information mixing systems. A-E refer to Figure 1.

This essay has illustrated some ways in which variation can be created (see Table 1), and in which variability can be regulated. Inter-individual differences in information-processing are likely to play an increasing role in our views of the brain, evolution, and society (Szathmari and Smith 1995), from which they have been largely excluded by the averaging inherent in diagnostic systems and most experimental techniques. Statistics based on populations, and simulations of homogeneous populations (e.g. neural nets; cellular automata (Weiss 2003)), have major limitations in studying neuropsychological functions of populations that show strongly multidimensional differences in these functions. Simulations of heterogeneous competing agents, acting without higher-level control, is likely to produce breakthroughs at cellular, regional, cognitive, and evolutionary levels. Clinically, the possibility that dysregulation of information turbulence underlies some brain disorders suggests new directions for research, particularly in drug mechanisms and concepts of disorder.

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References

Andersen, H. (2005) “Synchrony, Diachrony, and Evolution” *Models of linguistic change*, ON Thomsen, ed., John Benjamins, Amsterdam.

Andrews, PW, Gangestad, SW, Matthews, D (2002)“Adaptationism – how to carry out an exaptationist program” *Behav.Brain Sci*,25,489–504.

- Azevedo, R. B., Lohaus, R., Braun, V., Gumbel, M., Umamaheshwar, M., Agapow, P. M., Houthoofd, W., Platzer, U., Borgonie, G., Meinzer, H. P., and Leroi, A. M. (2005). "The simplicity of metazoan cell lineages." *Nature*, 433(7022), 152–156.
- Ball, P. (2004). "Critical Mass." Farrar, Straus and Giroux, New York.
- Bolton, D., Dearsley, P., Madronal-Luque, R., and Baron-Cohen, S. (2002). "Magical thinking in childhood and adolescence: Development and relation to obsessive compulsion." *Br. J. Dev. Psychol.*, 20, 479–494.
- Campbell, D. T. (1960). "Blind variation and selective retention in creative thought as in other knowledge processes." *Psychol Rev.*, 67, 380–400.
- Campbell, DT(1974) "Evolutionary epistemology" *The Philosophy of Karl Popper*, PA Schilpp, ed, Open Court, LaSalle, Illinois, 413–463. Campbell, D. T. (1969). "Ethnocentrism of disciplines and the fish-scale model of omniscience." *Interdisciplinary relationships in the social sciences*, M. Sherif, and C. W. Sherif, eds., Aldine Press, Chicago, 328–348.
- Chalup, S. K., and Blair, A. D. (2003). "Incremental training of first order recurrent neural networks to predict a context-sensitive language." *Neural Netw.*, 16(7), 955–972.
- Chen, G. (2001). "What does chaos have to do with systems and control engineering?" *J. Sys. Sci. Complex.*, 14(1), 32–39.
- Clarke, H. F., Dalley, J. W., Crofts, H. S., Robbins, T. W., and Roberts, A. C. (2004). "Cognitive inflexibility after prefrontal serotonin depletion." *Science*, 304(5672), 878–880.
- Darden, L., and Cain, J. A. (1989). "Selection type theories." *Philosophy of Science*, 56, 106–129.
- Dawkins, R. (1976). "The Selfish Gene." Oxford University Press, New York.
- Dietterich, T. G. (1997). "Machine-learning research." *AI Magazine*, 1997(Winter), 97–136.
- Durston, S, Tottenham, NT, Thomas, KM, Davidson, MC, Eigsti, IM, Yang, Y, Ulug, AM, and Casey, B. J. (2003). "Differential patterns of striatal activation in young children with and without ADHD." *Biol. Psychiatry*, 53(10), 871–878.
- Festinger, L. (1957). "A theory of cognitive dissonance." Stanford University Press, Stanford.
- Freeman, W. J. (1991). "The physiology of perception." *Sci. Am*, 264(2), 78–85.
- Frost, R. L., and Stirling, W. C. (2003). "A Satisficing Design for the Control of Cooperative Uninhabited Aerial Vehicles."
- Gharib, A, Gade, C, Roberts, S (2004). "Control of variation by reward probability." *J. Exp. Psychol Anim Behav. Process*, 30(4), 271–282.
- Hanoch, Y., and Vitouch, O. (2004). "When Less is More." *Theory & Psychology*, 14(4), 427–452.
- Haslam, N. (2003). "Categorical versus dimensional models of mental disorder." *Aust. N. Z. J. Psychiatry*, 37(6), 696–704.
- Hebb, D. O. (1955). "Drives and the CNS (Conceptual Nervous System)." *Psychol. Rev.*, 62, 243–254.
- Hull, D. L. (1990). "Science as a Process." University of Chicago Press, Chicago.
- Introna, L. D., and Whitley, E. A. (1996). "Against method-ism" *Information Technology & People*, 10(1), 31–45.
- Jackendoff, R. (1999). "Possible stages in the evolution of the language capacity." *Trends Cogn Sci.*, 3(7), 272–279.
- Johansson, C., and Rehn, M. (2005) Small-world connectivity and attractor neural networks. www.nada.kth.se/~cjo/documents/small_world.pdf.
- Kirschner, M., and Gerhart, J. (1998). "Evolvability." *Proc. Natl. Acad. Sci. U. S. A*, 95(15), 8420–8427.
- Lashley, K. (1950). "In search of the engram." *Symp. Soc. Exp. Biol.*, 4, 454–482.
- Luce, M. F., Bettman, J. R., and Payne, J. W. (1997). "Choice processing in emotionally difficult decisions." *J. Exp. Psychol Learn. Mem. Cogn*, 23(2), 384–405.
- McHugh, P. R., and Putnam, F. W. (1995). "Resolved: multiple personality disorder is an individually and socially created artifact." *J. Am. Acad. Child Adolesc. Psychiatry*, 34(7), 957–962.
- McReynolds, P. (1971). "Behavioral choice as a function of novelty-seeking and anxiety-avoidance" *Psychol. Rep.*, 29, 3–6.
- Metzgar, D., and Wills, C. (2000). "Evidence for the adaptive evolution of mutation rates." *Cell*, 101(6), 581–584.
- Moore, B. R. (2004). "The evolution of learning." *Biol. Rev. Camb. Philos. Soc.*, 79, 301–335.
- Neuringer, A. (2004). "Reinforced variability in animals and people" *Am. Psychol*, 59(9), 891–906.
- Olds, D. D. (2000). "A semiotic model of mind." *J. Am. Psychoanal. Assoc.*, 48(2), 497–529.

