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Changing Knowledge Production in the Brain & Cognition Research Field

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An analysis of the knowledge production process

Master Thesis (45 ECTs)

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Abstract

The knowledge production process is subject to change. The view on research and knowledge is changing. Research is increasingly expected to have social and/or economic relevance. Society demands wider public accountability for (public funded) research. Furthermore, knowledge is increasingly perceived as an important driver for economic growth. Empirical studies to this changing knowledge production process are lacking, while it has strong implications for science policy as the changes and dynamics are field specific.

This thesis aims to contribute to the theory and methodology on the changing knowledge production. A framework and method for empirically analysing the changing patterns of the knowledge production process in scientific fields are developed. The field of brain and cognition serves as a case in this study. Consequently, this thesis contributes to a better understanding of the dynamics of and interactions in the brain and cognition knowledge production process.

The framework for analysing the patterns of change in the knowledge production process is build with the 5 major attributes of the Mode 2 theory combined with the 3 levels of the complex adaptive system, and assisted by the concepts of search regimes and the science-society contract. This combination takes the whole system of knowledge production, including its dynamics and interactions, into account.

A comprehensive dataset is analysed, which contains both quantitative and qualitative data: bibliometric data, data from 13 semi-structured in-depth interviews, popular media publications, research programme descriptions and calls for proposals. The combination of these data enables a multidimensional analysis that covers both global and local dynamics.

The results show that the knowledge production process is indeed changing, in line with the commonly acknowledged trends. Brain and cognition knowledge is produced in an interactive, interdisciplinary and international way; in close relation to society; and with attention to social relevance and accountability. The lack of increased importance of economic accountability and industrial participation confirms the field specificity of the changing patterns. Subsequently, specific recommendations for science policy are provided. Furthermore, the developed framework and method prove to be useful heuristics for an empirical analysis of the changing patterns in the knowledge production process in a scientific field.

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1. Problem Description and Research Question

A brochure of the Dutch umbrella organization *National Initiative Brain & Cognition* (NIBC) states that the field of brain and cognition research has not increased “just for the sake of understanding, but also to find concrete solutions to brain-related problems in society” (NIBC, 2001, p. 2). This statement emphasizes a trend that has been noticed for over the last 20 years: a changing knowledge production process. There are numerous alterations in the knowledge production process acknowledged over the years. Research is increasingly expected to result in applications and to be relevant in social and/or economic terms. The traditional distinction between ‘basic’ and ‘applied’ science is being challenged and the science-society interaction is changing (Martin, 2010). The science system has changed from an isolated practice to interactive, multidisciplinary knowledge production (Gibbons et al., 1994; Martin, 2010; Nowotny et al., 2001). There is an ongoing interaction between science and other parts of society (Rip, 1990). Attention to the role of knowledge in social and economic performance is increasing. Knowledge is more and more perceived as the economic growth driver in our knowledge based economy, while demands for wider public accountability for research are increasing as well (Martin, 2010). The social contract between science and society has become much tighter. Society has more direct expectations of the economic and social benefits from public funded research (Gibbons, 1999; Martin, 2010).

The changing knowledge production process is a popular research topic. Though mainly descriptive studies have been done with different frameworks (e.g. Etzkowitz & Leydesdorff, 1998; Functowicz & Ravetz, 1993; Gibbons et al., 1994; Hessels & van Lente, 2008; Slaugther & Leslie, 1997; Ziman, 2000). Empirical studies to the changes in the knowledge production process and the accompanying science-society interactions are little present. One reason for this lack could be the field specificity; changes in the knowledge production process differ across scientific fields (Bonaccorsi, 2008; Heimeriks et al., 2008; Heimeriks & Leydesdorff, 2012). Consequently, indicators for measuring the science-society interactions might also differ across fields.

This thesis empirically addresses the changes in the knowledge production process, with the emphasis on the science-society interactions. It questions whether the changes discussed in the literature can be empirically identified in a certain specific field. The research & science activities will be analysed, as well as the science-society dynamics. Subsequently it is questioned whether these research/science and science-society changes are interrelated.

The main research question for this thesis is:

> *What changes took place in the knowledge production process in the field of brain and cognition in the period 1990-2009?*

The area of brain and cognition serves as the case for this analysis. This field is interesting to analyze as recently the umbrella organization National Initiative Brain & Cognition (NIBC) has been set up to support and control the multi-disciplinary research field of brain and cognition research. Its mission is to support scientists in finding concrete solutions to brain-related problems in society. Improving people's quality of life and society as a whole is the ultimate goal (NIBC, 2011). The program is thus placed at the intersection of science and society. Its main aim is to achieve collaboration between pioneering scientists and cooperation with social and business partners, all to address questions relating to cognition and behaviour (NIBC, 2011). So, this research field seems to deal with the earlier mentioned changes in knowledge production: multidisciplinary, interactive research with economic and social benefits.

The research question describes the characteristics of the brain and cognition research field. This field refers to all brain en cognition related activities, of both public and private organizations, involved in the knowledge production process. The scope of this thesis is the 20 years time-span from 1990 till 2009. This timeframe is chosen as the knowledge production process has changed significantly over the last 20 years (Gibbons et al., 1994; Nowotny et al., 2001; Martin, 2010). Furthermore, analyzing this time-span is realizable within the timeframe for this thesis.

The changes in the knowledge production dynamics have strong implications for science policy for two reasons. First, science and knowledge development is increasingly important as knowledge is recognized as a driver for economic growth in our knowledge based economy (Gibbons, 1994). Second, the changes in the knowledge production process call for changes in the policy intervention techniques (Heimeriks & Leydesdorff, 2012; Martin, 2010). For this reason this thesis provides policy implications for the brain and cognition research field.

Two goals are served by this thesis: (1) This thesis contributes to a better understanding of the science-society interactions involved in the knowledge production process in the brain and cognition research field. Hence, this thesis contributes to the policy-making (by the NIBC) and thereby, indirectly, to better coordinated and facilitated brain and cognition research that might result in more and better applications. (2) This thesis contributes to the development of innovation theory, in particular theory on the changing knowledge production process. It will deliver an empirical analysis of the dynamics of the knowledge production process and its socio-economic context in a scientific field and determine indicators for doing so.

2. The Brain & Cognition Research Field

The last decades have brought many new insights in and knowledge about the structure and functioning of our brain and the relation with our cognitive functions (NWO, 2009). Several programs have been launched recently to stimulate the utilization of this knowledge. Brain and cognition knowledge is applicable in several areas.

First of all, brain and cognition knowledge may provide solutions for healthcare problems. About 1/3 of the, already striking, healthcare costs is caused by brain-related problems, like brain damage, dementia, neurologic diseases and psychiatric disorders (NIBC, 2011). Due to the aging population the pressure on healthcare and thereby the costs are expected to rise significantly (ZIP, 2009). Consequently, there is an urgent need for applications for preventing, early identifying or fighting brain and cognitive disorders.

The Netherlands has a knowledge-based economy in which knowledge and education are very important. However, the Dutch educational system is characterized by several problems. Many children have learning problems and subsequently are facing arrears, and the number of dropouts is substantial (NWO, 2009). Brain and cognition knowledge can help in adjusting education programs and addressing educational problems.

A third field of application is social safety. Society is endangered by a rise in aggressive and antisocial behaviour. Methods for an early detection of problematic behaviour early, and changing this behaviour are needed. Furthermore, public professionals, like police and ambulance officers and soldiers, are under great emotional stress. Methods to cope with this stress are needed as well. Brain and cognition knowledge may result in useful applications in this regard (NWO, 2009).

Recently, the Dutch National Initiative Brain & Cognition (NIBC) was set up to coordinate and facilitate brain and cognition research and the application of the results. The NIBC functions as a major umbrella organization and brings together scientific and social partners. Its ultimate goal is to use brain and cognition knowledge to improve the quality of life of individuals and society as a whole.

The brain and cognition research field is a broad research field that includes many disciplines like medicine, neurobiology, psychology, linguistics and sociology. The field can be roughly divided into three categories: neuroscience (e.g. measuring neural cells) cognitive neuroscience (e.g. analysing behaviour in relation with MRI) and cognitive psychology (e.g. behaviour experiments). Together, these categories form the brain and cognition research field, which will be the subject under study in this thesis.

