VDI Technologiezentrum

EFMN

Issue Analysis Report

on the 2005 European Foresight Monitoring

Selected S&T issue for the 2005 cycle:

Cognitive science

Düsseldorf 10.10.05

Contents

1 The European Foresight Monitoring Network

The European Foresight Monitoring Network (EFMN) is an EC-funded network of policy professionals, foresight experts and practitioners as well as analysts of Science, Technology and Innovation related issues. The primary aim of the EFMN is to develop foresight related content and gather information about foresight projects from all over the world by means of a mapping process carried out by an international consortium – which includes ARC-SA, VDI, PREST, CKA, TNO, Atlantis, Fhg-ISI, Dialogik, and the Technology Centre Prague. Though in practice, the network is open to anyone to contribute data through a 'correspondent's network' – more on this below. The EFMN has several component parts, including (a) the mapping of information about foresight exercises into a database, (b) the preparation of short policy-oriented briefs on current and recently completed foresight exercises, and (c) the organisation of issue analysis workshops where a particular issue common to several foresight exercises is discussed and debated with a view to knowledge-sharing and networking across Member States.

The mapping of foresight exercises is done through a web-based platform called 'Dynamo', which is directly linked to the EFMN website (www.efmn.net). This platform is essentially an online database that is used to gather information on foresight exercises. Several indicators have been developed to map the exercises, drawing upon earlier work carried out in other projects (e.g. Eurofore), and where possible, using internationally accepted classification systems such as the OECD's Frascati and the EC's NACE.

The European Foresight Monitoring Network provides support to policy professionals by monitoring and analyzing foresight activities across the European Union, its neighbours and the world. The monitoring and analysis will be made available in a series of briefs and reports published on a regular basis at www.efmn.info. Monitoring and analysis relies on the efforts of a network of correspondents that gather and communicate information on ongoing foresight related initiatives. The work of correspondents is supported by DYNAMO the collaboration and knowledge platform of the TNO in the Netherlands at www.dynamo.tno.nl. The objective of EFMN is to establish a broad international foresight network, which aims at the identification of emerging issues and facilitates information exchange on foresight activities. The project has three main results:

- Foresight Briefs: About 30-40 briefs will be produced annually. In principle, there are two types of briefs. The Single issue briefs focus on a single S&T panel, sector or subject. The Overview briefs cover all fields within a particular region or the entire territory of a country, comprising a range of different topics.
- Mapping of foresight: A broad overview of recent and ongoing foresight activities will be mapped to facilitate information dissemination and to gain new insights. An annual foresight mapping report will be made to inform policy professionals, foresight experts and other interested users on foresight
- Issue analysis: The information gathered by the network will be analyzed on emerging issues. Each year an Issue Analysis workshop will be organized in which experts can discuss specific topics.

2 Executive Summary

The EFMN issue analysis (WP4 of the EFMN project) aims at identifying and analysing key emerging science and technology issues that are relevant for European Union policies. Each year, a selection is to be made of the international foresight themes, issues and activities that offer the highest potential to support European science and technology policies.

On an annual basis, the EFMN Network will

- exploit the outputs of the foresight mapping and the database in order to analyse the policy priorities that emerge from Foresight exercises throughout the world.
- identify and assess emerging S&T issues relevant to the European S&T policy making,
- prepare, convene and report upon an annual workshop involving the EU Commission and external experts.

The first phase (2005) findings consisted in an inventory of Foresight Exercises (EFMN/Dynamo Database), the issue selection, e.g. the development of an identification, selection and clustering conception, the validation of issue clusters and adaptation of / to Dynamo, the harvesting of key S&T issues (through exploitation of (current and emerging S & T issues in foresight exercises collected in) Dynamo and additionally bottom-up from EMFN network (validation)).

These processes resulted in the classification and listing of 21 "Emerging S&T issues 2005", which were ranked along their frequency in foresight exercises (backcasting) and additionally along their future importance (forecasting) by an expert team/EC voting.[1]

From all the information collected in this two-step process, a list of 21 "Emerging issues 2005" came up, as they appear in most recent foresight exercises (finalized in 2005 or still ongoing) and were ranked according to their frequency (**backcasting**).

The S&T issues that featured most prominently in the investigated foresight exercises were:

- "Construction/Urbanism/Rural Development",
- The "changing healthcare systems",
- The "knowledge based economy and society".

The results from this backcasting approach indicate on the one hand that these S&T issues have had already been relevant for a long time and are relevant for future national S&T policies; on the other hand, the results confirms the importance and partly the emergence of more specific S&T issues, such as

- "Construction and Urbanism / Infrastructure / Rural development",
- "Biotechnology / Nutrigenomics",

[1] Selection criteria of emerging S&T issues in (inter)national foresight exercises
- likely to take place over the next five to ten years
- tend to generate and promote possibilities for other scientific developments tend to benefit from international or global collaboration
- develop new approaches to multi- or interdisciplinary co-operation
- likely to result in major benefits to society
- linked with ethical aspects
- Contribution to EU policy objectives
- European research potential
- European added value

- "Cogno"

By virtue of their scientific knowledge, the EFMN team as well as the involved experts from EC staff had rather well different judgements on whether major scientific advances are likely in a given area over the next five to ten years, or on the likely impact on other S&T issues, or on the extent to which these fields are likely to be a priority for EU S&T/R&D policies.

The ranking of S&T issues through expert team/EC voting (**forecasting)** therefore arrived at different short lists, with a predominance of

"Construction and Urbanism / Infrastructure / Rural development"

"Changing Healthcare Systems",

"Energy",

"Cognitive Sciences and Systems".

The selected S&T issue from Foresight Exercises was for the EFMN year 2005 "Cogno" as represented in the most recent German, UK, and Danish foresight ecxercises. Cognition and Robotics / Understanding the Thought Processes/Cognitive Sciences.

3 The Issue Identification and Selection Process

On an annual basis, an issue analysis (WP4 of the EFMN project) will exploit the outputs of foresight monitoring and mapping in order to analyse the policy priorities that emerge from Foresight exercises in the Zone 1 and 2 countries.

The EFMN issue analysis aims at identifying and analysing key emerging science and technology issues that are relevant for European Union policies. Each year, a selection is to be made of the international foresight themes, issues and activities that offer the highest potential to support European science and technology policies.

On an annual basis, the EFM Network will

- exploit the outputs of the foresight mapping and the database in order to analyse the policy priorities that emerge from Foresight exercises throughout the world.
- identify and assess emerging S&T issues relevant to the European S&T policy making,
- prepare, convene and report upon an annual workshop involving the EU Commission and external experts.

3.1 Methodological Approach

Much methodological work has been undertaken to develop S&T indicators, however, these indicators have often failed to create effective policies for scientific and technological development. Therefore the process for the identification of the relevant foresight issues from international foresight exercises was built on the EFMN strength as a "bottom up" network through an iterative process, involving all national correspondents that have insight into their national foresight processes.

For the identification and filtering of "issues" from foresight exercises, the term "issues" should be interpreted in the sense of "trends and trendbreaks".

For the selection and choice of issues for the annual workshop, the mechanisms from the International Council for Science[2] was relevant as a guiding line, as well as the three major EC criteria for the identification of thematic domains of the 7th Framework Programme: Contribution to EU policy objectives, European research potential and European added value.[3]

This resulted in the following set of selection criteria for identifying those emerging S&T issues from (inter)national foresight exercises where the EU RTD systems might have a central role to play:

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[2] International Council for Science. 2002. Identification of Key emerging Issues in Science and Society: an International Perspective on National Foresight Studies. 28 pp. © ICSU 2002, ISBN 0-930357-54-X

VDI draft comments on kick-off meeting Sept 04.

[3] http://europa.eu.int/comm/research/future/themes/index_en.html#criteria

- issues that are likely to take place over the next five to ten years, where the necessary resources are likely to be made available to enable those scientific advance to take place (e.g. genomics, nanotechnology)
- issues that tend to generate and promote possibilities for other scientific developments or fields (e.g. new research instrumentation, modelling and simulation techniques)
- issues that tend to benefit from international or global collaboration (e.g. environmental sciences, space research)
- issues that develop new approaches to multi- or interdisciplinary co-operation (e.g. global warming, ageing)
- issues that are likely to result in major benefits to society, whether in the form of wealth creation, improved quality of life or risk reduction (e.g. new materials, earthquake prediction).
- issues that are linked with ethical aspects – for example, developments that are likely to reduce the digital divide/medical divide/nano divide...).
- issues that contribute to EU policy objectives[4]
- issues with high European research potential[5]
- issues with high potential for European added value[6].

3.2 The 2005 Selection-Process and Results:

The Issue Selection 2005 is the result of a five step process:

(1) the analysis of the EFMN foresight mapping system Dynamo (www.dynamo.tno.nl)

(2) the analysis of the input from the network partners

(3) the classification of step 1+2 result and the definition of the "Emerging issues 2005"

[4] The issue must generate new knowledge to meet societal needs and catalyse the delivery of a European policy objective(s), including the objective to transform Europe into a dynamic and competitive knowledge-based economy, capable of sustainable economic growth. Relevant policy objectives include those in the areas of health, consumer protection, energy, the environment, development aid, agriculture and fisheries, biotechnology, information and communication technologies, transport, education and training, employment, social affairs, economic and social cohesion, justice and home affairs. **The issue may be one of current importance or likely to become important in the medium to long term.**

[5] The issue is important whenever there is a strong potential for excellent research and technological development and for disseminating and converting the results into social and economic benefits. For example future support should, wherever possible, build on past and current investments and successes in relevant areas of research and its application.