- Omori, T., Mochizuki, A., Mizutani, K., and Nishizaki, M. (1999). "Emergence of symbolic behavior from brain like memory with dynamic attention." *Neural Netw.*, 12(7–8), 1157–1172.
- Park, B (1998) "A connectionist account of antidepressant action."
www.cnbc.cmu.edu/Resources/disordermodels/parkmodel.html.
- Pulvermuller, F. (2005). "Brain mechanisms linking language and action." *Nat. Rev. Neurosci.*, 6(7), 576–582.
- Redgrave, P, Prescott, TJ, and Gurney, K(1999)"The basal ganglia: a vertebrate solution to the selection problem?"*Neurosci*, 89, 1009–1023.
- Rougier, N. P., Noelle, D. C., Braver, T. S., Cohen, J. D., and O'Reilly, R. C. (2005). "Prefrontal cortex and flexible cognitive control: rules without symbols." *Proc. Natl. Acad. Sci. U. S. A.*, 102(20), 7338–7343.
- Schultz, W, Dayan, P, and Montague, PR (1997). "A neural substrate of prediction and reward." *Science*, 275(5306), 1593–1599.
- Silverstein, A. M. (2003). "Splitting the difference: the germline-somatic mutation debate" *Nat. Immunol.*, 4(9), 829–833.
- Sims, A. (2003). "Symptoms in the mind." Elsevier, Philadelphia.
- Surowiecki, J. (2004). "The wisdom of crowds." Doubleday.
- Szathmari, E., and Smith, J. M. (1995). "The major evolutionary transitions." *Nature*, 374(6519), 227–232.
- van Bueren, E. M. K. E.-H., and Koppenjan, J. F. M. (2003). "Dealing with wicked problems" *J. Public Admin. Res. Theory*, 13(2), 193–212.
- Weiss, P. (2003). "In search of a scientific revolution." *Science News*, 164(7), 106.
- Whitfield, J. (2005). "Complex systems: order out of chaos." *Nature*, 436(7053), 905–907.
- Williams, J., and Taylor, E. (2004). "Dopamine appetite and cognitive impairment in ADHD." *Neural Plasticity*, 11:1-2.
- Williams, JOH, Taylor, E (2005). "The evolution of hyperactivity, impulsivity, and behavioural diversity." *Roy. Soc. Interface*.
- Winchester, S. (1998). "The professor and the madman." HarperCollins, New York.
- Wolpert, D. H., and Tumer, K. (1999). "An introduction to collective intelligence." *Rep. No. NASA-ARC-IC-99-63*.
- Wood, J. N., and Grafman, J. (2003). "Human prefrontal cortex" *Nat. Rev. Neurosci.*, 4(2), 139–147.
- Yang, W., Ding, M., Mandell, A. J., and Ott, E. (1995). "Preserving chaos: Control strategies to preserve complex dynamics with potential relevance to biological disorders." *Phys. Rev. E*, 51(1), 102–110.