3. Justification

The value of knowledge is increasingly noticed. Knowledge is increasingly perceived as an important resource in addressing social challenges and a driver for economic growth (Heimeriks & Leydesdorff, 2012). The knowledge production process is changing, which is a frequently studied topic by scholars. Several conceptual frameworks are developed for addressing these changes (see section 4.2 for examples). These studies have focused on the dynamics of the knowledge production process in a mainly theoretical way. Hence, empirical work on the chancing knowledge production process is lacking. This thesis will deliver an empirical analysis of the dynamics of the knowledge production process with the brain and cognition research field as a case study. A method for mapping the science-society interactions in the brain and cognition research field will be developed.

Furthermore, this thesis contributes to a better understanding of the knowledge production process, and its science-society interactions, in the brain and cognition research field. Much research is done on the changing knowledge production process and major advances have been made in the past few decades. However, no studies have been conducted to the process of knowledge production in this promising field.

Recently the Dutch umbrella program National Initiative Brain & Cognition was created to support the implementation of the brain and cognition knowledge into practice, with the ultimate goal of improving "people's quality of life and society as a whole" (NIBC, 2011, p. 2). Research fields differ in knowledge production (Asheim et al., 2006). Subsequently the copying of best practices in research and innovation policy may fail (Heimeriks & Leydesdorff, 2012). A good understanding of the knowledge production process and the science-society interactions might contribute to a more appropriate and effective policy. Hence, this thesis will conclude with some policy recommendations.

4. Theoretical Framework

As his thesis will analyze the characteristics of the knowledge production process of a scientific field over time, theory on this process will form the basis of the theoretical framework and the conceptual model. This chapter will first discuss the evolution of the knowledge production process in general over the past decades. Next, some frameworks and the selected theory for analyzing the changing knowledge production process will be discussed. Finally, the conceptual framework guiding this thesis with its accompanying hypotheses is presented.

4.1 Evolution of the knowledge production process

There have been significant changes in the knowledge production process over the last 20 years (Gibbons et al., 1994; Nowotny et al., 2001; Martin, 2010). The history of these changes is very well described by Martin (2010). This description will be used to discuss the evolution of the knowledge production process, as this is necessary for a good and complete understanding of the changes in the knowledge production process and the corresponding science-society interactions.

At the end of 1944 the US President, Franklin D. Roosevelt, asked the Director of the Office of Scientific Research and Development, Vannevar Bush, to investigate how the science system could best be arranged for "the improvement of the national health, the creation of new enterprises bringing new jobs, and the betterment of the national standard of living" (Bush, 1945). The results of his study formed the basis of a system with a clear distinction between basic research and applied research, often referred to as the *Endless Frontier* model (Etzkowitz & Leydesdorff, 1998; Martin, 2003). Basic research was clearly a task for universities and other academic institutions, while applied research was largely performed in government and industrial laboratories. This dichotomy was based on the belief that discipline-based universities could best produce knowledge 'for its own sake' while performing educational tasks, while government and industrial labs where seen as creators of technological knowledge that could be applied to produce new inventions. Basic, or academic, science was funded by the government following the (over-simplified) linear science-push model and based on peer-reviews. This funding was further supported by the economic notion of market failure and the idealized view of scientific knowledge being a non-rival, non-excludable public good of which the production is subject to great uncertainty and of which the benefits can not be fully appropriated by the producers.

This dichotomy view persisted until the 1980's. From the 1980's onward the production of knowledge experienced significant changes. Society became increasingly knowledge-intensive. Scientific and technological knowledge gained more and more importance as the knowledge based economy rose up. Knowledge was perceived as an important resource. Combined with globalization and the resulting economic competition, this led to an increase in governmental spending on knowledge production. At the same time more explicit and wider public accountability of governmental spending was demanded. Public funded research should thus generate benefits for the economy and society. The relationship between science and society became much tighter.

4.2 Theory for analyzing the changing knowledge production

The relation between science and society can be viewed as a social contract. Using the notion of a contract is proved to be a useful heuristic for understanding and studying this relation and the concomitant interactions between science and society (Hessels et al., 2009). Guston and Kenniston (1994, p. 5; in Hessels et al., 2009) identify four reasons why the metaphor of a contract is useful:

- A contract "implies two distinct parties, each with different interests, who come together to reach a formal agreement on some common goal";
- a contract is settled trough negotiation, "arrived at through a series of exchanges in which each party tries to secure the most advantageous terms";
- a contract "suggests the possibility of conflict – or at least disparity of interests"; and
- "contracts can be renegotiated if conditions change for either party."'

This thesis will use the definition of a social contract as is given by Guston (2000, p62) and enriched by Hessels et al. (2009, p. 389): Society "agrees to provide resources to the scientific community and to allow the scientific community to retain its decision-making mechanisms and in return expects forthcoming but unspecified" (economic, social, cultural or political) "[...] benefits."

The science-society contract is correlated with the knowledge production process in a bilateral way. A changing knowledge production process shapes the science-society contract and vice versa. Some major changes of this contract and the knowledge production process are discussed by Martin (2010). For example: The funding mechanisms for science were linked to their industrial or social revenues instead of general university funding. Due to globalization and ICT developments more international collaborations between scientists took place, resulting in a fiercer competition. Research furthermore became a more interdisciplinary network process with many interactions between the industry and universities. A last change is that technology and innovation depend more on developments in science, they are becoming more science-based.

Several concepts for analyzing the changing knowledge production process (and more or less its correlation with the science-society contract) are developed over time, such as: *Finalization in science* by Böhme et al. (1983), *Strategic Science* by

Irvine and Martin (1984); *Post normal science* by Functowitz and Ravetz (1993), *Innovation Systems* by Edquist (1997), *Academic Capitalism* by Slaugther and Leslie (1997), *Post academic science* by Ziman (2000) and *Triple Helix* by Etzkowitz and Leydesdorff (2000). Probably the most popular and most used concept for analyzing the transformation of the knowledge production process is the *Mode 2* concept by Gibbons et al. (1994)(Hessels & Van Lente, 2008). Hessels and Van Lente (2008) briefly discuss and compare these 7 concepts with the Mode 2 theory. They conclude that, despite some serious critics, the Mode 2 concept is a very useful theory for analyzing the transforming science system. Its main advantage is that this theory has the widest scope and takes cognitive, organizational and societal changes into account. As this thesis aims to analyze the changes in the knowledge production process, with the emphasis on the science-society interactions, the Mode 2 concept will form the basis of the theoretical framework.

Gibbons et al. present their concept of Mode 2 knowledge production, or *the new production of knowledge* like the title of their book, for the first time in 1994 as the outcome of a large collaborative research project. In the book the distinction is made between Mode 1 knowledge production and Mode 2, taking into account that Mode 1 has always existed, and still exists, and Mode 2 is the new emergent and ground-gaining form of knowledge production. The differences between the two modes can be most easily clarified by the five main attributes of this theory, like is done by Hessels & Van Lente (2008). The first attribute is the *context of knowledge production*. Mode 1 knowledge is generated in an academic context separated from the context of application. This doesn't mean that Mode 1 knowledge can't result in practical outcomes at all, but it is less likely and for doing so the transfer of knowledge is needed. Mode 2 knowledge, on the contrary, is produced directly in de context of application. Next, there is a difference in *disciplinarity*. Mode 1 knowledge is produced within scientific disciplines with little or less interaction between them. Mode 2 knowledge production is characterised by a dynamic interaction between disciplines, referred to as *transdisciplinarity*. Subsequently Mode 2 knowledge is transdisciplinary in nature and cannot be reduced to specific disciplines. Furthermore, this form of knowledge already diffuses to the context of application during the production. The third attribute of difference is the *homogeneity* versus *heterogeneity*. The production of Mode 1 knowledge takes primarily place in scientific institutions, while Mode 2 knowledge is generated in a heterogeneous environment, i.e. in a variety of organizations that mutually interact through communication networks. Fourth, Mode 1 knowledge production is perceived as an *autonomous* practice, while on the other hand Mode 2 knowledge is produced in a *dialogical* process. Subsequently Mode 2 knowledge is more contemplative and can incorporate multiple views and thus is often more social accountable. The fifth and last difference between Mode 1 and Mode 2 concerns the *quality control*. The knowledge produced in Mode 2 is also reviewed on economic, social, political or cultural criteria besides the traditional discipline-based peer review of Mode 1. In consequence the label of 'good science' cannot as easily be given to the Mode 2 knowledge. The transformation of the knowledge production process is often referred to as a shift in the science system from Mode 1 to Mode 2. These differences between Mode 1 and Mode 2 knowledge production are summarised in Table 1.