[6] **For the issue progress, there must be a strong need for additional intervention at a European level**. Additional public funding to be justified by the externalities and wider benefits from the research and by the need to attract increased public and private investments. European level intervention to be justified by the need for European centres of excellence through collaborative research: to create the necessary multi-disciplinarity and critical mass of scale and scope; to overcome fragmentation and unnecessary duplication, lack of connections and of interoperability; to complement other intergovernmental, national and private actions; to address shared or European level problems; or to enhance visibility of European research excellence.

(4) the ranking by the network partners of “Emerging issues 2005”

(5) the selection of one issue for the issue analysis workshop by the EFMN core team and the EC.[7]

The first phase (2005) findings consisted in an inventory of Foresight Exercises (EFMN/Dynamo Database), the issue selection, e.g. the development of an identification, selection and clustering conception, the validation of issue clusters and adaptation of / to Dynamo, the harvesting of key S&T issues (through exploitation of (current and emerging S & T issues in foresight exercises collected in) Dynamo and additionally bottom-up from EMFN network (validation)). (Steps 1-3)

These processes resulted in the classification and listing of 21 “Emerging S&T issues 2005”, which were ranked along their frequency in foresight exercises (backcasting) and additionally along their future importance (forecasting) by an expert team/EC voting. The selected S&T issue from Foresight Exercises was for the EFMN year 2005 “Cogno” as represented in the most recent German[8], UK[9], and Danish foresight exercises[10].

3.2.1 Step One: Issue Analysis Sandbox in Dynamo

For the reduction and ranking of the large number of issues and topics featured in foresight exercises to a manageable number of key issues for analysis, the “Issue Analysis Sandbox” (www.dynamo.tno.nl) was produced. With this tool, the number of themes and subjects can be ranked, and politically / socially / economically contextualised.

There are 132 Issues collected in the Issue Analysis Sandbox (Status: 05.07.2005). For 32 of these 132 issues, no reference was given corresponding to the issues, i.e. wherein these issues are addressed

--> these 32 issues had therefore to remain out of consideration.

Under the remaining 100 issues it was checked which issues had been addressed in a foresight study either in 2004 or in 2005 or even in a study which is still ongoing.

The issues which were addressed in earlier studies were not taken into account (on behalf of the EC).

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[7] Prior to this selection process the following tasks had been performed:

Sept 04- Dec 04: Development of Issue analysis conception, various definition approaches to „issues“

Jan 05 – March 05: First list of collected issues – iterative process, first clustering approach

April – May 05: issue clusters validation and input into Dynamo - Telecon among all WP 4 partners, confirmation of working schedule

June 05 – July 05: VDI Issues Analysis of current and emerging S & T issues in foresights from Dynamo and bottom-up from EMFN network (WP4 team) - first summary issue list and "shortlist" - ranking by EMFN network (WP4 team) - ranking by EC

[8] Understanding the Thought Processes

[9] Cognitive Systems

[10] Cognition and Robotics

Result of this check: 27 issues from the Issue Analysis Sandbox (Dynamo) were actually addressed in a recent and/or ongoing new foresight exercise (2004-2005).

3.2.2 Step Two: Analysis of Input from the European Foresight Monitoring Network

The network partners delivered hand selected information about the foresight exercises in the countries they have taken responsibility for. Affluent information was available on foresight exercises in: the UK, Ireland, Turkey, Germany, Netherlands, Belgium, Luxemburg, Canada, USA, Malta, France, Switzerland, Liechtenstein, Czech Republic, Slovakia, Poland, Latvia, Lithuania, Estonia, Greece, Cyprus, Romania, Bulgaria.

No relevant information was available for the following countries: China, Japan, Korea, Sweden, Portugal, Hungary, Iceland, Brazil.

In these cases, either no information could have been collected from the national correspondents in a bottom-up process or the available information could not have been exploited in absence of English translations of the foresight reports. This was especially the case for the Chinese foresight process (completed 2004) and for the Japanese 8th Delphi round, for which results had just been published in Japanese in May 2005 and which are not translated yet.

3.2.3 Step Three: Classification and definition of the "Emerging issues 2005" - Backcasting approach

From all this information a list of 21 **"Emerging issues 2005"** (socio-economic issues, but also technological and scientific ones) came up, classified according to the Dynamo Manual along the topics, as they appear in the foresight exercises.

Emerging Issues in most recent Foresight Studies (finalized 2005 or still ongoing)

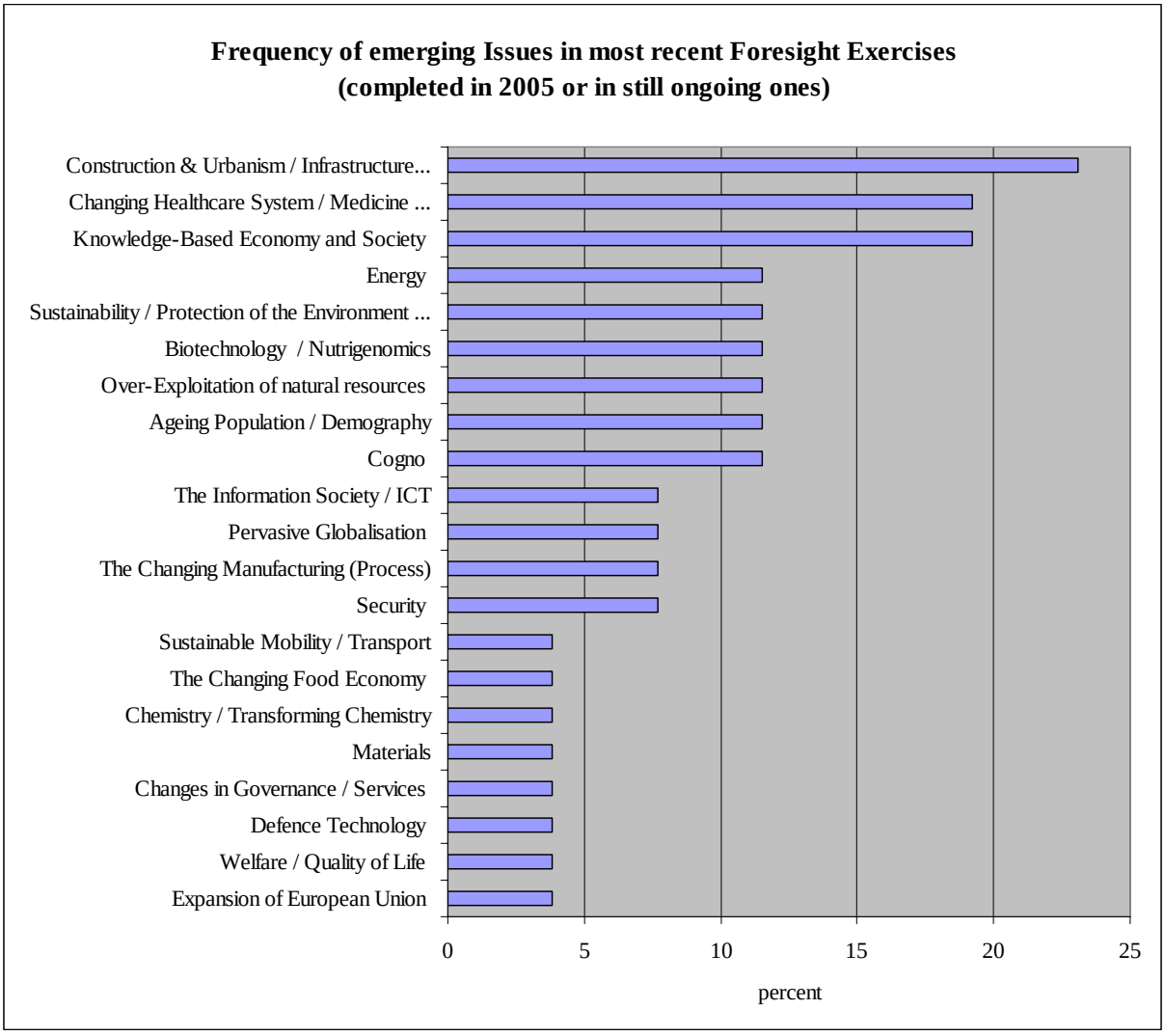
- Changes in Governance -- Services, - Modernization of public services
- Ageing Population / Demography
- Biotechnology - Nutrigenomics
- Chemistry / Transforming Chemistry
- Cogno - Cognition and Robotics, Understanding Thought Process
- Construction and Urbanism / Infrastructure / Rural Development
- Defence Technology
- Energy -- Renewable Power Sources, - Reliability of electric networks and distribution centres of high voltage, - Use of Hydrogen and Fuel Cells as Power sources, - New Nuclear technologies for generating electricity , high-potential heat and hydrogen, Reducing energy intensity in operating buildings, Mobil Power Management
- Expansion of European Union
- The Changing Manufacturing (Process)- Industrial Development
- Materials
- Over-Exploitation of natural resources - Securing the Energy Supply, - Water as Resource / Vision for a guaranteed supply and access for all in the 21st century
- Pervasive Globalisation - Living in a networked world: individual and secure
- Security - Observation of the Earth and Risks
- Sustainability / Protection of the Environment / Reduction of Environmental Quality - Observation of the Earth and Risks, Sustainable Regional Planning
- Sustainable Mobility / Transport
- The Changing Food Economy - Food and Drinks Industry, Healthy and Vital Throughout Life by Prevention / Quality of Life through Healthy Nutrition
- The Changing Healthcare System / Health / Medicine / Pharmacy - Nutrigenomics
- The Information Society / ICT- Creating Open Access to Tomorrow's World of Learning
- To a Knowledge-Based Economy and Society- Knowledge-Intensive Business Services, Lack of Scientists (JP), Market Demand for Overall Solutions, Understanding Thought Process
- Welfare / Quality of Life - Social and Health Services

The basic classification for this clustering approach is the predefined clusters given in the Issue Analysis Sandbox in Dynamo (www.dynamo.tno.nl): Each topic was clustered either as an issue, an innovation or a S&T Development, whereas:

- "Issue = the problem side of society, with focus on societal issues and specific research needs that can be addressed by innovations. (Definition Dynamo Manual)
- Innovation = a change of fulfilling a specific social function, by applying a new scientific or technological development in a commercial successful way. (Definition Dynamo Manual)

- S&T Development = development in research or technology, which can / could lead to Innovations, in order to provide a solution to one socio-economic issue.)"[11]

The Issue Analysis Sandbox helps to reduce the large number of issues and topics featured in foresight exercises to a manageable number of key issues for analysis. This is, of course, the critical element. Not only have the number of themes and subjects to be ranked, but as part of this process, they have to be politically / socially / economically contextualised. This is necessary before listing and before full analysis can begin.