On Turbulence and Language Change

The notion of turbulence has never played a role in linguistics, historical or otherwise – either in the technical sense of the word, as in Hans Pecseli’s contribution above, or in the various more or less metaphorical senses in which the word is used in Jonathan Williams’ paper. For an observer who notices that no-one in a speech community speaks precisely like anyone else, the co-existence of the community’s multifarious speech patterns might seem to exemplify a sort of turbulence. But once it is realized that language is not just speech, but that speech is derived from the systematic mental representations or competences of individuals, the initial, superficial impression yields to the understanding that the nature of

language is very different from turbulence, whether in its literal or metaphorical sense.

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Rules, rules, rules

From the Sumerian–Akkadian grammatical translation tables of ancient Babylon (ca. 1900 B.C.) to the descriptive linguistics of the recent 1900s, the

linguist’s pursuit has always been based on the assumption that language behavior is rule governed. Consequently, that pursuit has always been dominated by (i) a search for observable regularities in speech, (ii) the formulating of grammar rules to which the observables would conform, and (iii) a quest for the principles – metarules, if you will – that govern the form of such rules. These are the aims of linguistic investigation articulated by Chomsky (1965) in his famous demand for observational, descriptive, and explanatory adequacy, but they can be recognized in linguistic writings as far back as our written records reach (Robins 1967).

Admittedly, usage is not completely regular. Even the best of us begin sentences we do not finish and produce sentences that begin one way and somehow change track and end another way. Words are often used in decidedly irregular ways. The morning paper writes about “a bullet-ridden street” (for *bullet-riddled*), an event that “was propitiated” by another (instead of *precipitated*), and someone who “did not have an inclination that NN was gay ... [but] thought he was living with some woman” (for *inkling*; or *indication*; or both?). But this sort of linguistic disorderliness is not turbulence by any definition. It is significant, rather, that in conversation we are not fazed by irregularities like these. We mostly hear right through them, for we mostly attend to what we are being told and not the details of syntax or vocabulary used. If there is any turbulence in speech, language users are not aware of it. And linguists have not described it.

Variation (1)

Something akin to turbulence enters linguistic science in the guise – and much later under the name – of *variation* in the early 1800s. It is characteristic that when Bredsdorff (1821) observes the variant pronunciations of Danish unstressed *e*, he casts this observation in the shape of a rule: it may be a “fairly pure *e* before *s*, approach *ɛ* before *r*, or, most commonly *ø*”. And when he records the different ways in which city folk pronounce everyday speech in Copenhagen, he assigns the variation (not yet so called) to two distinct styles, a formal and a colloquial (1817). A hundred years later Jules Gilliéron knew variation was a problem in collecting materials for the French dialect atlas. Unable to deal with it he decided to banish it from view by instructing his field worker Edmond Edmont to ignore any variant pronunciations by the informants and consistently note down only their first response to each item in the questionnaire (Bottiglioni 1986). Only a hundred and fifty years after Bredsdorff did variation in speech become a serious object of study, in the work of William Labov and his students. In short order, numerous variable features were described in phonetics, morphology, and syntax along the parameters of style, social status, age, gender, and ethnicity, first in American English and soon after in many other languages.

Turbulence?

This work had serious implications for an understanding of language.

First of all, different cases of variation could be described (i) as the variable output of a rule, (ii) as the variable application of a rule (an optional rule), or (iii) as variable constraints on the application of a rule; many cases of variation turned out to be quite complex, with several, hierarchically ordered constraints. (A few simple examples follow below.) Although individual sociolinguistic investigations naturally focused (and continue to focus) on one or a few individual cases of variation at a time, it quickly became apparent that what was being described was perhaps just bits and pieces of a vast congeries of patterns of variation, each one describable only in statistical terms; and that congeries was normal, everyday speech.

This was startling news to the grammarian who had been weaned on the idea of speech as rule-governed behavior. It seemed that once we recognized the existence of an unlimited set of variations in language, in part of great complexity, we might have to conceptualize the flow of human speech as literal or metaphorical turbulence.

