

ESF Exploratory Workshop on

Models of Language Evolution, Acquisition and Processing

EW 06-093

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Executive Summary

Language, and especially its spoken variety, has been characterised as perhaps the most complex cognitive skill of the most advanced species in the known universe. Language has been widely and intensively studied by a number of scientific disciplines. While linguistics, which in itself has several branches, has been the major discipline involved in the study of language, it has been joined by other disciplines, such as biology, evolution, psychology, brain sciences, cognitive science, sociology, computer science and artificial intelligence. Different disciplines have addressed different aspects of language evolution, language acquisition and language processing, using different –and sometimes quite unrelated- methods and techniques.

During the last decades of the 20th century substantial progress has been made in all disciplines that touch upon language evolution, acquisition and processing. However, it is fair to say that progress in individual disciplines has not yet resulted in an integrative theory that explains how phylogenetic, ontogenetic and epigenetic developments support speech and language processing by humans and machines. Yet, it is widely believed that no single discipline and no single research approach will ever be able to give satisfactory and comprehensive answers to questions such as “How did language emerge as an extremely powerful communication system?”, “How did the wide range of different languages develop?”, “How do children manage to learn such a complex communication system in such a short time with such incomplete input?”, “How do humans manage to produce and understand speech seemingly without effort?”, “Why is it so difficult to develop automatic language processing systems with a performance that comes close to the skills of a five year old?”, etc. As a consequence, there is a widely felt need for an overview of the state-of-the-art in all relevant disciplines, which can form the basis for intensive and effective cross-disciplinary communication and collaboration and –eventually- a roadmap for future research that should result in comprehensive models of language evolution, acquisition and processing.

Evidently, composing such an overview and roadmap is not an enterprise that can be accomplished by a single person or a single research team. Rather, contributions of a number of researchers working in different environments are needed. In the workshop the relevant disciplines were covered by tutorial and overview presentations given by renowned experts in the individual fields. All presentations were followed by discussions moderated by experts from different fields. By doing so it was attempted to clarify the contributions that one discipline can make to advance the state-of-the-art in others. Presentations and discussions were prepared by requesting all participants to write an eight page (on average) paper summarizing of the state-of-the-art in their specific field of research and identifying one or more ‘burning questions’.

The workshop started on Sunday 25 November with an informal gathering of most of the participants in the hotel where everybody was staying. On Monday 26 November the formal part of the workshop started in the Faculty Club of the Catholic University of Leuven with a short introduction of the goals and format by the conveners, and a short introduction of all participants. These introductions were really needed, because many of the participants only knew each others’ names from the literature, and one goal of the workshop, viz. gathering scientists who do not normally meet was clearly met.

The better part of Monday morning was devoted to two presentations addressing aspects of the neural substrate of language. Sophie Scott explained recent progress in brain imaging

research. Nicolas Rougier explained the limitations, pitfalls and potentials of computational modelling of neural and cognitive processing, showing ways for avoiding circularity in experiments. Monday afternoon was completely devoted to psycholinguistic approaches to language acquisition and language processing. Anne Cutler gave an overview of recent progress in research in spoken word comprehension, emphasizing attempts to build computational models of cognitive processes suggested by behavioural experiments. Paula Fikkert summarized the results of research into the early stages of language acquisition, with a focus on speech perception.

Tuesday morning was devoted to aspects of language evolution. Pierre-Yves Oudeyer showed that artificial agents, endowed with elementary sound production and reinforcement learning skills, will develop a common mapping of a continuous space onto a discrete symbolic representation, simple as a result of perceiving each others' vocalisations. Tecumseh Fitch gave an overview of language-like behaviours that can be learned by such diverse species as parrots and dogs. These presentations strongly suggest that there is only a small part of the human language faculty that relies on neural structures that are specific for humans.