Table 1: Differences between Mode 1 and Mode 2 knowledge production (based on Hessels & Van Lente, 2008)

Mode 1	**Mode 2**
Academic context	Context of application
Disciplinary	Transdisciplinary
Homogeneous	Heterogeneous
Autonomous	Reflexive
Peer-review	Divers quality control

In his dissertation Hessels (2010) concludes that the Mode 1 and Mode 2 types should not be seen as existing and isolated forms of knowledge production, but rather as ideal practises. Furthermore, it's advised to study the 5 above mentioned attributes of knowledge production separately, as the coherence is limited and not undisputed.

4.3 Conceptual framework

The brain and cognition research field can be identified as a search regime. The notion of scientists searching for solutions to scientific problems in a particular scientific field forms the basis for this concept. A search regime is 'a summary description of the pattern of development of scientific knowledge and of the actual carrying out of research' (Heimeriks & Leydesdorff, 2012, based on Bonaccorsi's definition, 2004 p. 2). Search regimes may be characterized by different dynamics in knowledge production and science-society interactions (Bonaccorsi, 2008; Heimeriks & Leydesdorff, 2012). The characteristics can differ in three dimensions: the rate of growth, the diversity of growth and the level of complementarity (referring to the dependence on other researchers, institutions or infrastructures within the same or other institutional environments) (Bonaccorsi, 2004). The search regime concept is used to delineate the brain and cognition research field.

The changes in the knowledge production process described earlier can be distributed over three categories corresponding to the levels of Rip's (1990) evolutionary model of knowledge development: *the researching level* with scientists and researchers' daily activities and their ongoing local practices; *the scientizing level* with coordination and control mechanisms (like interactions in communicating and using scientific end-products to acquire recognition, e.g. for acquiring funding; and *the politicking level* with all interactions outside the scientific community, the political and social contexts (Rip, 1990; Heimeriks & Vasileiadou, 2008).

Heimeriks & Leydesdorff (2012) further developed the three-level system of Rip (1990) into what they call the 'complex adaptive system' of science. Their model analyses the dynamics of knowledge production among the three levels (research, science and society), taking the concept of search regimes into account. This model allows for analyzing the dynamics within the search regimes (vertical, level, dynamics) and between search regimes (horizontal, field specific, dynamics) and is thus a perfect tool for analyzing the dynamics of the knowledge production process in the brain and cognition search regime. The next section describes the characteristics of the changing knowledge production process per level and subsequently forms hypotheses.

Research

Within the Mode 2 theory, but also in the other concepts for analyzing the changing knowledge production process, an increase in collaborations in scientific activities is noticed (Etzkowitz & Leydesdorff, 1998; Functowicz & Ravetz, 1993; Gibbons et al., 1994; Heimeriks & Vasileiadou, 2008; Hessels & van Lente, 2008; Rip, 1990; Slaugther & Leslie, 1997; Ziman, 2000;). According to the European Union ' Lisbon agenda' research activities within the EU should be better integrated and coordinated, aiming at a common European knowledge society with many collaborations to increase efficiency, innovativeness and finally competitiveness (European Council, 2000). Furthermore, scientists nowadays are very mobile and can easily move globally. The transnational movements are influencing the characteristics of the knowledge production process (Jöns, 2007). Due to the growing importance of knowledge as an economic source, scientists are increasingly circulating globally (Jöns, 2007). The collaborations, and thereby the search regime, are subsequently expected to become more international. The research activities are also expected to be increasingly transdisciplinary, according to the Mode 2 diagnosis. Contemporary (social) problems, where science is expected to find solutions for, are growing in complexity (ASHE, 2009). Subsequently, experts with different disciplinary backgrounds are expected to be forced to cooperate (ASHE, 2009). Research activities that address these problems are increasingly interdisciplinary in nature (Weingart and Sterh, 2000, in ASHE, 2009). Furthermore, interdisciplinary research is perceived as stimulating scientific advancement, enhancing scientists' productivity and improving social goods (Sa, 2007, Van Rijnsoever et al., 2008). To determine whether these developments are present in the field of brain and cognition research the following hypotheses are tested:

> *H1a: Research in the brain and cognition search regime is characterised by an increase in collaboration.*
> *H1b: The brain and cognition search regime is becoming more international.*
> *H1c: The brain and cognition search regime is becoming increasingly trans- or interdisciplinary.*

The increasing collaboration in the science system is also present at the organisational level. According to the Mode 2 knowledge production theory the knowledge production is becoming increasingly heterogeneous; the science system is becoming more divers in organizational terms. The share of extra-academic contributions to research activities is increasing (Godwin & Gingras, 2000). Collaborations between scientists and non-university actors are considered valuable by current innovation insights and these interactions are currently increasing (Van Rijnsoever et al., 2008). These collaborations involve a wide array of institutional actors (Mowery, 1998 in Carayol, 2003). The scientific system has become much closer to industry, it has become increasingly industrialised (Slaughter & Leslie, 1997). According to Gibbons et al. (1994) and Hessels & Van Lente (2008) this industrialisation resulted in the development of new kinds of organizations at the academic-industry intersection. Examples of types of these organizations are research centres and consultancy firms. Thus, more organizations and more different types of organizations are active in research activities. To determine whether these developments hold true for the brain and cognition search regime the following hypotheses are tested:

> *H2a: The number of organizations involved in scientific activities in the brain and cognition search regime is increasing.*
> *H2b: The variety of organizations involved in scientific activities in the brain and cognition search regime is increasing.*

Science

A research field can be operationalised on the science level as an evolving set of related publications (Heimeriks & Leydesdorff, 2012). The number of publications is increasing rapidly in new science fields. Brain and cognition research falls within the scope of health and life science, which is such a new science field (Bonaccorsi, 2007). New science fields are further characterised by a large variety in topics of studies and research projects. They are marked by a divergent growth direction (Bonaccorsi, 2007). The rate and direction of growth have an influence on the knowledge production process, in terms of competition and uncertainty (Bonaccorsi, 2004, 2007). Both the rate and direction of growth of the brain and cognition search regime are expected to be high:

> *H3a: The brain and cognition search regime is characterised by a high growth rate.*
> *H3b: The brain and cognition search regime is characterised by divergent growth.*

Society

The analysis of the dynamics of the knowledge production on the society level will focus on the interactions between science and society. Following the Mode 2 concept, knowledge production has become a more reflexive process. According to the extensive study by Gibbons et al. (1994) social accountability reaches through the whole process of knowledge production. Knowledge production has become a dialogical process. As the issues dealt with are complex and not only scientific and technical by nature, researchers need to reflect all other actors involved (Gibbons, 2001). According to Heimeriks & Leydesdorff (2012) science can be seen as "an open communication system that is coupled to other parts of society". The interactions are part of the social contract, an unwritten agreement between science and society.

The social contract between science and society is twofold. Society asks researchers and scientists to do certain tasks and jobs it cannot do by itself, like providing solutions for existing (or future) problems. On the other hand, science is depended on society. Public support is a condition for the existence and survival of scientists (Hessels et al., 2009). In this sense, science and society are interacting and may influence each other. Scientists and researchers may induce a change in the behaviour of society, while society in turn may influence the behaviour of researchers. This interaction between society and science can be seen as a productive interaction. According to the European framework programme SIAMPI (Social Impact Assessment Methods for research and funding instruments through the study of Productive Interaction) one can speak of productive interactions when interactions between stakeholders (society) and researchers lead to changes in the behaviour of the directed group (SIAMPI, 2010). As this thesis focuses on the changes in knowledge production, the interactions leading to changes in the researcher's behaviour are of interest here. An example of a change in the behaviour of researchers is a change in their research agendas. Productive interactions can thus be seen as an underlying motivation or explanation for changes at the researchers side in the knowledge production process.