The single issues that had been dealt with in recent and/or ongoing foresight exercises, were added up and scored as percentage to make the comparison easier: The issues that featured most prominently in foresight exercises are: "Construction/Urbanism/Rural Development" (25%), the "changing healthcare systems" and the "knowledge based economy and society". For various reasons less popular in recent foresight studies are the issues "Expansion of the EU", "Quality of Life", "Defence Technology", "Materials", etc. addressed in less than 5% of the Foresight studies.

[11] www.dynamo.tno.nl

These results approve on the one hand the expectations and common sense. These issues are relevant for future EU and national policies and have already been relevant for a long time. Issues like "The Changing Healthcare System", "Energy", "The Knowledge-based society" or "Sustainability / Protection of the Environment", which are global challenges and had been already addressed in former Foresight exercises, are hence still important for the next future.

On the other hand, the diagram confirms the importance and partly the emergence of more specific S&T issues, such as "Construction and Urbanism / Infrastructure / Rural development", "Biotechnology / Nutrigenomics", "Cogno" etc.

3.2.4 Step Four: Ranking of the Emerging Issues of Foresight Studies completed in 2005 or of still ongoing ones by team members - forecasting approach

The issues analysis team selected the most interesting issues from the 21 emerging issues by a voting system (the 10 issue perceived to be the most important ones). Their ranking was weighted in the following way: the most important issue scored 10 points, the second-most one scored 9 points, et cetera, and the least important one (i.e. for each ranking the 10^{th}) scored only 1 point. The points associated to the 21 issues were then added up and compared directly.

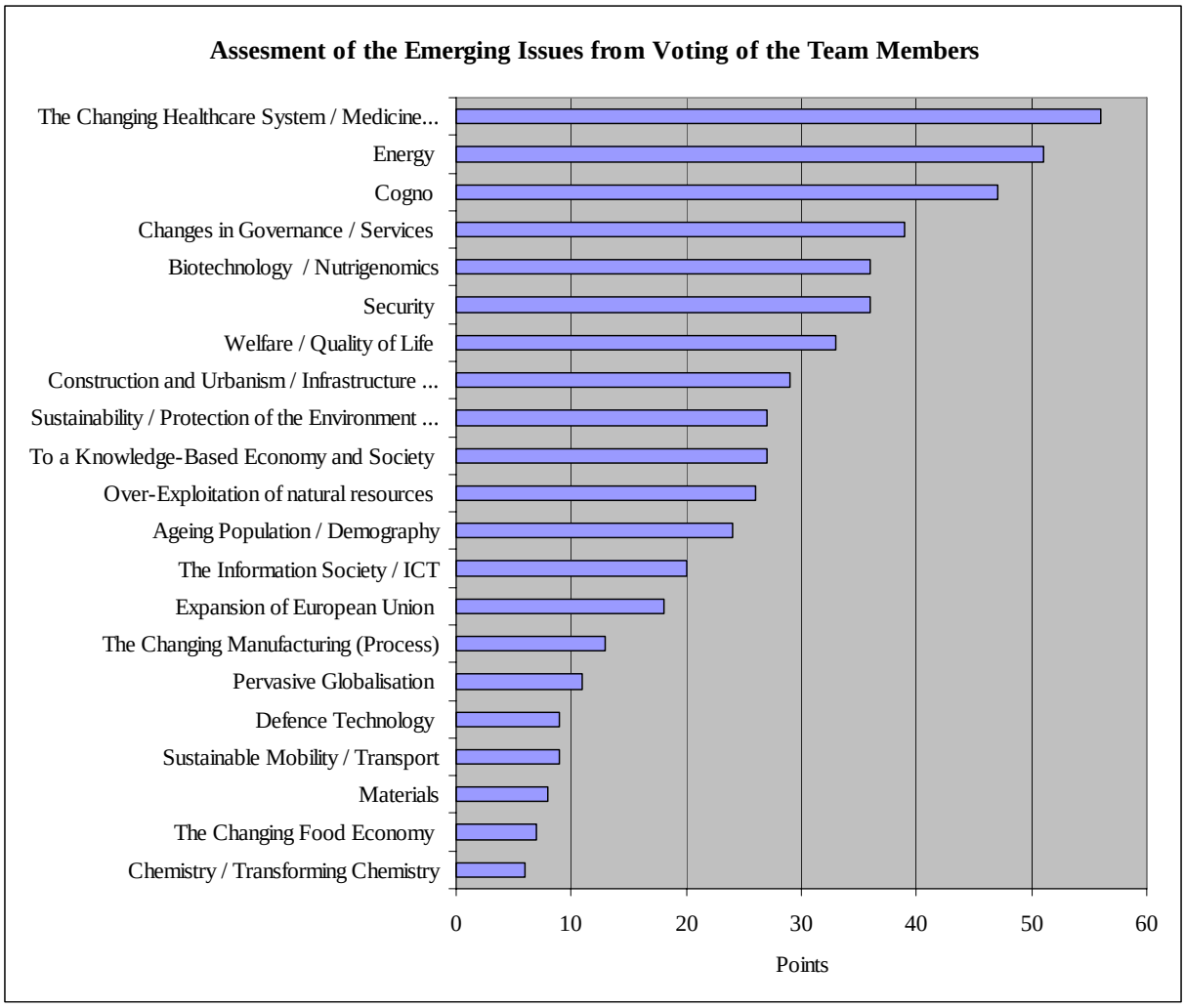
The importance of each single issue is therefore a combination of two facts:

(1) How often does the issue belong to the 10 most important ones each partner chose out?

(6) Which place in each partner's ranking does the issue take?

The most important issue amongst respondents was that of 'Changing Healthcare Systems" followed by "Energy" and "Cogno".

Less importance was perceived by the EFMN network correspondents for "Transforming Chemistry", "the changing food economy" and "materials".



3.2.5 Step Five: the selection of one issue for the issue analysis workshop by the EFMN core team and the EC

The results and outcomes from steps 1-4 and the responses from the EC were regrouped according to an arbitrary classification (some sub-themes indeed might have been classified in more than one general theme). Classifying the responses into the chosen categories was difficult because of the non homogeneity of the answers. The identification of the data was not easy; some responses were more specific than others, and many topics overlapped. The respondents didn't all identify the same issues as the most important and relevant ones for the EU policy,, explaining the broad thematic scope of the answers and why the total frequency of themes sited exceeds the number of participants.

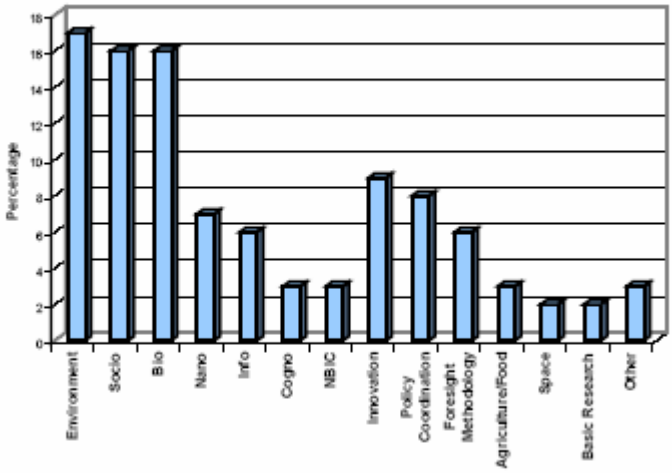
3.2.6 Additional information taken into account

A call for ideas has been launched in March 2004 by unit K2 in DG Research of the European Commission to provide inputs on the future research topics to be considered for the next Framework Pro-

grammes.[12] The results of that consultation provided a list of RTD priority themes for Foresight activities in FP7:

The results mentioned in "diagram 7a" show that the most popular topics amongst respondents was that of 'Environmental Issues', which was mentioned in 17% of all responses. This theme includes direct references to "Environmental Issues and Technologies' as well as references to 'Energy, Sustainable Development and Transport/Mobility'. The second and third topics were 'Social Issues' and 'Bio-topics' both being mentioned separately in 16% of all responses. The theme 'Social Issues' incorporates most issues concerning economics, society and political science whilst the theme 'Bio-topics' includes most biotechnology, genomics, health issues and life sciences. It is also interesting to note that there was a relatively high reference to Innovation policy (9%) and the coordination of Research policy (8%) at all different levels, with a specific focus on the role of Regional Foresight. Regional Foresight was also mentioned as a key element for sustainable regional development in the environmental issues. A special focus was also given on Foresight Methodology, Evaluation and Funding (6%).

Diagram 7a: importance of RTD priority themes



Source: ftp://ftp.cordis.lu/pub/foresight/docs/consultation2004_final2.pdf

For the EFMN selection emerging S&T issues it was not so much the aim to provide a suitable inventory of S&T priorities in national Foresights, but rather to extract the first two or three most important scientific developments from which the EC scientific agenda could profit, and to prompt a fruitful discussion of these emerging S&T issues.