Tuesday afternoon was devoted to issues in learning, with a strong emphasis on machine learning. Walter Daelemans gave an introduction to machine learning techniques, with an emphasis on memory based learning. Rens Bod explained his approach to data oriented parsing. Both speakers stressed the fact that there is no clear-cut border line between rule-based and data-oriented processing.

Wednesday morning was devoted to novel approaches to automatic speech recognition, as one potential approach to building comprehensive computational models of language acquisition and processing. Chin Lee presented his approach to speech recognition based on extracting a wide range of potentially overlapping and redundant features from the acoustic speech signal. Jeff Bilmes introduced the concept of graphical models, as a very general and large class of computational models that can address specific shortcomings of existing models of speech and language processing in a unified mathematical framework.

The workshop was concluded on Wednesday afternoon with a session devoted to follow-up actions. Plans were made for publishing a book based on the contributions of the keynote speakers, completed with chapters contributed by the other participants. Rather than a loose collection of papers, the book will be a coherent presentation of the state-of-the-art in the field, and concrete suggestions for future research. As to establishing a roadmap for future research, there was a strong commitment of many participants for establishing a research network (LEAP; Language models of Evolution, Acquisition, and Processing) under the aegis of ESF or COST. Last but not least, options for forming consortia for FP7 proposals were mentioned, especially in the field of Cognitive Systems and Future and Emerging Technologies.

In the sessions the atmosphere was very open, and all participants appeared to be eager to learn from colleagues working in other disciplines and using other research methods than their own. During the welcome party on Sunday and breakfasts, lunches and dinners on Monday and Tuesday extremely lively discussions were held, very often involving groups of persons who had met for the first time during this workshop.

Scientific Content of the Event

Language is arguably the most complex communication system –and one of the most complex cognitive systems- in the known universe. For more than a century discussions have been ongoing about the question whether, and if so in what respects, human language is fundamentally different from the communication systems used by other species, from ants and bees to monkeys and apes. Closely related are questions such as how language, or language-like communication systems could develop during evolution of species, and especially for human languages questions such as how infants can acquire their native language in so short a time, with input that seems to be desperately incomplete and contradictory, and why it seems to be utterly impossible to build automatic systems that can process language at a level comparable to a six-year old.

Not surprisingly, a phenomenon that is as complex and at the same time as important for the social and economic wellness of people has been investigated by a wide range of scientific disciplines, each with its own traditions, research methods, and terminology. During the workshop it appeared once again that communication across disciplinary borders is often complicated by the fact that several disciplines use the same terms with quite different meanings. Fortunately, the attendants of the workshop were able to spot misunderstandings before they made communication impossible. However, one of the conclusions at the end of the workshop was that there is an urgent need for a platform that can help in establishing a terminology that is common to all disciplines that investigate aspects of language and communication. This is the more important because there is general agreement that the big questions about language can only be answered if many disciplines can make contributions that can be integrated.

It is now generally agreed that language can only be unravelled on the basis of a deep understanding of the physical and biological systems that support it and of how language could emerge in the course of evolution in the first place. While substantial progress has been made in the areas of the physics and physiology of language, research into the issue of how language could emerge was banned from the scientific discourse because of the lack of scientifically sound methods for investigating the relation between archaeological finds and language. Recent developments have changed this situation for the better, to a large extent thanks to methods developed in comparative biology that allow making inferences about the evolution and emergence of specific functions and behaviours.

Another development that is becoming increasingly important for coming to grips with the phylogenetic, ontogenetic and epigenetic development of language is computational modelling. The ever increasing computational power of digital computers and the rapid growth in the amount of memory are enabling a completely new approach to the analysis of very complex, yet structured phenomena by means of computer simulations. Combining knowledge from such diverse fields as artificial intelligence, psycholinguistics, biology and evolution it is now becoming possible to show that embodied, and therefore grounded, agents can effectively and efficiently learn very complex behaviours such as language using simple and biologically and cognitively plausible learning algorithms. During the workshop several promising results from computer simulations of phylogenetic and ontogenetic development of language were presented and discussed.