The second major implication of these findings was for our understanding of the human capacity for language. It was obvious, from Labov’s earliest work onwards, that sociolinguistic variation is meaningful. For example, his (1963) paper on the variant pronunciation of the /ai/ and /au/ diphthongs on the island of Martha’s Vineyard, Massachusetts showed that speakers who used one set of variants identified more with the island community, whereas speakers who used the other set expressed greater allegiance with the mainland. Later investigations tested variables in a variety of settings, such as spontaneous conversation, responses in a formal interview, reading a text aloud, and reading a list of words aloud. These quite mundane conditions left no doubt either: the observable variation in usage is not random but well-ordered; speakers know what they are doing, they choose pronunciation variants to fit the situation they

are in. Precisely how much or detailed insight speakers have into the choices they make as they speak is a matter of debate. But it is clear that language behavior is indeed guided by rules; however, the rules may have variable outputs, may be optional, or may apply with a variety of constraints, and in each case the alternatives can be described as statistically weighted.

Variation (2)

There was a paradox in these discoveries. Few linguists had given much thought to the variability of language usage, and fewer thought it was significant. But at the very time its full extent was revealed, it was shown to be a great deal more orderly than anyone could have imagined.

Sociolinguists are typically cautious when speaking about the output of variable rules and traditionally use the detached language of statistics, in which speakers' gender, age group, or socio-economic group are spoken of as 'factors' that 'determine' the output of the respective variable rules. This output is cautiously called 'markers' of gender, age group, or socio-economic group, as the case may be. But of course an individual's choice of 'markers' is not *determined* by their biological age, though it may reflect their perceived relative age; it is not *determined* by their socioeconomic (gross income) status, but more likely reflects their perceived class membership. Similarly gender markers are not *determined* by biological sex, but signal the speaker's placement along a (language or community-specific) scale of femininity–masculinity. The 'markers' are signs, technically, indexes. The subjective basis for speakers' choices of stylistic and social-class indexes accounts for a great deal of the observed range of variation; it has an obvious blurring effect in the statistics. It is essential for an understanding of the nature of variation to recognize both this subjective element and the limits defined by social convention within which speakers can exercise their choices.

But despite the subjective choices made by speakers, different variables largely correlate. For instance, in New York City speech the presence of syllable-final *r* (*beard, four*) increases in frequency across styles (from casual speech to word lists) and across social classes (from lower class to middle class); similarly the use of [d] for *th* (*them, those*) decreases across styles (from casual speech to word lists) and across social classes (from lower to middle). And each of such style and class correlations conforms to a chronological progression. The formerly 'r-less' New York dialect is acquiring syllable-final *r* through exposure to general American pronunciation; the reinstated *r* occurs earlier in higher than in lower classes and earlier (for all classes) in more than in less careful styles. The local, stigmatized [d] for *th* is yielding to general American ð; this change too occurs earlier in higher than in lower classes and is observed earlier in more careful than in less careful styles (Wolfram and Fasold 1974). Similar examples can be found in all languages.

It is by no means all variations that reflect changes in progress, and the way age grading reflects ongoing change is not in every case direct. But on the whole, the general picture is clear: Each speaker has a passive knowledge of most or all variations that currently serve to index the social classification (age, gender, class) of members of the speech community; and for each variation, the speaker commands a range commensurate with their individual social-class membership, which the speaker uses to index

different speech styles. Speakers know which behavior is appropriate under which circumstances. Each speaker's communicative competence includes a personal version of the community's appropriateness norms.

This conception of variation is important for a coherent account not only of variation but also of language change.

Language change

It has always been a mystery why languages change. Many linguists are convinced that speakers change their languages to improve them. But this cannot be generally correct, for languages change all the time, and there is no evidence that they are getting better and better. On the other hand, speakers who are thoroughly familiar with a language, such as mature speakers, usually agree that new ways of speaking that are being inflicted on their language by the younger generation are changing it for the worse. But there is no evidence that they are right either. Evidently, the problem of language change needs to be approached with a little more circumspection.

Before asking *why* languages change, one must consider *how* change comes about, which is less of a mystery. Typically one or more speakers create a new expression, or a new pronunciation, and use it; others adopt it and use it in their speech; once enough speakers use it, new cohorts of speakers will learn that expression or pronunciation as part and parcel of the language. So, for every individual change we can ask why a given new expression or pronunciation was created, and why it was widely adopted. Once an expression has been adopted widely and is in widespread use, it is not surprising that it would be acquired by new cohorts of learners. To put it differently, change follows as an unsurprising consequence of innovations of different kinds, which may have come about for different reasons.