By virtue of their scientific knowledge, the EFMN team as well as the involved experts from EC staff had rather well different judgements on whether major scientific advances are likely in a given area

[12] More than 400 questionnaires were sent by e-mail to Foresighters. The low number of answers (67) does not allow to draw significant conclusions, but some sectoral trends can be extracted. These deserve further attention by a more systematic exploration.

over the next five to ten years, or on the likely impact on other S&T issues, or on the extent to which these fields are likely to be a priority for EU S&T/R&D policies.

The ranking of S&T issues through expert team/EC voting (forecasting) therefore arrived at different short lists, with a predominance of

"Construction and Urbanism / Infrastructure / Rural development"

"Changing Healthcare Systems",

"Energy",

"Cognitive Sciences and Systems".

Therefore and despite these difficulties the selected S&T issue from Foresight Exercises was for the EFMN year 2005 "Cogno" (covering also the converging technologies Nano, Bio, Info, Neuro, Cogno and the economic, social and environmental topics that belong to it). as represented in the most recent German, UK, and Danish foresight exercises. Cognition and Robotics / Understanding the Thought Processes/Cognitive Sciences.

Cognitive Science as has been selected in the EFMN first analysis cycle for various reasons:

1. Europe, which holds a large part of the responsibility and merit for launching cognitive science and fuelling it with some of its key insights, must make a very resolute effort to remain in the lead, in the face of the increased level of competition brought about by China, and the US which is giving cognitive neuroscience top priority.

2. Europe is motivated to do so, in part for reasons shared with its competitors, in part for reasons of its own, such as the specific problems of a diverse, multicultural, complex, and ageing population.

3. It also has the means to realize this ambition: cutting-edge teams in various areas, strong traditions in the core disciplines, a respect for diversity which has preserved a pool of seminal ideas and active traditions which will be needed in the search for the more sophisticated and differentiated ideas required as the simple intuitions of the early stages no longer suffice, last but not least an excellently trained population of top students.

4. Building a strong European cognitive science is a goal which all the members of the EC can contribute to, as all of them can, and have begun to, promote research in the field, which does not require the heavy artillery of 'big science'.

5. There are many obstacles where the EC could intervene: some having to do with the handicaps shared by all of European science, some related specifically to cognitive science, such as, an unfocused perception of its nature and potential in academic institutions and policy-making bodies; the competition of reigning branches in the core disciplines; a less than positive attitude towards interdisciplinary work; a reluctance to change basic organizational patterns, and a generally slow pace in the implementation of innovative policies.

6. Even though the performance of EU science in understanding neuronal processes is recognized worldwide, more synergies could be achieved in cognitive sciences Europe, especially with regard to the ability to compete on an international level.

4 The Issue Analysis 2005: Cognitive Sciences

4.1 Definition

Cognitive Science can be defined as "...the interdisciplinary study of mind and brain, combining the concepts, methods and insights of large parts of psychology, neuroscience, evolutionary biology, linguistics, philosophy, anthropology and other social sciences, and formal methods from computer science, mathematics and physics. It capitalizes on polar oppositions such as function (the cognitive/peceptual/motor/emotional faculties and abilities identified by psychology, linguistics and philosophy) vs form (the biological, mechanical, or formal-computational realizations of these functions); infant vs adult; normal vs inpaired; human vs prehuman, non-human primate and non-primate animal; natural vs artificial; individual vs social/distributed. It is entering a phase of explosive development as neuroimaging techniques bring new methods of evidence-gathering to the field at just about the moment where it has reached a level of integration, sophistication and knowledge which were simply unthinkable when it emerged half a century ago. **Cognitive science thus understood is a major challenge and undertaking in pure science for the XXIst century.** The potential for applications, in the medical and psychiatric realm, for sensory and motor prostheses, for normal, remedial, and compensatory education, for cognitive, communicative, and decision-making tools is enormous. The impact on individual, social, and cultural practices and self-understanding, with implications in the political, economic, and ethical realms, cannot be underestimated. Finally, the stimulation which cognitive science brings to its core contributing disciplines, and to the general movement of scientific and cultural ideas, is considerable."[13]

4.2 The Global Perspective on Cognitive Sciences

> "Cognitive science will provide insights into ways to present information to human beings so they can use it most effectively."... If the Cognitive Scientists can think it, the Nano people can build it, the Bio people can implement it, and the IT people can monitor and control it".[14]

Worldwide a mood of optimism can be observed with regard to cognitive sciences, connected to a paradigmatic change within the entire range of neurosciences, including the integration of computer models and the pervasion of mathematics. In some countries, a massive increase in the support of research and training programmes can be seen. In the area of 'cogno', many groups, team, organisations and institutions, as for example the five American 'Sloan Centers for Theoretical Neurobiology' should be mentioned, as well as the 'Center for Neural Computation' in Israel, the 'Gatsby Computational Neuroscience Unit' in the United Kingdom, the 'Institute of Neuroinformatics'

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[13] Daniel Andler (2005), COGNITIVE SCIENCE, Report for the Directorate-General for Research, Directorate K, Key technologies for Europe, Paris; ftp://ftp.cordis.lu/pub/foresight/docs/kte_cognitive.pdf.

[14] Roco, M.H.; Bainbridge, W.S.(2004): Converging Technologies for Improving Human Performance: Nanotechnology, Biotechnology, Information Technology and Cognitive Science. www.wtec.org/ConvergingTechnologies p. 12

in Switzerland, and a considerable number of groups with a very good research profile in Germany, as well as the 'RIKEN Brain Science Institute' in Japan.

The US National Science Foundation (NSF) and Department of Commerce issued a report on "Converging Technologies for Improving Human Performance" in July 2002, and held the NBIC conference in February 2003 in Los Angeles. Both examine the integrated role of nanotechnology, biotechnology, information technology, and cognitive science (NBIC) in improving human mental and physical performance.

Leading experts from government, the academic research community and the private sector explored the nature and scope of the potential opportunities in NBIC convergence. The impact on quality of life may be dramatic, with research ultimately affecting medicine and manufacture. Over the next 20 years, converging NBIC technologies could allow such capabilities as:

- Direct human brain/machine connections, transforming work, sports and art;
- Computers and environmental sensors worn as part of everyday attire;
- More robust, healthy, energetic human body, easier to repair when necessary;
- Practically any structure made of tailored materials, able to adapt to changing situations, offer energy efficiency while remaining environmentally friendly;
- Treatments for many physical and mental disabilities, perhaps completely eradicating some handicaps such as paralysis or blindness.

It appears the goal of the NSF report was to create an international initiative and funding to exploit the concepts in the report. Five areas where accelerated efforts to achieve technological convergence would be especially worthwhile are:

(1) The Human Cognome Project, a proposed multidisciplinary effort to understand the structure, functions, and potential enhancement of the human mind.

(2) personal sensory device interfaces,

(3) enriched community through humanized technology,

(4) learning how to learn, and

(5) enhanced tools for creativity.

Key visionary ideas and projects discussed in this report

a) Overall Potential of Converging Technologies[15]

b) Expanding Human Cognition and Communication[16]

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[15] Changing human activities towards the "innovation age"
Human cognome project and cognitive evolution
Brain-to-brain interactions and group communication
Spatial cognition and visual language using converging technologies
Enhanced tools for learning and creativity

[16] Predictive science of societal behavior
Healthcare, body replacements, and physiological self-regulation
Brain-machine interfaces and neuromorphing engineering

c) Improving Human Health and Physical Capabilities[17]

d) Enhancing Group and Societal Outcomes[18]

e) National Security[19]

f) Unifying Science and Education Changing the human culture

4.3 The EU Perspective on Cognitive Sciences

4.3.1 EU High Level Expert Group on "Foresighting the New Technology Wave" - Converging Technologies –Shaping the Future of European Societies

To formulate an appropriate answer to the NBIC-project the European Union has installed an Expert Group on Foresighting the New Technology Wave. [20]

The European Commission first drew attention to Converging Technologies (CTs) in the June 2003 issue of the Foresighting Europe newsletter.

"In order to deal with the questions developed in the US NBIC report, the Commission envisages the establishment of a high level expert group on Converging Technologies."[21]

The expert group was charged with exploring in breadth the potential and the risks of CTs. Rather than develop merely a European answer to the US report, the expert group had to consider also the specific limitations of previous approaches to NBIC convergence. It therefore confronted a dual demand, namely

- to delineate areas of interest and fields of application for CTs, and
- to relate these CTs to the European environment and policy goals.

The group met this demand by placing CTs in the larger context of the Lisbon strategy for an ageing and diverse European knowledge society committed to just and sustainable living patterns. It developed an expanded vision of convergence, broadly captured in the acronym "CTEKS: Converging Technologies for the European Knowledge Society."

Improving sensorial capacities and expanding functions
Improving quality of life of disabled people

[17] Aging with dignity and life extension
The Communicator: enhancing group interaction and creativity
Cognitive engineering and enhancing productivity
Revolutionary products, including "aircraft of the future"

[18] Networked society, with bio-inspired culture
Enhancing physical and mental capacity of a soldier
Enhancing readiness and threat anticipation tools
Globally linked detection devices

[19] Uninhabited combat vehicles
Unifying science from the nanoscale and integrative principles
Cognitive, civic, and ethical changes in a networked society
Breadth, depth, "trading zones," and reshaping education at all levels

[20] http://europa.eu.int/comm/research/conferences/2004/ntw/pdf/final_report_en.pdf.

[21] Foresighting Europe, June 2003, issue 2 of the Newsletter of the Science and Technology Foresight Unit, European Commission, Directorate-General for Research, p. 2-4.

The Expert Group has formulated eight special recommendations in the field of cogno and ICT and added three challenge problems. The Expert Group asked for special attention to;

- Software synthesis
- Intelligent user interfaces
- Uncertainty reasoning, argumentation
- Ontologies and knowledge bases in education, legal issues and on science and technology foresights
- Deduction
- Semantic web
- Knowledge extraction
- Evolution and self-organization

The three challenge problems are:

- Natural Language Processing
- Integrated Hybrid transportation System
- Assistant with Global 'Conscience'

Cognitive sciences feature in this report on various occasions and the need for the support of basic cognitive science is highlighted in it recommendation No 6: Commission and Member States should expand and deepen their commitment to Cognitive Science.