Productive interactions may occur through three main channels (SIAMPI):

1. Direct interactions: personal interactions via face-to-face contact of direct communication by telephone, e-mail or videoconferences.
2. Indirect interactions: interaction via some kind of information material, for example publications, TV items, radio programmes.
3. Financial interactions: an economic exchange between researchers and stakeholders. These interactions include research contracts, financial contributions and funding, but also intellectual property rights.

The social contract and the corresponding interactions between science and society are also noticed by Gibbons (1999). According to him science has to be produced in interaction with society. Knowledge is shifting from being 'reliable' to socially robust (Gibbons, 1999; Nowotny et al., 2001). Reliable knowledge becomes established "in terms of the replicability of research statements and the formation of a consensus within the relevant peer group (Ziman, 1991 in Gibbons, 1999). Socially robust knowledge, on the other hand, has three different characteristics: (1) it's valid both inside and outside the laboratory, (2) it involves a large group of experts through whom the validity is achieved and (3) it is less likely that this knowledge will be questioned as society has participated in its creation (Gibbons, 1999). The shift from reliable to socially robust knowledge goes paired with some changes. Science now needs to take into account many more social implications and many more factors need to be included before the results or solutions can be adopted (Gibbons, 1999). These changes led to a migration of the process of framing and defining social and scientific problems and the negotiations on their solutions. Instead of in the institutional locations, these processes now take place in the "'agora' – the public space in which both 'science meets the public' en the public 'speaks back' to science" (Gibbons, 1999, p. C83). Science is not working autonomously anymore. To become socially robust the knowledge has to be produced transparently and in open interaction with society.

According to Gibbons (1999) the borders between science and society have almost vanished away. Previously, the distinction between science and society was clear. Science was perceived as the "head of all knowledge" and communicated its results to society. Society then picked up these results and transformed them into new processes and products. However, science itself increased the range of problem areas that it serves, including new and non-traditional disciplines, leading to a change in the relationship with society. Science has become more and more involved in society. Society is actually demanding from science that it produces or contributes to various innovations (Gibbons, 1999). The communication between science and society is no longer unidirectional, society is "speaking back" to society (Bleiklie and Byrkjeflot, 2002; Gibbons, 1999).

According to Gibbons (1999) the media is very active in the 'agora'. Via several media scientists and researcher can pronounce their ideas, plans and agendas, while society can pronounce their demands from science. Thus, the media can really function as an agora' of indirect interactions.

Due to the above discussed developments it is expected that the communication and interactions between science and society have increased, leading to the following hypotheses:

> *H4a: The direct communication between knowledge producers and their socio-economic context is increasing.*
> *H4b: The indirect communication between knowledge producers and their socio-economic context is increasing.*

As mentioned before, knowledge is increasingly produced interdisciplinary and both theoretical and practical in nature. These changes in the nature of knowledge production influences institutional relations. Universities and industry are brought closer together (Viale and Etzkowitz, 2010). Governments actively encourage collaboration between university and industry as it might improve innovation efficiency and thereby wealth creation when international competition increases (Barnes et al., 2002). University-industry collaborations may provide industry with access to advanced technologies and knowledge at lower cost and risk. Scientists may benefit of these collaborations in terms of attracting additional funding and an increase in income from licensing and patenting (Barnes et al., 2002; Nieminen and Kaukonen, 2001 and Harman, 2001. The last two both in Van Rijnsoever et al., 2008). Financial aspects thus play a large role in these collaborations. So the third channel of productive interactions, financial interactions, is present here. As discussed earlier, international competition is increasing and thus university-industry collaboration is expected to increase as well. It is expected that the same holds for other extra-academic actors (i.e. institutes), as social relevant research is characterised by a crossover of institutional boundaries (Spaapen et al., 2007). According to Van Rijnsoever et al. (2008) a number of studies indicated that the interactions between scientists and extra-academic actors are increasing. The forgoing results in the following hypothesis:

> *H5: The role of industry and institutes is increasing in the brain and cognition search regime.*

Concerning the financial interactions Geuna (1999) shows that scientific research encounters increasing budgetary stringency (Geuna, 1999). This forces researchers to search for alternative external income from industry and social organizations. The earlier discussed speaking back of society is also visible in research activities, whether carried out by public or private laboratories: socio-economic demands are increasingly taken into account, and the same holds for the policies of funding organizations (Gibbons, 1999). Major funding agencies changed their requirements, for example in demanding (more) social goals being served by the research activities (Spaapen et al., 2007). This is in line with the context of application attribute of the Mode 2 diagnosis. Knowledge is intended to have an industrial or social usefulness and is preceded by a broad range of consideration (Gibbons, 2001). This development leads to an increase in cross-institutional links and subsequently it changes the composition of funding sources for research activities (Gibbons, 1999). It is expected that these developments stimulate the seeking of external income from industry and/or social organizations and also lead to more and clear social objectives in research programme descriptions. The Mode 2 theory further states that a divers range of criteria is added to the assessment of the quality of researchers. Besides the scientific (disciplinary) peer-review, the quality control now incorporates social, economic and political criteria. This is also a logic consequence of the wider set of research objectives. All these developments lead to the last three hypotheses of this thesis:

H6: The share of industry and social organizations in the composition of funding sources for brain and cognition research projects is increasing.
H7: Brain and cognition research programmes are increasingly aimed at serving social and/or economic goals.
H8: The set of criteria for quality control research activities are judged on is getting broader.

Table 2 shows the hypotheses, distributed over the system levels and Mode 2 attributes.

Table 2: Overview of the hypothesis per system level and Mode 2 attribute.

Level	**Attribute**	***Hypothesis***
Research	Transdisciplinary	*H1a: Research in the brain and cognition search regime is characterised by an increase in collaboration.*
		H1b: The brain and cognition search regime is becoming more international.
		H1c: The brain and cognition search regime is becoming increasingly trans- or interdisciplinary.
	Heterogeneity	*H2a: The number of organizations involved in scientific activities in the brain and cognition search regime is increasing.*
		H2b: The variety of organizations involved in scientific activities in the brain and cognition search regime is increasing.
Science		*H3a: The brain and cognition search regime is characterised by a high growth rate.*
		H3b: The brain and cognition search regime is characterised by divergent growth.
Society	Reflexivity	*H4a: The direct communication between knowledge producers and their socio-economic context is increasing.*
		H4b: The indirect communication between knowledge producers and their socio-economic context is increasing.
	Heterogeneity	*H5: The role of industry and institutes is increasing in the brain and cognition search regime.*
	Context of application	*H6: The share of industry and social organizations in the composition of funding sources for brain and cognition research projects is increasing.*
		H7: Brain and cognition research programmes are increasingly aimed at serving social and/or economic goals.
	Quality control	*H8: The set of criteria for quality control research activities are judges on is getting broader.*

5. Methodology

The brain and cognition search regime is analyzed on the three levels research, science and society. Each level has its own hypotheses as presented before. For testing these hypotheses indicators are developed and data is collected. The indicators and data are unique and dependent on the hypothesis. The development of the indicators will be discussed per level and will be preceded by the method for collecting the data.

5.1 Data collection

The first part of the analysis in this thesis will consist of a bibliometric analysis. A bibliometric analysis can be seen as a quantitative study of the production, communication and utilization of scientific activity, represented by (a selection of) its scientific publications (Bayer, 1982; Estabrooks et al., 2004, Lundberg, 2006). According to Heimeriks et al. (2003) "a scientific discipline can be defined as a network of journals dealing with similar research questions and methodologies and referring to a largely overlapping set of literature." The bibliometric analyses starts with selecting the most important core journals. These journals will be selected on the basis of expert interviews; three experts in the field of brain and cognition research will be asked to indentify the core journals in their field. The selected core journals are used for an in-depth analysis. All records of all articles, notes, letters and reviews from the journals are downloaded from the *Science Citation Index* and the *Social Science Citation Index* of the ISI Web of Knowledge database. This data provides more detailed information about the knowledge production network: (co-) authors and their institutional addresses, titles and abstracts (and thus research topics and keywords) and the category the study belongs to.