But before we go on, notice that the initial innovation, the new expression or pronunciation, the moment it is created and when it is adopted, is a variant of an already existing expression or pronunciation. (In the limiting case of a new word for a new concept, the new expression is an alternative to a circumlocution.) I will leave aside for now the types of change that happen simply as language is transmitted from generation to generation. Instead, we will look at several kinds of 'contact change'.

Consider first the introduction of syllable-final *r* in the New York City dialect (*beard*, *four*). The very first speakers who modified their *r*-less speech may have done so because they found the *r*-ful pronunciation better, either because it was closer to the spelling, or because it was that of the radio and television networks or a majority of conscripts in the armed forces; this is an empirical issue, which can be investigated. To modify their speech these New Yorkers immediately made their *r*-dropping rule optional. Those who adopted this usage similarly made their *r*-rule optional, perhaps for the same reason or reasons as the innovators.

In the time since this happened, generations of New Yorkers have acquired an optional *r*-rule, which has gradually been applied less and less. They have acquired it in a community with two kinds of speakers (from the linguist's point of view): natives with variable usage and newcomers to New York with consistent *r*-ful usage. But notice that in reality new learners in this community have encountered, besides the consistently *r*-ful usage, a range of different degrees of variable usage; for

since it first became optional, the *r*-rule has been applied differently by different age groups and different classes in different styles. To an outsider, this usage would seem chaotic and confusing. But this multivariant picture has not prevented new generations of native New Yorkers from continuing to acquire the *r*-rule and its variable usage in conformity with their own age group norms, social class norms, and corresponding stylistic norms. At the same time, successive cohorts of speakers have acquired the *r*-rule with gradually decreasing frequency of application. And more and more native New Yorkers have acquired the *r*-rule only as passive knowledge, while in their own usage they consistently pronounce syllable-final *r*. (For an explanation of such gradual change, see Andersen 2001.)

Mixed languages

The second example of contact change we will consider is the situation when several languages are used in a community. In such a case, an observer might easily find the community usage chaotic.

Linguists distinguish several kinds of ‘mixed languages’, the most important ones being pidgins and creoles. A pidgin is an *ad hoc* language created for practical purposes by speakers of different languages. It combines elements of these languages and is typically used for specific topics of communication, such as trade or work. A creole is a language that has developed from an ‘expanded pidgin’. It is spoken in part, predominantly, or exclusively by speakers who have acquired it as their first language. No longer *ad hoc*, it has been adapted to communication on all topics relating to community life (Mufwene 2001).

It is sometimes said that pidgins are not ‘real’ languages, or ‘natural’ languages. Such statements reflect the outsider’s point of view. In fact, the makeshift character of a pidgin merely results from an elaboration of individual speakers’ competences. It arises when individual speakers add to their full first-language (L_1) competence expressions and constructions they adopt from speakers of a contact language (L_2). These elements are adopted as variants of existing L_1 -elements, they have special social value, and they serve to adapt the individual’s speech to socially defined situations and/or addressees. Speakers of the other language (L_2) may also adapt their speech in those situations, and it may well be that L_2 -based speech is quite different from L_1 -based speech – although the two are mutually comprehensible. The combined L_1 and L_2 usage may strike an outsider as chaotic. But it results from individuals using vocabulary and syntax that they have added to their initial grammatical competence by means of ‘adaptive rules’ (Andersen 1973). There is nothing unreal or unnatural about pidgins. But they differ from regular languages by (i) being used for limited purposes, and (ii) by their *ad hoc* character, their lack of community-wide appropriateness norms.

Creoles are regular languages, used for general purposes and according to community-wide norms. They are interesting to the linguist by the fact that their vocabulary and syntax are not received from a single tradition of speaking, but contain elements from several languages. A few creoles are known in which these different elements have an orderly distribution. In Michif (spoken in North Dakota), for instance, verbs are Cree (an Algonquian language), but most nouns are French (Thomason and Kaufman 1988). But in most creoles, the different language elements are not distributed by any clear functional principle. In terms of their origin,

therefore, they appear to be helter-skelter. But this has no relevance for the speakers. And the grammar of any creole is just as well organized as that of any other traditional language.

Variation (3)

It is impossible to exemplify in speech the “random fluctuation of local velocities and pressures” of the dictionary definition of turbulence. The objectively chaotic usage in dialects or languages in contact is as close as one can get. But a closer look at such examples suggests why turbulence does not play a role either in speech or in the transmission of language.