"For the purposes of CTEKS, this includes basic research on social cognition, the replacement of commonsense psychology as the basis of social science research, an investigation of potentials and limits of "engineering of the mind"- approaches, and the study of the effects on cognitive processes by technical environments such as video game culture."[22]

The expert group's report shows how this expanded vision can serve to shape research and development (R&D) in the context of the Lisbon strategy.

They found that cognitive science needs to investigate the physical and social determinants of cognition as well as their interplay. Also, the effects on cognitive processes by technical environments should be investigated: If the video game culture has altered how students learn, the pervasively artificial environments of the future will have a more profound effect.

4.3.2 EU "Key Technologies" Expert Group: Reports on Converging Technologies

On behalf of the Direktorate K of the RTF Directorate the EU "Key Technologies" Expert Group has approached the future of several key technologies which are all crucial for Europe's future. Among various research and technology fields (biotechnology, nanotechnology, information technologies, communication technologies, transport technologies, energy technologies, environmental research, social sciences and humanities, manufacturing and materials technologies, health research, agricultural

[22] http://europa.eu.int/comm/research/conferences/2004/ntw/pdf/final_report_en.pdf

research, safety technologies, complexity research and systemic, research in the services sector) cognitive sciences featured prominently.[23]

Already in 2004 a "Special Interest Group Report" for the European Commission [24] defined some of the particularly challenging issues, to be[25]:

Influence of nanotechnology on cognitive sciences:

- Difficult to link N & C conventionally except via I due to lack of knowledge of non-electronic processing systems
- Sensory augmentation via nanotech particles or structures
- Mechanical intelligence via MEMS and NEMS?
- Intelligence via basic physics and chemistry using emergence from small-scale interactions

Influence of biotechnology on cognitive sciences:

- Little understanding of biological computation methods
- Only biological intelligence mechanism is neural based
- Positive feedback loop is strong between B&C
- Use of stem cells in brain regeneration after stroke or accident

Influence of ICT on cognitive sciences:

- Concepts of cyberspace are still very immature, so we don't know how artificially intelligent entities could progress
- Persistent lack of understanding of consciousness
- Little understanding of what makes life
- Strong AI researchers seen by many as cranks
- Lack of legal framework for independent inorganic artificial life or conscious machines
- No understanding how we might manage hybrid life forms that exist both in cyberspace and physical world
- Use of cyberspace linked to augment objects in physical world
- Smart responsive environments, AmI & PICT
- Obvious commercial advantages from high levels of AI
- Conscious computers can handle extra kinds of tasks
- Affective computing
- Human-free companies
- Autonomous systems

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[23] Daniel Andler (2005), COGNITIVE SCIENCE, Report for the Directorate-General for Research, Directorate K, Key technologies for Europe, Paris; ftp://ftp.cordis.lu/pub/foresight/docs/kte_cognitive.pdf.

[24] Foresighting the New Technology Wave, (W. Bibel, D. Andler, O. da Costa, G. Küppers, I. D. Pearson)

[25] Bibel, W. (2004): Converging Technologies and the Natural, Social and Cultural World - Special Interest Group Report for the European Commission via an Expert Group on Foresighting the New Technology Wave. Rapporteur and Editor: W. Bibel, Members: D. Andler, O. da Costa, G. Küppers, I. D. Pearson. 26 July 2004

Influence of Nano-Bio-Info on cognitive sciences:

- Powerful technology combination attractive to weapon use – policing difficult
- Sensors & Sensor nets
- Hybrid systems
- Biological customisation
- Smart bacteria
- Full direct brain link
- Mental immortality

The report elaborated recommendations to the European Commission in view of the NBIC (nano, bio, info, cogno) technology wave and its forseeable impacts and the general recommendations of the group are:

- The technological development must not continue to destroy the delicate balance in the natural and cultural world in the crude way as in the past, but rather contribute to the preservation of the wonderful variety in all aspects (including material, technological, ecological, cultural ones, etc.) fortunately still in existence in this world and particularly in Europe.
- In larger NBIC projects an ongoing assessment of the potential impact of the developed technology is considered essential. The methods of assessment should be empirical by way of installing and testing prototype systems, but also be done in a simulative and modelling manner. In order to improve the modelling techniques an expansion of basic research in Intellectics (i.e. AI and Cognitive Science) towards positively influencing a "hardening" of the social sciences is deemed necessary.
- The development of quantitative methods and assessment tools for the entire life cycle of the new converging technologies as well as for its full system impact including regulations and laws should receive a high priority. This includes support for the decision making from the funding phase through the implementation and maintenance of the technology within some environment, thereby respecting assessed technical and ethical limits.
- Encourage the development of a whole society model from which the impact of special recommendations can be analysed which might produce recommendations for European market potentials thereby exploiting the potential of the advanced simulation and modelling techniques including those from AI.
- Converging technologies as well as scientific knowledge accumulated in Intellectics and Neuroscience shed a harsh light on the dubious boundaries between the traditional disciplines. It is strongly recommended to the Commission to contribute by its various actions, not least by its funding policy, to a truly scientific evaluation of the merits of this traditional structure as well as of the role of some of the disciplines, and also to take steps towards a structure which is more in line with the modern scientific "Weltbild".
- Europe must focus its balanced efforts to keep its leading position or, where needed, catch up in the individual basic research and development areas involved in NBIC as well as in its converging technologies.
- Explore the development of an advanced ethic which is consistent with the modern
- scientific "Weltbild" and rests on the European values which evolved over the centuries.
- Funding recommendation: We propose to lay a particular emphasis in the funding of 1. Software synthesis; 2. Intelligent user interfaces; 3. Uncertainty reasoning, argumentation; 4. Ontologies and knowledge bases (KB); 4.1 KBs in education; 4.2 Legal KBs; 4.3 KB on science & technol-

ogy foresight; 5. Deduction; 6. Semantic web; 7. Knowledge extraction; 8. Evolution and self-organization.

4.3.3 NEST Pathfinder

The European Commission has launched an open call for proposals for new and emerging science and technology (NEST) - Pathfinder - under the 'anticipating scientific and technological needs' activity of the Sixth Framework Programme (FP6). This is one of the areas covered by the 'integrating and strengthening the European Research Area' specific programme.[26]

This call covers the areas: Complex systems, Synthetic biology, What it means to be human[27]:

Complex systems

Complexity is a critical challenge for many areas of science and technology. Emerging areas of science such as 'systems biology' and 'biocomplexity' are founded on the idea that phenomena need to be understood in the context of highly interactive processes operating at different levels. Similarly, there is an increasingly urgent need to understand and predict the behaviour of highly interacting manmade systems in areas such as communications and transport, which permeate the modern world. The same applies to human networks such as social, political and financial systems, where technology has tended to vastly increase both the complexity and speed of interaction, which is sometimes nearly instantaneous.

The aim of the initiative is to give an impulse to complex systems research in Europe by supporting cross disciplinary research on complexity as well as collaboration between the field of 'complex systems science' and particular disciplinary areas of science where complexity is a key issue, such as in biological systems, the environment and ecosystems. It will promote the creation of new, interdisciplinary partnerships between researchers within the field of complex systems and those in a range of other fields, as well as the extension and generalisation of successful techniques for dealing with complexity from one area of research into others.

Synthetic biology

Scientific and technological capabilities have now reached a point where 'synthetic biology' - novel engineering systems making use of complex biological processes - can be envisaged. A new realm of possibilities for biology based technologies is on the horizon, with the promise of an acceleration in both scientific discovery and innovation.

The goal of this initiative is to stimulate forward looking, cross disciplinary research to demonstrate key principles and generate tools and building blocks for synthetic biology. The research will focus on design and engineering of new biology based systems and processes with substantially different characteristics from natural systems and with real applications in mind. This could involve, for example:

- design, development and demonstration of key components of engineering systems based on biological processes (genetic circuits, metabolic pathways, signal transduction pathways) and their sub components (functional proteins, metabolites);

[26] http://fp6.cordis.lu/nest/calls.cfm

[27] http://fp6.cordis.lu/nest/call_details.cfm?CALL_ID=118

- applications in areas such as synthetic chemistry, production of new materials, energy production, communication and signalling systems and biological sentinels.

What it means to be human

Advances in molecular biology, neuroscience and genetics, have opened new perspectives for cognitive science and associated fields such as linguistics and anthropology. The question 'what makes humans different?', once a matter of philosophical speculation, has now become central to science. It is at the core of current efforts to build an integrated understanding of the human mind.

With its common values, varied cultures and strong research tradition in many relevant fields, Europe has a vital interest in this area and real potential for fostering scientific advance. To exploit this potential, this initiative will support cross disciplinary research which brings to bear the latest insights from fields including genetics, biology, neuroscience, psychology, linguistics and anthropology to examine 'how and why are human cognitive facilities unique?'

4.3.4 EU-Information Society Technologies

The strategic objectives of the IST thematic priority are updated regularly. The objectives for 2005-06 have been defined in a changing environment for undertaking research in Information and Communication Technologies (ICT):

- ICT research is increasingly organised on an international scale, as firms seek to relocate their R&D activities in the face of accelerating competition in global markets,
- innovation processes are more open, with wider and faster exchange of ideas, people and resources,
- technology chains are increasingly complex, making it more difficult for any single player to establish industrial leadership in any ICT field,
- new promising fields are emerging at the cross-over between ICT and other disciplines such as biotechnologies, materials and cognitive sciences.