A bibliometric analysis does not provide sufficient insights in the brain and cognition search regime to study all three levels. On the society level there exist interactions with other parts of society, which are not visible in a bibliometric dataset. Therefore, non-bibliometric data is used for the analysis of the society level. This data is coming from Lexis Nexis (a large database that contains many archives from newspapers, magazines and other printed sources), semi-structured in-depth interviews and programme descriptions and calls for proposals related to brain and cognition research. 13 researchers (Appendix B – List of interviewees) from all three categories (neuroscience, cognitive neuroscience and cognitive psychology), from different organizations and with different ranks (Table 3) will be interviewed. The research programme descriptions and calls for proposals will come from the Dutch research council(s) and the largest private grant providers in the field of brain and cognition.

It will become clear that the indicators for the research and science level have a global focus, while the socio-economic indicators are characterised by a national focus. This is due to the fact that the codified knowledge system is global in nature, while the context of application is more local. The interviewed scientists are questioned about their experiences with changes in knowledge production, its context and interactions, and the incentives or rationales behind these developments. Consequently, the respondents are also questioned about research and science level indicators. Hence, some multilevel analyses are possible that may provide additional interesting information about the dynamics in the brain and cognition search regime.

Table 3: Distribution of respondents over categories, organizations and ranks*

Research category	Organization	Rank
Neuroscience (5) Cognitive Neuroscience (4) Cognitive Psychology (5)	Leiden University Medical Centre (1) Netherlands Institute for Neuroscience (3) Readout University Nijmegen (1) University Medical Centre Rotterdam (1) Utrecht University (3) VU University Amsterdam (2) VU University Medical Centre Amsterdam (2)	Full professor (6) Associate professor (1) Post-doc (4) PhD-student (1) Senior Researcher (1)**

** The sum of respondents by category is 14 instead of 13; one respondent was active in two categories.*
*** One respondent was a senior researcher with no academic tasks or rank.*

5.2 Indicators

Research

The research level will be analyzed by five hypotheses. The first hypothesis is about the increasing collaboration in the brain and cognition search regime. As discussed before, scientific activity can be represented by scientific publications. So, the number of authors per publication can represent the number of researchers doing scientific activity together. Therefore, hypothesis H1a will be tested with two indicators: the share of articles with two or more authors, and the number of authors per publication. An increase in the share of articles with two or more authors indicates that more research activities are done in collaboration. An increase in the number of authors per publication indicates that research activities are increasingly performed by more researchers, which also points to more collaboration. Data for this analysis comes from the bibliometric dataset.

Hypothesis H1b states that the brain and cognition search regime is becoming more international. An analysis of the geographical origin of researchers can provide the answer to this hypothesis. The first indicator for doing so is the share of publications with authors from two or more different countries. An increase in this number implies that scientific activities in the brain and cognition search regime increasingly involve international co-authors and thus that the search regime is becoming more international. Next, the number of countries per publication is used as a second indicator. An increase in this number indicates that scientific activities involve increasingly more countries, pointing to an increase in the magnitude of the internationalization of the brain and cognition search regime.

The next indicators are developed to test whether the brain and cognition search regime is becoming increasingly trans- or interdisciplinary. Discovering the main discipline all authors are working in would be a very time consuming task, which is not possible due to time constraints. To measure the rate of 'trans- or interdisciplinarity' in some way it is chosen to use the affiliated university departments in the bibliometric dataset. University departments are the smallest unit in the dataset and represent specific disciplines. An increase in the total of affiliated departments indicates that more disciplines are involved in the brain and cognition search regime, while the number of affiliated departments per article implies that research projects are becoming increasingly trans- or interdisciplinary. The indicators corresponding with hypothesis H1c therefore become: The total number of affiliated departments and the number of affiliated departments per publication.

Hypotheses 2a and 2b are about the organizational composition of scientific activities. To analyze the number of organizations involved in scientific activities (H2a) the indicators 'share of publications with two or more contributing organizations' and 'the number of organizations per publication' are used. An increase in the share of publications involving two or more organizations indicates that more scientific activities are done in collaboration. An increase in the number of organizations per publication indicates that the magnitude of the increase in collaboration between organizations is growing. 'The share of each type of organization in the publication set' is the indicators for hypothesis H2b. This indicator shows the extent to which each type of organization is involved and whether this variety has changed.

Science

The science level is analyzed on the growth characteristics of the brain and cognition search regime. The first hypothesis of this level (H3a) is about the rate of growth. As the science level can be operationalized by an evolving set of related publications the indicator for H3a is 'the number of publications in the bibliometric dataset'. A large increase in this number indicates a high growth rate of the search regime. The direction of growth (H3b) is analyzed with the correlation between keyword ranks in the publication set, which represent the variety in topics of scientific activities. A decrease of the correlation between keyword ranks indicates a large variety and thus divergent growth, while an increase of the correlation indicates a small variety and convergent growth. For this analyses the *KeyWords Plus* from the ISI Web of

Knowledge database are used. These keywords reveal the publications content with greater depth and variety (Garfield, 1990; Malarvizhi, 2010).

Society

The first hypothesis on the society level (H4a) states that direct communication between knowledge producers and their socio-economic context is increasing. The level of direct communication cannot easily be analyzed as these interactions are not registered. Therefore, the researchers will be questioned during the interviews whether they perceive the degree of direct, formal and informal contact is high and whether this rate has changed. Furthermore, the attending of conferences, where direct interactions take place, is perceived as an important type of interaction (Meyer-Krahmer & Schmoch, 1998). Subsequently, during the interviews researchers will be asked whether they perceive the number conferences related to brain and cognition research has increased.

The hypothesis on the increasing indirect communication between knowledge producers and their socio-economic context (H4a) is tested by analyzing the publications about brain and cognition research in public media. Publications in public media indicate that information about brain and cognition activities is communicated to society. The indicator for this hypothesis is the number of public media publications. An increase in the number of public media publications implies an increase in indirect communication. Data for this analysis will come from LexisNexis.

The role of the industry in the brain and cognition search regime is expected to increase, according to hypothesis 5. The role of industry and other institutes is operationalized by the contribution of industry and institutes to scientific activities. One indicator for this hypothesis therefore is the share of each type of organization in the bibliometric dataset. Next, the number of collaborations between universities, public research organizations and industry will function as a second indicator for H5. An increase of these numbers indicates that industry and institutes are increasingly involved to scientific activities and thus increasing their role.

Due to increasing budgetary stringency it is expected that scientific activities in the brain and cognition search regime will be increasingly financed by industry and social organizations (H6). This hypothesis can be tested with the indicator: share of each type of organization in the financing of research activities. However, quantitative data on the composition of research financing is not available and cannot be gathered for this thesis. Subsequently, data for this analysis is coming from interviews with researcher in the brain and cognition field. They will also be questioned whether the funding composition of their research activities has changed, and if so in what way.

The changing contract between science and society is said to have resulted in more social and economic orientated scientific activities. Research is increasingly aimed at serving social and/or economic goals (H7). The goals of research programmes are presented in their programme descriptions and calls for proposals. The indicator for testing the next hypothesis will therefore be the objectives of research programmes. These objectives will be assigned to one of the categories serving scientific, economic or social goals. An increase of the number of economic and/or social objectives per research programme implies an increase in the serving of social and/or economic goals. Data for this analysis is coming from brain and cognition research programme descriptions and calls for proposals as well as from the interviews.

The last hypothesis H8 is about the quality control of researchers and their activities. The theory states that the range of criteria where researchers and research activities are judged on has broadened. The indicator corresponding to this hypothesis is the collection of judgement criteria for quality control in brain and cognition research. The selection criteria mentioned in calls for proposals and the interviews with researchers will form the data for this analysis.

Table 4 below presents an overview of the hypotheses, indicators and the used data per level. The used data will present the main data source as the interviews with the researchers will treat all indicators of the three levels of analysis.