Speech is rule-governed behavior in which each individual’s usage is guided by rules. The rules may be variable in a number of ways and may differ from those of other members of the speech community. But they do so in an orderly way and in accordance with a system of appropriateness norms shared by the members of the community. The one exception to this is the *ad hoc* limited-purpose pidgins.

Learners of a language – any language, including creoles – approach the usage they hear with definite expectations regarding basic semantic and phonological categories and elementary construction types on all levels of linguistic structure, but also with a readiness to grasp apparent fluctuation in usage as well-ordered variable usage. They are aided in this task, undoubtedly, by an expectation that each case of variation that is not phonologically or grammatically conditioned serves to index social group membership – age, gender, social class, or ethnicity – but never other features of speakers (skin color, stature, or other physical characteristics). Furthermore, it appears, they are ready to assign values to such variables in such a way that on the whole, the values of each category of variation are congruent with those of others. The resulting system of values thereby acquires a high degree of cohesion. In addition, they typically do this with such a high degree of uniformity that the members of a community tacitly subscribe to practically identical conventions (Andersen 2001).

We can imagine that at some level of detail – in the occurrence of phonetic, syntactic or other features – there is a threshold above which learners readily impose patterns of variation, typically similar patterns to those of the speakers they choose as their models. In this way patterns of variation may remain relatively stable in a tradition of speaking. Undoubtedly, below this threshold there are objectively speaking unordered distributions or fluctuations of detail. But this flux is devoid of significance for the speakers. It can become significant – that is, socially meaningful – only (i) if it is grasped as regular (rule governed) and ascribed social meaning, and used in accordance with such an innovative interpretation; (ii) if this pattern of usage is adopted and used by sufficiently many others; and (iii) if it is subsequently acquired by new cohorts of speakers (Andersen 1989).

Our innate capacity for language is, or includes, a capacity for imposing order on speech data. One might say that the nature of language is antithetical to the notion of turbulence.

References

- Andersen, Henning. 1973. “Abductive and deductive change”. *Language* 49.567–595.
Andersen, Henning. 1989. “Understanding linguistic innovations”. *Language Change: Contributions to the Study of its Causes* ed. by Leiv Egil Breivik and Ernst Haakon Jahr, 5–28. Berlin: Mouton de Gruyter.

On Turbulence and Language Change

- Andersen, Henning. 2001. "Actualization and the (uni)directionality of change", *Actualization* (Current Issues in Linguistic Theory, 219.) ed. by Henning Andersen, 225–248. Amsterdam–Philadelphia: Benjamins.
- Bottiglioni, Gino. "Linguistic geography: achievements, methods, and orientations". *Dialect and Language Variation* ed. by Harold B. Allen and Michael D. Linn, 5–19. San Diego: Academic Press.
- Bredsdorff, Jacob Hornemann. 1817. *Prøve af en efter Udtalen indrettet dansk Retskrivning*. Copenhagen. Reprinted in Jørgen Glahder, *J. H. Bredsdorffs Udvalgte Afhandlinger inden for Sprogvidenskab og Runologi*, 77–90. Copenhagen: Munksgaard, 1933.
- Bredsdorff, Jacob Hornemann. 1821. *On the Causes of Linguistic Change*. Copenhagen. English translation with commentary and an essay on J. H. Bredsdorff by Henning Andersen. *Historiographia Linguistica* 9.1–41, 1982.
- Chomsky, Noam. 1965. *Aspects of the Theory of Syntax*. Cambridge: The MIT Press.
- Labov, William. 1963. "The social motivation of a sound change". *Word* 19.273–309. Reprinted in his *Sociolinguistic Patterns*, 1–42. Philadelphia: University of Pennsylvania Press, 1972.
- Mufwene, Salikoko S. 2001. *The Ecology of Language Evolution*. Cambridge: University Press.
- Robins, R. H. 1967. *A Short History of Linguistics*. London and Harlow: Longmans, Green and Co.
- Thomason, Sarah G. and Terrence Kaufman. 1988. *Language Contact, Creolization, and Genetic Linguistics*. Berkeley–Los Angeles–London: University of California Press.
- Wolfram, Walt and Ralph W. Fasold. 1974. *The Study of Social Dialects in American English*. Englewood Cliffs, N.J.: Prentice-Hall.

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■ This booklet contains 32 articles related to a series of presentations held at luncheon seminars at the Centre for

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Henning Andersen

from the research groups *Attention-*

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