Better understanding of the physical and biological substrate of human language may not provide fast and hard answers to the question what sets human language apart from similar communication systems developed by other species. However, it is reasonable to expect that here too computer simulations of situated language acquisition and processing can be used to generate hypotheses that can explain the rapidly increasing pool of experimental and observational data, and that can suggest new experiments to complete the picture.

Assessment of the Results and Future Directions

All participants were very happy with the workshop, the overall organization, the venue, the contents and the possibilities for forging contacts with scientists from other disciplines. Formal and informal discussions always involved persons from disciplines that do not meet in the usual –often highly disciplinary- conferences and workshops.

During the closing meeting there was general agreement on the need for creating a community and network, for which the acronym LEAP was coined, for Language Evolution, Acquisition, and Processing. The conveners of the workshop will explore several possibilities for setting up a platform for exchange of information, databases, experimental results and software across the borders of the disciplines that take an interest in computational modeling of language evolution, acquisition and processing. As a start the conveners will claim a url containing the word LEAP. The website will be used as a depository for literature references, software and similar resources. In addition, an e-mail list with the same name will be created. Not surprisingly in an emerging community with members from many different disciplines, an urgent need was expressed for establishing a common and well-defined terminology. It was seen as an important part of the mission of the LEAP community/network to help creating such a common terminology.

A substantial list of research topics was mentioned during the closing sessions in which cross-disciplinary collaboration is necessary for obtaining real breakthroughs. These topics include sensorimotor integration, episodic vs abstract representations, priors vs learning, the faculty of language in the broad sense versus narrow sense, human and/or animal studies, animal communication, and baby communication. Obviously, this list reflects the cross-disciplinary discussions during the workshop. From this list it is equally clear that much work is still needed to draw a detailed roadmap for future research that can properly address all these issues in combination.

The conveners of this workshop will form a task group that will prepare a proposal for an ESF Networking Programme that can be submitted in the year 2008. In doing so, care will be taken to include prominent representatives of a range of disciplines and to focus on the research topics mentioned in the previous paragraph. The same (or if needed a slightly different) task group will explore the options for submitting a proposal for a COST Programme in the field of language evolution, acquisition and processing.

Several discussions were started during the workshop to explore the options for forming consortia that can prepare proposals for research initiatives in FP7. Specifically, options for proposals in the area of Cognitive Systems, Interaction, Robotics (ICT) or in Future and Emerging Technologies (also in ICT). It was stressed that membership in a consortium was not restricted to participants in the workshop, but that the workshop was meant to as a starting point for discussions about possible projects.

Since the workshop was co-organised by the FET project ACORNS one obvious follow-up event will be the workshop that will be organized by ACORNS towards the conclusion of the project. Another spin-off workshop will be in the framework of a new NWO-funded research programme entitled “A Computational Model of Language Acquisition”, awarded to Lou Boves (one of the conveners) and Paula Fikkert (one of the participants of this workshop).

Last but not least, the publication of a book related to the workshop was discussed. The most likely publisher is Lawrence Erlbaum.

Statistical Information on the Participants

The final 31 participants represented 12 countries: Netherlands (7), United Kingdom (7), France (3), Germany (1), United States (2), Switzerland (2), Belgium (3), Sweden (2), Finland (1), Norway (1), Ireland (1), Hungary (1).

Of the 31 participants, 6 were female and 25 were male. This gender ratio does reflect the situation in the relevant research fields.

Of the 31 participants, 6 were between 30 and 40, 11 were between 40 and 50, 10 were between 50 and 60, and 4 were older than 60 years of age.

Final Programme

Sunday 25 November 2007

evening *arrival*
21:00 hours **Welcome drinks**, IBIS hotel in the bar.