Table 4: Hypotheses, indicators and data per level

Level	Hypothesis	Indicators	Data
Research	H1a: Research in the brain and cognition search regime is characterised by an increase in collaboration.	Share of articles with two or more authors	Bibliometric dataset
		Number of authors per publication	Bibliometric dataset
	H1b: The brain and cognition search regime is becoming more international.	Share of publications with authors from two or more different countries	Bibliometric dataset
		Number of countries per publication	Bibliometric dataset
	H1c: The brain and cognition search regime is becoming increasingly interdisciplinary.	Total number of affiliated departments	Bibliometric dataset
		Number of affiliated departments per publication	Bibliometric dataset
	H2a: The number of organizations involved in scientific activities in the brain and cognition search regime is increasing.	Share of publications with two or more contributing organizations	Bibliometric dataset
		Number of organizations per publication	Bibliometric dataset
	H2b: The variety of organizations involved in scientific activities in the brain and cognition search regime is increasing.	Share of each type of organization in the publication set	Bibliometric dataset

Science	H3a: The brain and cognition search regime is characterised by a high growth rate.	Number of publications in the bibliometric dataset	Bibliometric dataset
	H3b: The brain and cognition search regime is characterised by divergent growth.	Correlation of keyword ranks in the publication set	Bibliometric dataset
Society	H4a: The direct communication between brain and cognition knowledge producers and their socio-economic context is increasing.	Number of conferences related to brain and cognition research	Interviews
	H4b: The indirect communication between brain and cognition knowledge producers and their socio-economic context is increasing.	Number of public media publications	LexisNexis
	H5: The role of the industry and institutes is increasing in the brain and cognition search regime.	Share of each type of organization in the bibliometric dataset	Bibliometric dataset
		Number of collaborations between universities, public research organizations and industry	Bibliometric dataset
	H6: The share of industry and social organizations in the composition of funding sources for brain and cognition research projects is increasing.	Share of each type of funding organization in the financing of research activities	Interviews
	H7: Brain and cognition research programmes are increasingly aimed at serving social and/or economic goals.	Objectives in research programmes and calls for proposals	Research programme descriptions / Calls for proposals
	H8: The set of criteria for quality control research activities are judges on is getting broader.	Collection of judgement criteria for quality control	Research programmes descriptions / Calls for proposals
			Interviews

6. Results

In this section the results of the analysis as described in the methodology section will be presented. The results will be presented per hypothesis per level of the complex adaptive system of science. As the period 1990-2009 is analysed the tables with the results per year are quite extensive. Therefore, some of these tables are presented in the appendix while an abbreviated version is presented here. The outcomes of the interviews, when these are not the main data 100source, are presented after each set of hypotheses (i.e. after H1c, after H2b, and so on). But first the selected core journals and the composition of the bibliometric dataset are displayed, as well as the collected programme descriptions and calls for proposals.

6.1 Collected data

Based on interviews with three experts in the field (Appendix A – List of consulted experts) 7 core journals for the brain and cognition search regime are selected. These journals represent the whole search regime and cover the three categories neuroscience, cognitive neuroscience and cognitive psychology. As discussed in the methodology section, all records of all articles, notes, letters and reviews from these journals between 1990 and 2009 are downloaded from the ISI Web of Knowledge database. The selected journals, their impact factor and the number of publications are presented in Table 5.

Table 5: Composition of the bibliometric dataset

	Psychological science	**Psychological Review**	**Journal of Neuroscience**	**Journal of Cognitive Neuroscience**	**Journal of Experimental Psychology General**	**Neuron**	**Neuroimage**	***Total***
IF	**4.70**	**7.78**	**7.27**	**5.36**	**5.04**	**14.03**	**5.93**	
5Year IF	**6.33**	**11.37**	**8.07**	**6.28**	**6.80**	**14.93**	**6.82**	
1990	90	39	365	0	34	180	0	*708*
1991	101	30	367	36	37	187	0	*758*
1992	88	40	422	35	45	220	0	*850*
1993	88	38	445	32	31	209	0	*843*
1994	89	59	642	31	25	240	11	*1097*
1995	67	33	721	40	22	282	34	*1199*
1996	72	36	765	49	24	263	72	*1281*
1997	89	32	906	57	24	228	63	*1399*
1998	88	34	989	486	22	285	70	*1974*
1999	102	38	1082	538	28	299	123	*2210*
2000	93	41	1085	816	35	319	143	*2532*
2001	99	39	1098	88	43	382	1599	*3348*
2002	102	41	1214	830	35	434	465	*3121*
2003	114	37	1307	104	30	426	489	*2507*
2004	151	54	1262	154	32	396	663	*2712*
2005	173	58	1287	1260	41	423	581	*3823*
2006	183	48	1515	168	40	400	937	*3291*

2007	198	58	1553	168	42	388	705	*3112*
2008	206	71	1511	176	42	422	950	*3378*
2009	236	46	1610	185	33	349	715	*3174*
Total	*2429*	*872*	*20146*	*5253*	*665*	*6332*	*7620*	*43317*

Table 6 shows the documents that were analyzed for answering hypothesis 7 and 8. The number of programme descriptions and calls for proposals is limited due to several reasons. Before the year 2000 brain and cognition were seen as separate scientific fields by the Dutch research council (Kroon, 2011). Hence, no research programmes on brain and cognition existed before. Next, research programmes have a relatively long duration and a programme is set up only once in a couple of years. Third, unfortunately not all past calls for proposals from the research council are available anymore. Unfortunately, extensive documents from the most relevant private grant providers could not be obtained. Subsequently, the only information available is coming from the private organizations' websites.

Table 6: Analyzed programme descriptions and calls

Organization	**Year**	**Programme**	**Type of document**
NWO	2000	ToKeN	Programme description Call for proposals
NWO	2001	Cognition	Programme description
NWO	2002	Evolution and Behaviour	Programme description
NL Agency; Smartmix	2007	BrainGain	Programme Description
NWO	2008	Brain & Cognition: Programmes for Excellence	Call for proposals
NWO	2008	Brain & Cognition: Joint-Forces Network	Call for proposals
NWO	2008	Brain & Cognition: Interdisciplinary education	Call for proposals
NWO	2009	Youth and Family	Call for proposals
NWO	2009	HCMI - Brain & Cognition: Social innovation in health care, education and social safety	Programme description Call for proposals
Alzheimer Nederland	2011	*Website*	General information annual grant round[1]
Brain Foundation (Hersenstichting)	2011	*Website*	Research objectives[2] Method and Subsidies[3]

[1] http://www.alzheimer-nederland.nl/onderzoek/subsidies-alzheimer-nederland/jaarlijkse-subsidieronde-dementie-onderzoek.aspx
[2] http://hersenstichting.nl/onderzoek/doelstellingen-onderzoek.html, accessed on November 3rd, 2011.
[3] http://hersenstichting.nl/onderzoek/werkwijze-en-subsidies.html, accessed on November 3rd, 2011.

International Foundation Alzheimer Research (ISAO)	2011	*Website*	General information[4] Proposal review[5]

6.2 Research level

H1a: Research in the brain and cognition search regime is characterised by an increase in collaboration.

The first analysis determines whether the collaboration between researchers whitin the brain and cognition search regime has increased, as is expected following the theory. Figure 1 shows the results for the first indicator, *share of articles with two or more authors*. The chart shows a clear decrease of the share of single-authored publications and an increase in publication that are multi-authored, pointing at an increase in collaboration. The average number of authors per publication, and thus the number of researchers collaborating in research activities (Lundberg, 2006), has increased with factor 1.7 (Figure 2).