Applied IST research aims to extend the scope and efficiency of IST-based solutions addressing major societal and economic challenges, and to make them accessible in the most trusted and natural way to citizens, businesses and organisations. The applied research therefore focuses on - among others - research activities on "e-inclusion" will mainstream accessibility in consumer goods and services, including public services, through applied research and development of advanced technologies. This will help ensure equal access, independent living and participation for all in the Information Society. Activities aim to develop next generation assistive systems that help persons with disabilities (in particular cognitive) and aging citizens to play a full role in society and to increase their autonomy.

Within the program "FET" (future emerging technologies - 320 M€ in FP6) Cognitive Science becomes the driving paradigm (Computation is cognitive') with genetically determined brain and brain plasticity, and pleaded for a new computational science as glue (challenge for FET in FP7!)

The role of Cognitive science and ICT is to provide an open and proactive approach, a critical mass, and a multi-disciplinary approach (at the frontier of technologies but goal-driven). Even though the goals largely set by the research community there are new options where roadblocks are foreseen. The position of Cognition Research in this programme is to address advanced issues in intelligence and

cognition, from neuronal to cognitive level for autonomous systems, devices or interfaces, and consciousness research.

4.3.5 EC Vision - European Cognitive Vision Network

One of the projects (Project 35454) of the EU IST Programme is EC Vision, a research network which was formed to promote research, education, and application systems engineering in cognitive AI-enabled computer vision.[28]

EC Vision has four main activities:

- Research Planning
- Education and Training
- Information Dissemination
- Industrial Liaison

It started March 2002 and was established for a period of three years. It has published a white paper on industrial applications and a research roadmap of cognitive vision. The Research Roadmap identifies seven major 'challenges' that constitute the priority topics for research in cognitive vision. Four of them are related to the scientific foundations, the other three deal with methodological issues. Most challenges are formulated at a rather high level of abstraction, such as 'advancement of methods for continuous learning' and 'identification of minimal system architecture', though they set the stage for a more detailed elaboration. In a "roadmap" EC Vision emphasizes that computer vision is an important and maturing engineering science. In its white paper on industrial applications it highlights the challenges in the field of cognitive vision from an application oriented perspective.

"The term cognitive vision has been introduced to encapsulate an attempt to achieve more robust, resilient and adaptable computer vision systems, by endowing them with a cognitive facility; the ability to learn, adapt, weigh alternative solutions, develop new strategies for analysis and interpretation, generalize to new contexts and application domains, and communicate with other systems, including humans."[29]

4.3.6 IPTS Study on Converging Technologies for Enabling the Information Society

The IPTS study on Converging Technologies for Enabling the Information Society is directed at providing an overview on the R&D landscape regarding the convergence of techno-scientific disciplines around ICT, with a special focus on the convergence of ICT with cognitive science.

The study aims to develop a vision on the converging technologies that give recommendations for EU R&D policy in this field.

The study was conducted in 2005 by the Institute for Strategy, Technology and Policy of the Netherlands Institute for Applied Scientific Research (TNO-STB) in collaboration with VDI Technologiezentrum GmbH (VDI TZ, Future Technologies Division), and the Dutch Centre for Science and Technology Studies (CWTS) of the University of Leiden, The Netherlands. TNO-STB will be the

[28] http://www.ecvision.org/home/Home.htm

[29] EC Vision, 2005; p. 1 EC Vision (2005). A Research Roadmap of Cognitive Vision. vs 4.2 February 2005.

Lead Contractor for the study, responsible for overall project management, outcomes and deliverables, as well as for communications with IPTS.

Emphasis was given to the provision of an overview of the R&D situation in the field of ICT and Cognitive Science, and ICT and other emergent disciplines such as biotechnology, nanotechnology and material sciences. The study is based on a combination of bibliometric and patent analysis complemented with an open-web method to gather in-depth information about the key centres in the field of ICT and Cognitive science within the EU25. A comparison will be made with the situation in the USA and Japan. Trends and prospects were collected and market potential sketched. A similar exercise took place for the convergence of ICT with biotechnology, nanotechnology and material sciences. This exercise also made use of bibliometric and patent analysis and a co-nomination procedure that is enrolled through the web.

4.4 EU Foresight Studies:

Among the most recent foresight studies on Cognitive Sciences and Systems are the UK Foresight, the German Futur and the Danish Teknologisk Fremsyn, as well as an the IPTS study on Converging Technologie and the EC-roadmap on Cognitive Vision. These studies and papers highlight specific European trends and prospects in the field of cognitive science.

4.4.1 UK Foresight on Cognitive Systems[30]

The British Foresight-Programme is carried out by the Department of Trade and Industry. The "second round" of the programme considered here was based upon 14 sector or topic-specific interdisciplinary expert panels drawn from representatives of business, science and government who met in several workshops. The goal of the programme was to identify crucial market prospects and hazards as well as future development opportunities within each sector up until 2020. Additionally significant cross sectional topics in the fields of politics, statutes, training and education were intended to be emphasised and appropriate future work and research fields examined. What remains relatively unclear is how the topics for panel discussion came about and were evaluated.

The UK Foresight Panel describes Cognitive Systems as being "natural or artificial information processing systems, including those responsible for perception, learning, reasoning, decision-making, communication and action."[31] The cognitive Systems project began in April 2002 and is now in its aftercare phase. It aimed to provide a vision for the future development of cognitive systems through an exploration of recent advances in neuroscience and computer science.

The aim was to produce a vision for the future development of cognitive systems through an exploration of recent advances in neuroscience, computer science and related fields, and their potential for future interaction. The objectives of the project were:

- to examine recent progress in two major areas of research - artificial and living cognitive systems - and their related disciplines (including computer science, neuroscience, cognitive science, artificial intelligence) - to understand whether progress in understanding cognition in living systems has new insights to offer those researching the construction of artificial cognitive systems;
- to scope the likely developments in these fields over the next decade, and in particular to scope the likely rate of progress in our capability to build artificial cognitive systems;
- to articulate significant conclusions from this, if any, which are worthy of communication to a wider audience.[32]

The reason for the initiative was the added value for the communities of neuroscience and computer science to work together; and that without co-operation there were unlikely to be advances in some of those areas. The UK Cognitive systems project aims at the provision of a vision for the future of re-

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30 http://www.foresight.gov.uk/Previous_Projects/Cognitive_Systems/index.html

31 [UK Foresight, 200?] Project overview http://www.foresight.gov.uk/Previous_Projects/Cognitive_Systems/Reports_and_Publications/General_Reports/cognitive_overview_of_the_project.pdf (25 May 2005)

32 http://www.foresight.gov.uk/Previous_Projects/Cognitive_Systems/Defining_the_Project/Aim_and_Objectives.html

search in cognitive systems conducted between international researchers in both fields. The major question is, what sorts of systems and applications will come up as major applications of the emerging science – what areas will bring user value and economic activity together? How will new application areas be received in the broad community – will they pose particular challenges that demand public policy responses?

Among the key findings was the perception that the interface between life science and physical science will accelerate progress in both – fundamental challenges on both fronts; that the cognitive capabilities will be pervasive vs. cognitive systems; and that there will be profound social implications, already emerging from pioneers – fact, fiction and ambition intertwined in debates about what it means to be human.

The project is widely perceived as having been successful in:

- Helping to define an emerging field of new science - cognitive systems - to which life and physical scientists are contributing, with the emerging definition of it being:
- Identifying relevant groups of UK-based scientists and engineers, based in industry and academia, and bringing them together for interactive workshops at which common ground was established.
- Identifying exemplar "grand challenges" that constitute fertile ground for further research.
- Creating an accessible summary of the work done during the year, with the assistance of a consultant science writer (Michael Kenward) and distributing this to a wide range of relevant groups (CUGPOP, members of Research Councils and their Research Boards, selected scientists in other countries working on similar topics). A book is also in preparation.
- Establishing “Foster Parents” (professional societies) to carry work forward in the years ahead, a framework of “Foresight Fellowships” (to be funded by EPSRC and MRC) for small cross-disciplinary pilot projects, and an “Action Plan” to ensure self-sustaining research networks.[33]
- As we rely more and more on complex systems for our essential services we will need self adapting, self learning systems to ensure their dependability.
- Cognitive systems will be an important underpinning technology in the future as the ability to ‘think’ is built into more and more infrastructure and objects and information processing power becomes a commodity.
- Cognitive systems will have significant economic and social implications.
- In certain areas advances might only be possible with collaboration.
- The neuroscience community needs better models and artificial cognitive systems to analyse the ever increasing amounts of information generated as they move to recording multi-neurone activity. Such technology could lead to significant advances in the treatment of mental disorders.
- The current list of prospective grand-challenge workshops includes: Knowledge, Memory and Learning; Robotics; Self-Organisation; Speech and Language; Vision.

Among the more significant outcomes of the project was the conclusion that research into natural and artificial cognitive systems is indeed at a exciting stage. A future framework is recommended that consists in an environment in which cognitive systems can flourish, e.g. adequate training; a critical mass of scientists, technology and instrumentation, the launch of exemplar areas and the start of the debate on the social and economic implications.

[33] http://www.foresight.gov.uk/Previous_Projects/Cognitive_Systems/Defining_the_Project/Cognitive_Systems__A_Summary.html

The researchers who took part in the project also agree that there could be great benefits in bringing together the life sciences and physical sciences to consider how they can collectively accelerate progress in cognitive systems. For a decade or more, the two disciplines had, with a few exceptions, worked separately. To a certain extent this was a result of earlier disappointments in artificial intelligence, based on incomplete and oversimplified views of how the brain works. In brain research, the physical sciences have played a key role in developing new tools and techniques. For example, functional magnetic resonance imaging (fMRI), allows increasingly detailed measurements at better resolution in time and space. Researchers can also record the activity of ever larger arrays of individual neurons. Over the past decade information technology (IT) has continued its usual relentless path. Declining costs have made massive amounts of computing power available to ever more users. The challenge for the future is not how to continue to supply more computing power but how to make best use of it.[34]

Key issues for EU RTD

Training – Future research in cognitive systems will need contributions from researchers who are comfortable to work across traditional disciplinary boundaries while still being experts in their own field. This could be encouraged through "cross discipline" PhD students with supervisors from the life sciences and physical sciences. For established researchers, fellowships could provide opportunities for life scientists to acquire knowledge of the physical sciences, and vice versa.