Monday 26 November 2007

09.00-09.30 **Welcome by Lou Boves**, Radboud University Nijmegen
and **Roger Moore**, Sheffield University

09:30-09:50 **Presentation of the European Science Foundation (ESF)**
Monique van Donzel (Standing Committee for the Humanities)

Session 1: Brains

09:50-10:40 **Sophie Scott**, Institute of Cognitive Neuroscience, London, UK

10:40-11:10 *Coffee break*

11:10-12:00 **Nicolas Rougier**, LORIA, Vandoeuvre-lès-Nancy

12:00-12:30 Discussion with speakers

Moderator: Istvan Winkler, Hungarian Academy of Sciences
Discussants: Hynek Hermansky, IDIAP, Martigny and **Rens Bod**,
University of Amsterdam, NL, and University of St. Andrews, UK

12:30-14:00 *Lunch*

Session 2: Psycholinguistics

14:00-14:50 **Anne Cutler**, Max-Planck-Institute for Psycholinguistics, Nijmegen

14:50-15:40 **Paula Fikkert**, Radboud University Nijmegen

15:40-16:10 *Coffee/tea break*

16:10-16:40 Discussion with speakers

Leader: Padraic Monaghan, University of Lancaster, UK
Discussants: Dirk Van Compernelle, Katholieke Universiteit
Leuven, Belgium and **Sven Behnke**, University of Freiburg,
Germany

16:40-17:20 General discussion on first day

Moderator: Roger Moore

17:20-17:30 Concluding remarks

Lou Boves and **Roger Moore**

evening *Dinner*

Tuesday 27 November 2007

Session 3: Evolution

- 09:00-09:50 **Pierre-Yves Oudeyer**, Sony CSL Paris
- 09:50-10:40 **Tecumseh Fitch**, University of St. Andrews
- 10:40-11:10 *Coffee break*
- 11:10-12:20 Discussion with speakers
Leader: Roger K. Moore
Discussants: Mark Steedman, University of Edinburgh and
Francisco Lacerda, Stockholm University
- 12:20-12:30 Concluding remarks
Lou Boves and **Roger Moore**
- 12:30-14:00 *Lunch*

Session 4: Learning

- 14:00-14:50 **Rens Bod**, University van Amsterdam, NL, and University of St. Andrews, UK.
- 14:50-15:40 **Walter Daelemans**, University of Antwerp, Belgium
- 15:40-16:10 *Coffee/tea break*
- 16:10-16:40 Discussion with speakers
Leader: Jeff Bilmes, University of Washington, Seattle
Discussants: Tecumseh Fitch, University of St. Andrews and
Paula Fikkert, Radboud University Nijmegen
- 16:40-17:20 **Louis ten Bosch**, Radboud University Nijmegen, ACORNS
- 17:20 -18:10 General discussion on second day
Moderator: Louis ten Bosch, Radboud University Nijmegen
- 18:10-18:20 Concluding remarks
Roger Moore and **Lou Boves**
- evening *Dinner*

Wednesday 28 November 2007

Session 5: Automatic Speech Recognition

- 09:00-09:50 **Chin-Hui Lee**, Georgia Institute of Technology, Atlanta
- 09:50-10:40 **Jeff Bilmes**, University of Washington, Seattle
- 10:40-11:10 *Coffee break*
- 11:10-11:40 Discussion with speakers
Leader: Hervé Bourlard, IDIAP, Martigny
Discussants: Ian Howard, dept Neuroscience, Univ of Cambridge, UK, **Bastiaan Kleijn**, KTH, Sweden
- 11:40-12:20 General discussion
Moderator: Hervé Bourlard, IDIAP, Martigny

12:20-12:30	Concluding remarks Hervé Bourlard , IDIAP, Martigny
12:30-14:00	<i>Lunch</i>
14:00-15:00	Plans for future research Roger K. Moore (/Lou Boves/Louis ten Bosch)
15:00-15:15	Concluding remarks Roger K. Moore /Lou Boves
15:15	Farewell coffee

Final List of Participants

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