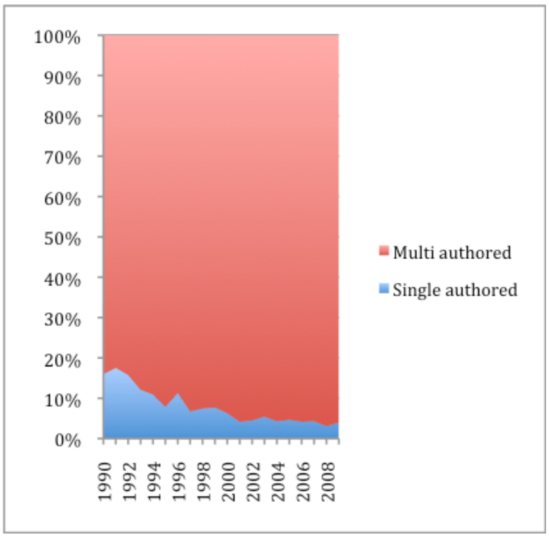


Figure 1: Share of articles with one and more authors

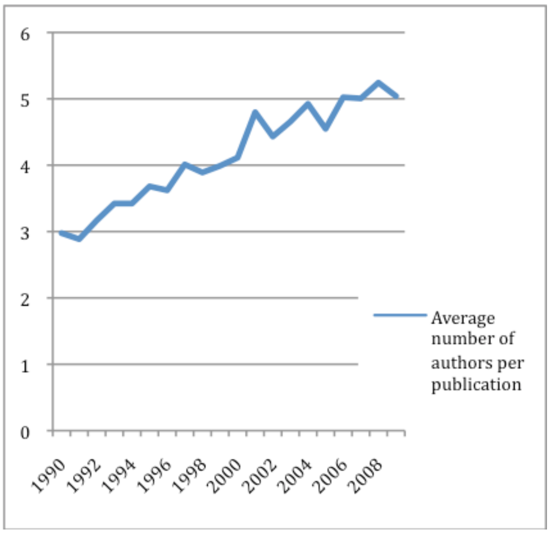


Figure 2: Average number of authors per publication

The analysis of the share of articles with two or more authors treats all publications with two or more authors alike and thus makes no distinction between the numbers of multiple authors. As the average number of authors starts already at 3, a more in-depth analysis of the distribution of authors per publication is made. The results, presented in Figure 3a & 3b, show a decrease in the share of publications with 1, 2 and 3 contributing authors and an increase of the publications with a higher number

[4] http://www.alzheimer.nl/onderzoekersalgemeen.html, accessed on November 3rd, 2011.
[5] http://www.alzheimer.nl/beoordeling.html, accessed on November 3rd, 2011.

of contributing authors. These analyses point at an increase in the number of researchers collaborating in research activities, particularly in the higher numbers of collaborating researchers. Hence, hypothesis H1a is confirmed.

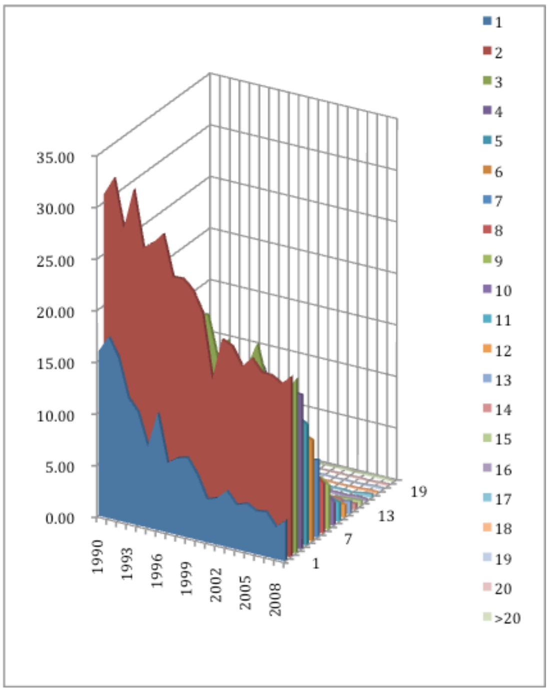


Figure 3a: Distribution of number of authors per publication

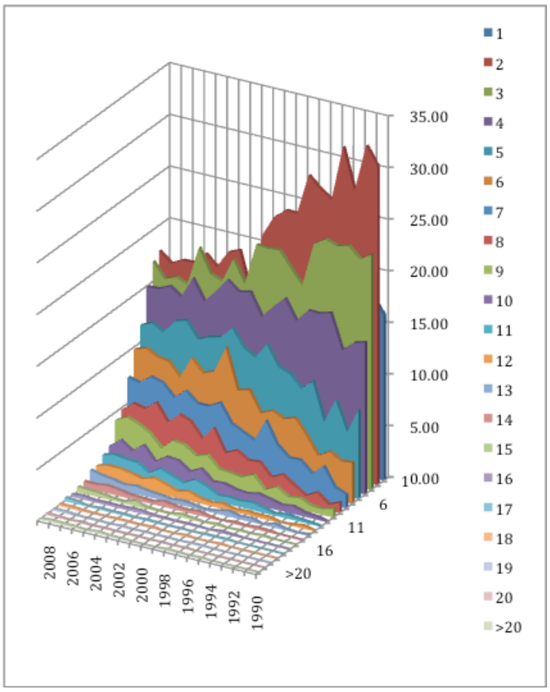


Figure 3b: Rotated reproduction of the distribution of number of authors per publication

H1b: The brain and cognition search regime is becoming more international.

Next, it is analyzed whether the brain and cognition search regime has become more international. Two indicators are used for this test. First, the number of countries active in the brain and cognition search regime is analysed to determine whether more countries have entered this domain. A clear increase in this number is visible in the results presented in Figure 4 and Table 7. The number of countries active in the brain and cognition search regime has more than doubled. Figure 5 shows the number of active countries per continent to see whether there are geographical developments. This analysis, however, does not clarify the geographical concentration of research activities and whether the 'new' countries significantly contribute to the knowledge production process in the brain and cognition search regime. Therefore, the distribution of publications over the active countries is calculated. As the data per country per year is too varying and too extensive, the analysis is made per continent per 5-year period. The results are presented in Table 8 and Figure 6 (Appendix E – Extensive Table 8: Share of each continent in bibliometric dataset contains the corresponding extensive table).

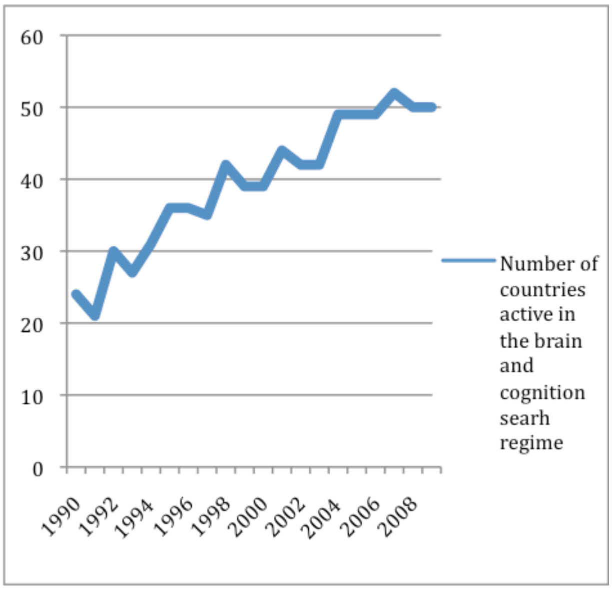


Figure 4: Number of countries active in the brain and cognition search regime

Table 7: Number of countries active in the brain and cognition search regime

Year	*#*	*Year*	*#*
1990	24	**2000**	39
1991	21	**2001**	44
1992	30	**2002**	42
1993	27	**2003**	42
1994	31	**2004**	49
1995	36	**2005**	49
1996	36	**2006**	49
1997	35	**2007**	52
1998	42	**2008**	50
1999	39	**2009**	50