Funding – there are exciting opportunities in research across disciplinary boundaries. While there is certainly a case for investigating the possibility of further funding mechanisms, the European national Research Councils and minitries and other organisations have already shown interest in discipline breaking research and are likely to reflect this in future funding decisions. There is a need to enable cross-disciplinary proposals on EU level.

Public debate – Research in natural and artificial cognitive systems has enormous social implications. If society is to appreciate the possibilities, to accept novel applications and technologies and to influence their development, it is important to debate the issues in advance.

Applications areas

- Business & Commercialisation
- The Ambient Web
- From PDA to PDE - The Personal Digital Environment
- Embodied Cognition - Robots and Smart Things
- Health, Well-being & Performance
- Transport
- Sociable Technologies: Arts, Entertainment and Companions
- Education
- Military

[34] An overview of the Cognitive Systems project including project outcomes. Michael Kenward, November 2003, http://www.foresight.gov.uk/Previous_Projects/Cognitive_Systems/Reports_and_Publications/General_Reports/index.html

4.4.2 The German Foresight Process FUTUR: Understanding thought processes[35]

"Future – the German Research Dialogue" was carried out by a project consortium on behalf of the German RTD Ministry, utilising a mixture of methods. Participatory and interdisciplinary applied workshops took the place of expert enquiries, as for example used in the Delphi procedure. The aim of Future is to develop so-called leading visions for 2020 on behalf of the BMBF with which research projects may subsequently be planned. The proceedings began with a search for topics. It is intended that three to four topics per year be developed are to be elaborated and explored.

The broader number of participants was roughly 1100 people involved in proceedings all to various degrees, of which roughly 400 were active. It was attempted to involve other participants than the traditional actors, however, selection was relatively unmethodical. Proceedings themselves were subject to stark changes while in operation and as a whole were not very transparent. The work on the topics themselves took place in an interdisciplinary setting, and the implementation of the results was directly linked to proceedings and a graphic scenario made the results easily understandable.[36]

The aim of the Futur Lead Vision "Understanding Thought Processes" is:

- to explain the function of the human brain through its structure and neuronal dynamics.
- to build upon this knowledge, applications in medicine, in the biological sciences, in artificial intelligence systems and particularly in research on learning represent goals of social importance.

The human brain is the most complex structure of biological evolution. The vision of 'Understanding Thought Processes' should therefore be viewed as a research task comparable in importance to the human genome project. It requires interdisciplinary cooperation on the part of neuroscience, theoretical physics, mathematics, computer science, biology and medicine. Experimenters and theorists need to cooperate in a networked fashion on this joint project. The time is favourable for this lead vision, as research in these areas is being intensified worldwide. The scientific breakthroughs of the last few years in the young field of 'computational neuroscience' and, on the practical applications side, in the artificial neuronal networks, hold the promise of great progress in realising the vision of 'Understanding Thought Processes' in the course of the next decade.

The way that thinking works is still one of Nature's secrets. However, neuroscientists have increasingly made progress in recent times in answering this basic question – basic too for our entire understanding of ourselves. Investigative methods developed in physics and the application of the most modern computer technology are playing an ever-greater role in this research. What new opportunities will be opened up when we better understand how information processing, cognition and creativity take place in the brain? On the one hand, more efficient teaching and learning strategies could be developed using this knowledge. On the other hand, better knowledge of the processes in the brain is a prerequisite for the development of new or improved neuroprotheses in medicine, which could reduce or eliminate handicaps – for example, an artificial retina for the blind. Already, technical procedures are being used, which represent an imitation of biological principles. Would it not be possible to successfully apply this bionic approach – learning from Nature – to electronic data processing too?

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[35] http://www.futur.de/en/6458.htm

[36] Futur Lead Vision „Understanding Thought Processes", Berlin, July, 2002 http://www.futur.de/en/6458_6560.htm

Future Research Priorities

Among the future research priorities are: computational neurosciences, bioanalogous information processing, organic computing, internationalisation, linking to the OECD's ‚International Neuroinformatics Coordinating Council' and support from supradepartmental efforts (biotechnology, software, health, general education system).

With regard to future research priorities, the study emphasizes the combination of experiment, modelling and mathematical theory building. This will lead to a highly disciplinary field consisting of neuroscientists, cognitive psychologists, ICT-specialists, mathematicians and biologists.

Germany has at present a strong position in this interdisciplinary field. It also is one of the leading countries with respect to neuro-implantats (such as the artificial cochlea and retina).

Computational Neuroscience

Neuronal dynamics are distinguished by strong non-linearity and manifold interlocked feedback loops. Clarification of the structure-function relations would therefore appear most promising in the form of a close combination of experiments, computer models and mathematical theory construction. In the last few years, a very dynamic field of research, 'Computational Neuroscience', has developed from this approach. Now, building upon the experiences and successes hitherto attained, the mutual effects of neuronal dynamics and information processing are to be investigated on the different neuronal levels of organisation.

Bioanalogous Information Processing

Interdisciplinary cooperation should be continued in the area of bioanalogous information processing in technical systems. Current focal points of research include, for example, 'organic computing', the principles of self-organisation in complex technical forms of interaction and networked structures, the technical application of the models to cognitive processes (e.g. the processing of vague knowledge and emotional information, anthropomorphic perception and movement capabilities in robots), information coding according to biological models, all the way to the use of robust biological principles for autonomous robots in complex natural environments. Additionally, the newly acquired solutions in information processing contribute to model building and to our understanding of the brain's functions.

Teaching And Learning Strategies

The models for understanding learning processes in the brain are still in their beginning stages. Recent findings show that the brain displays more plasticity even in adulthood than has been assumed hitherto. Research on the correlation of structural change and learning processes in the brain could therefore lead to new possibilities in the research of learning and the development of learning strategies.

Neuroimplants For Medicine

In the area of health care, understanding the processes taking place in the brain is the prerequisite for developing new and improved neuroprotheses. The artificial inner ear has already become reality; the development of an artificial retina for the blind is currently the subject of intensive research and development. The voluntary control of the movement of single groups of muscles by thought in the case of stroke or paraplegia patients is still a perspective of the future.

The first step toward realising the vision of 'Understanding Thought Processes' consists of connecting Theory and experiment, including the interdisciplinary education of young scientists in the field of the neurosciences. An approach to attaining this goal is the support of a regional centralisation of high-ranking interdisciplinary expertise. Internationally, this approach has already been chosen in many cases internationally. The focussing of expertise thus created has led to a clear increase in the speed of development in the field. The new facet, going beyond this approach, consists of a close networking of the regional nodes, characterised by the specific exchange of experimental data, methods of analysis, computer models and Theoretical approaches. The connection to the OECD's planned 'International Neuroinformatics Coordinating Council' is to be a central component of the strategy.

The focussing and expansion of existing, but hitherto 'subliminal' local capacities will create an intellectual and structural environment, which will effect new impulses in international competition and create room for innovative developments with great promise for the future. The work of these centres is to be supplemented by research programmes in the various areas of emphasis in the lead vision.

The German Futur Process focuses on understanding thought processes and identifies a number of cogno relevant priorities:

- clarification of the neuronal foundation of the brain performance
- R&D into technical systems (coupling of information processing with biological systems)
- neuro-implantates (artificial cochlea and retina)
- new knowledge of learning and learning strategies

A central concern according to the study is "the clarification of the brain performance from processing complex sensory stimuli through learning processes and the call-up of stored information to the planning and precise coordination of patterns of movement with relevance for behaviour."[37] The study emphasizes that neuronal information processing works according o totally different principles than current approaches in ICT. A better understanding of neuronal systems will influence computer architectures and algorithms of the future (keywords: asynchronous dynamics, error tolerance, insensitivity to unclear input signals, distributed representation, associative data processing, adaptation). Understanding thought processes will lead to powerful solutions for autonomous robots.

[37] Futur Lead Vision „Understanding Thought Processes", Berlin, July, 2002 http://www.futur.de/en/6458_6560.htm

4.4.3 Teknologisk Fremsyn Denmark - Cognition and Robotics[38]

The Danish Technology – Foresight - Project was organised by the Ministry of Science, Technology and Innovation, employing a series of interdisciplinary panels. The foresight exercise runs in all of 2005 and is expected to end in the beginning of 2006.

The purpose of the foresight is to provide a wide knowledgebase in regards to possible innovation related to the development of robot technology. On this basis, the steering group should point out, motivate and describe 3-5 different fields, where the use of robot technology seems particularly promising both commercially and industrially.

Furthermore, it is the purpose of each of the appointed fields of potential to formulate a research and development agenda for a research and innovation effort within robot technology, which both includes medical, sociological and psychological cognitive research and also includes technical scientific robot research and which also implicates present and future users and manufacturers of robot technological solutions.

The project must be carried out as a combined process of analysis and dialogue and has as its explicit objective that the thought process must include crossing existing scientific fields, which are concerned with basic problem statements in regards to cognition and research attached to cognitive learning and machinery's conversion to action via robots. This objective has to have take-off in future possibilities for application and user demands.

The time perspective for the foresight is 10 years.

The result of the project shall be a foresight report, which presents and puts the results of the accomplished analysis and dialogue process into perspective. The report must also describe and motivate the 3-5 different research and development programmes/agendas for an effort within a research and innovation for robot technology, which is prioritised throughout the project.

The target audience for the result of the foresight is the Ministry of Science, Technology and Innovation, Danish research council system and the Danish Council for Technology and Innovation, relevant knowledge institutions and universities along with companies on both the development side and user side of the technologies, which are in focus in the foresight.

A steering group of 8 experts has been selected to carry out the foresight.

The subject of "Cognition and Robotics" in the Danish Foresight aims at the formulation of a research and development agenda within robot technology by expert reports.

Perception, locomotion, navigation and social and socio-technical approaches are among the important dimensions of research in cognition. Users are mostly interested in useful robots, socio-technical design and organising, adaptation to new settings. The question is how to create mutual interests and spaces for interaction and learning across different knowledge domains. Are cognitive researchers interested in robotics and vice versa? The answers are due to the different research agendas respectively.

[38] http://www.teknologiskfremsyn.dk/index.php?id=6

5 The EFMN Annual Issue Analysis Workshop

The workshop was organised as part of the "European Foresight Monitoring Network" – EFMN (http://www.efmn.info/), performed for the European Commission Directorate General for Research by a Consortium led by TNO as part of a series of initiatives intended to provide a Foresight Knowledge Sharing Platform for foresight practitioners and policy makers in the European Union.

The workshop shall help consolidate the assessment of the 2005 EFMN foresight issue "Cognitive Science" for European policy and to foster cooperation between Member States that developed relevant foresight activities on cognitive sciences issues .

The basis for the workshop was a consolidation paper on "Cognitive sciences" in Foresight Exercises, performed by VDI-FTD, that entails the analysis of the foresight exercises and initiatives in various EU countries, the issue analysis process and the criteria to identify thematic domains, the 2005 selection process and results. A global and an EU perspective on cognitive sciences was presented, together with an overview of the national foresight exercises in the field of cognitive sciences ("cogno", "cogsci").

The purpose of this first Issue Analysis Workshop was an exchange information in cognitive sciences (as being one of the key emerging S&T areas) on the one hand, and an interlinkage with national foresight experiences (in the relevant field) on the other hand..

The underlying idea was to bring together experts from Cognitive Sciences Community with those from the Foresight Community in order to exchange ideas and thoughts and to share experiences on where strategic policy support is going.

Participants:
Invited Experts: Daniel Andler (Ecole normale supérieure & Université Paris-Sorbonne, France),
Christian Clausen (Technical University of Denmark, Kobenhavn),
Susanne Giesecke (ARC systems research GmbH Vienna, Austria),
Ivan M. Havel (Charles University, Prague, Czech Republic),
M. de Kamps (Technische University München, Germany),
Richard M Young (UCL Interaction Centre, University College London),
Kristina Kadlecikova (Technology Centre AS CR, Czech Republic),
Lars Kluver (Danish Board of Technology, Kobenhavn, Denmark),
Paco Gomez-Molinero (Visual Tools S.A., Madrid, Spain),
Bill Sharpe (The Appliance Studio Ltd, Bristol, UK)
EFMN Consortium: Anette Braun (VDI, Germany), Sylvie Rijkers-Defrasne (VDI, Germany), Maurits Butter (TNO, Netherlands), Michael Keenan (PREST, University of Manchester, UK), Patrick Crehan (CKA, Brussels, Belgium), Effie Amanatidou (ATLANTIS Consulting S.A., Greece).
European Commission: Theodius Lennon (DG Research, Head of Social Sciences), Paraskevas Caracostas (DG Research, Foresight Unit), Belmiro Martins (DG Research, Foresight Unit), Werner

Wobbe (DG Research, Foresight Unit), Carmen Marcus (DG Research, Foresight Unit), Elie Faroult (Foresight Unit), Philippe Cupers (DG Research), Norbert Malanowski (JRC- IPTS), Walter Van de Velde (DG INFSO), Shamila Nair (DG Research – NEST).

The workshop gave the participants the opportunity to discuss the options for strategic policy support through the „Cogno" community. The immediate concern was to discuss how to interlink national foresights in emerging areas (by the example of „Cogno") and which limits could be expected to obstruct mutual learning.

The participants agreed that this interdisciplinary workshop was an interesting experience and that much can be learnt from recent experiences (UK, Danish and German foresights, but also from the EC Vision project and other EC Services´ work, such as the IPTS study on Converging Technologies for Enabling the Information Society, NEST and FET). The workshop gave an impetus to further observe the driving forces in cognitive sciences, and how the S&T/R&D environment will evolve, particularly how national governments shape their research activities. The participants appreciated the opportunity to acknowledge how other communities/nations/regions/foresight exercises display the issue of cognitive sciences and to learn what "is in the pipeline", even though a direct comparison is not possible for too much differing objectives, aims and motivations. The workshop was perceived a useful tool for an inter-disciplinary exchange of information on what the future of „Cogno" holds, for discussion of good practice and exploitation of the state of the art in strategic policy support in the field of cognitive sciences.

Cognitive science is usually seen as compatible with and interdependent from the physical sciences, and makes frequent use of the scientific method, as well as simulation or modelling, often comparing the output of models with aspects of human behaviour. Still, there is much disagreement about the exact relationship between cognitive science and other fields, and the inter-disciplinary nature of cognitive science is largely both unrealized and circumscribed.

Cognitive science has given rise to models of human risk perception, and has been influential in the development of behavioural finance, in the rise of a new theory of the philosophy of mathematics, and many theories of artificial intelligence, persuasion and coercion. It has made its presence firmly known in philosophy of language and epistemology - a modern revival of rationalism - as well as constituting a substantial wing of modern linguistics.

Particular subtopics of cognitive science arguably include perception, attention, consciousness and memory. However, these are all long established fields within psychology, and there is a constant risk that cognitive scientists will merely reinvent discarded psychological analyses under a new vocabulary.

However, it should be recognized that cognitive science is not equally concerned with every topic which might bear on the nature and operation of the mind or intelligence. Social and cultural factors, emotion, consciousness, animal cognition, comparative and evolutionary approaches are frequently de-emphasized or excluded outright, often on the basis of key philosophical conflicts. Some within the cognitive science community, however, consider these to be vital topics, and advocate the importance of investigating them.

Questions which had to remain open and which were to be taken home surround issues such as:

- How to design a roadmap for European Cognitive Sciences in a Sustainable Knowledge Society?
- Are national S&T areas leading the EU cognitive sciences agenda or vice versa? How to interlink national foresights in Cognitive Sciences?
- How will different organisations try to meet the required changes?
- What is the participants (institute's) strategy in relation to these forces?
- What kinds of strategic conclusions should be drawn by the European „Cogno" community?

Critics of cognitive science have mentioned the following challenges:

- The emotion challenge: Cognitive science neglects the important role of emotions in human thinking.
- The consciousness challenge: Cognitive science ignores the importance of consciousness in human thinking.
- The world challenge: Cognitive science disregards the significant role of physical environments in human thinking.
- The body challenge: Cognitive science neglects the contribution of the body to human thought and action.
- The social challenge: Human thought is inherently social in ways that cognitive science ignores.
- The dynamical systems challenge: The mind is a dynamical system, not a computational system.
- The mathematics challenge: Mathematical results show that human thinking cannot be computational in the standard sense, so the brain must operate differently, perhaps as a quantum computer.

The workshop results suggest a resolutely top-down approach to get European cognitive science off the ground, based on a combination of 'Europeanized' centers of excellence, thematic networks, direct encouragement of pre-identified teams of excellence and the usual competitive call for proposals. It was also proposed to initiate on EC level a number of concrete measures to avoid the perhaps overly-emphasized pitfalls, to save islands of excellence threatened with extinction, or to promote work in areas where progress is crucially required. In order to finalize the diagnosis and policy choices to be made, and to conduct an ongoing, proactive application and adjustment of these choices, an assessment of operations in progress, and the planning of the next stages, it was proposed to have a High Authority for Cognitive Science in Europe.[39]

Recommended paths for leading cognitive science into the future:

- Strengthen the cognitive kernels within the main disciplines when they are worth strengthening;

[39] Daniel Andler (2005), COGNITIVE SCIENCE, Report for the Directorate-General for Research, Directorate K, Key technologies for Europe, Paris; ftp://ftp.cordis.lu/pub/foresight/docs/kte_cognitive.pdf.

- At the same time and with equal determination, develop a strong, inclusive, federative structure, which can oversee or initiate graduate programs, workshops, networks, and research funding, leaving no good team or community outside.
- Set up foresight and policy groups composed of top researchers who really can, and want to, do some hard thinking and present the case to the policy makers.

6 Outlook and follow up for the second EFMN cycle in 2006

Some adjustments in the 2006 issue analysis cycle shall be considered.

Since the 2005 issue analysis process was mainly determined by the process of setting-up the huge EFMN network and getting it working, much of the issue identification, selection and analysis process was performed with the character of trial and error and learning by doing. This can be better systematisized and there remains much to be improved for the next round in 2006.

The gathering, selection and mapping procedure of the focal emerging issues in foresight exercises (WP2, WP3) was suboptimal, hence, the issue analysis, which is entirely based on this input, can only develop likewise. It is strongly dependend on the frictionless advances of WP2 and WP3. Hence, more interaction and synchronization with the mapping (WP2, WP3) and briefs (WP5) production would be helpful.

The issue analysis was mainly performed by the work package leader. Active interaction with the other responsible partners was limited due to several reasons. This will be improved by starting the second cycle (2006) with a WP4 face to face meeting actively involving all repornsible partners from the beginning. (Travel expenses will be covered by the WP 4 budget of each partner).

The procedure of issue selection and analysis would gain from formalisation.

The objectives of the issue analysis workshop are not fully clear and need to be clarified in interaction with the EC.

Looking at the experience gained during the first cycle, the Issue Analysis was considered to be “of high profile and of much importance to gain momentum for the Network."

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