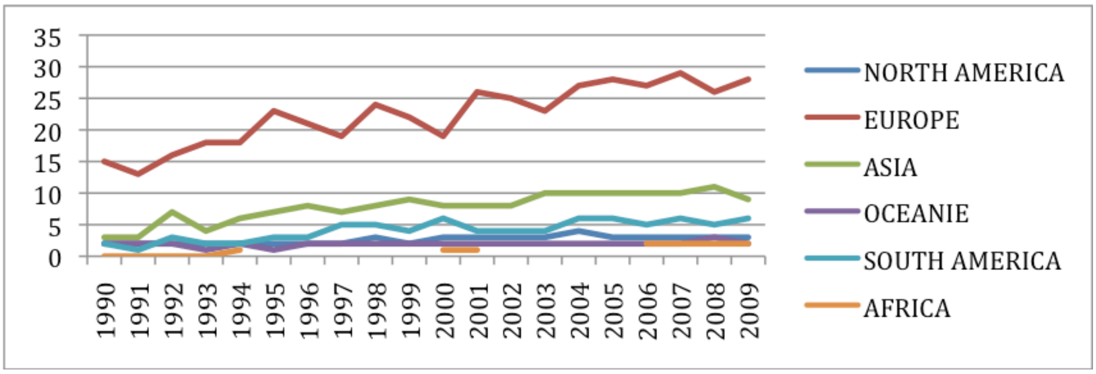


Figure 5: Numbers of active countries per continent

Table 8: Share of each continent in bibliometric dataset per 5-year period

CONTINENT	**1990-1994**	**1995-2000**	**2000-2004**	**2005-2009**	**Average**	**Change**
AFRICA	0.02%	0.00%	0.01%	0.04%	0.02%	0.03%
ASIA	3.61%	5.44%	7.58%	8.58%	7.30%	4.97%
EUROPE	17.58%	25.05%	34.54%	37.55%	32.81%	19.97%
NORTH AMERICA	77.69%	67.86%	55.62%	51.37%	57.73%	-26.31%
OCEANIE	0.84%	1.08%	1.59%	1.74%	1.49%	0.90%
SOUTH AMERICA	0.27%	0.56%	0.66%	0.72%	0.64%	0.45%

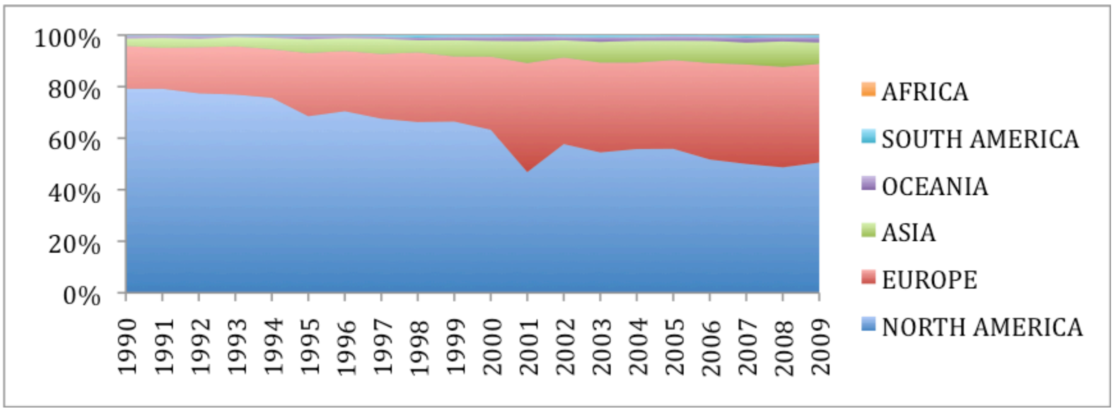


Figure 6: Share of each continent in bibliometric dataset per 5-year period

It becomes clear that the share of North America has decreased heavily (over 26%) while the shares of Asia and in particular Europe are strongly increasing (respectively almost 5% and 20%). These results suggest that the concentration of research activity is shifting towards a more proportional distribution among the continents and that the 'new' countries contribute to the brain and cognition knowledge production process.

Next, the share of publications with authors residing in two different countries is calculated. The results in Figure 7 and Table 9 show an increase of over 20% in the share of internationally co-authored publications. The majority of brain and cognition research activities is still conducted on a national basis, however the international research activities are considerably gaining ground.

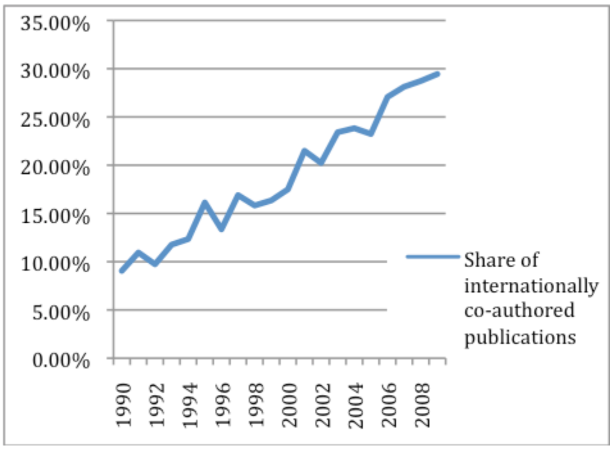


Figure 7: Share of internationally co-authored publications

Table 9: Share of internationally co-authored publications

Year	*Share*	*Year*	*Share*
1990	9.05%	**2000**	17.49%
1991	10.95%	**2001**	21.49%
1992	9.73%	**2002**	20.23%
1993	11.76%	**2003**	23.41%
1994	12.35%	**2004**	23.83%
1995	16.13%	**2005**	23.24%
1996	13.35%	**2006**	27.07%
1997	16.90%	**2007**	28.13%
1998	15.82%	**2008**	28.73%
1999	16.35%	**2009**	29.44%
Change		*20.39%*	

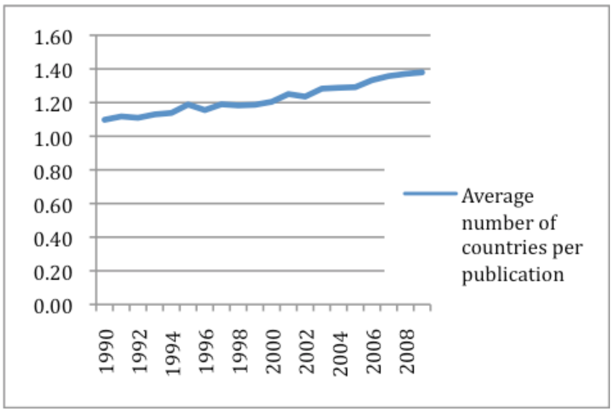


Figure 8: Average number of countries per publication

Table 10: Average number of countries per publication

Year	#	Year	#
1990	1.10	**2000**	1.20
1991	1.12	**2001**	1.25
1992	1.11	**2002**	1.24
1993	1.13	**2003**	1.28
1994	1.14	**2004**	1.29
1995	1.19	**2005**	1.29
1996	1.16	**2006**	1.33
1997	1.19	**2007**	1.36
1998	1.18	**2008**	1.37
1999	1.19	**2009**	1.38
Change		*0.28 | 25.67%*	

The second indicator for H1b tests the magnitude of the internationalization by analysing the average number of countries contributing to a publication. Also here an increase can be notified, see Figure 8 and Table 10. The average number of countries started at 1.10 and has increased with over 25% to 1.38. This result also points at an increase in the internationalization of the brain and cognition research activities, though the research activities on a national base prevail. However, the results of both analyses direct at an increase in the level of internationalization and thus confirm hypothes H1b.

H1c: The brain and cognition search regime is becoming increasingly trans- or interdisciplinary.

Another changing characteristic of the knowledge production process is the level of trans- or interdisciplinary. Whether this change is present in the brain and cognition search regime is tested with two indicators, the number of unique affiliated university departments in the bibliometric dataset and that number per publication. To correct for the risk of measuring only departments of the same discipline but from different universities, the number of unique affiliated universities in total and per publication is added. Figure 9 shows the combined results of this analysis. The results show that the total number of unique affiliated has increased with a factor higher than 7, starting at almost 500 in 1990 and expanding to almost 3800 by 2009. At the same time the number of affiliated universities 'only' increased from 178 to 754. The number of departments has increased significantly, so more disciplines are involved in the brain and cognition research activities. The number of unique departments affiliated per publication has increased from ± 0.70 to 1.20, a factor of 1.67, while the number of unique affiliated universities per publications has slightly decreased. This states that more departments within universities, which each represent a different discipline, are contributing to the same publication. These results point to an increase in the trans- or interdisciplinarity of the brain and cognition search regime and thus confirm hypotheses H1c.

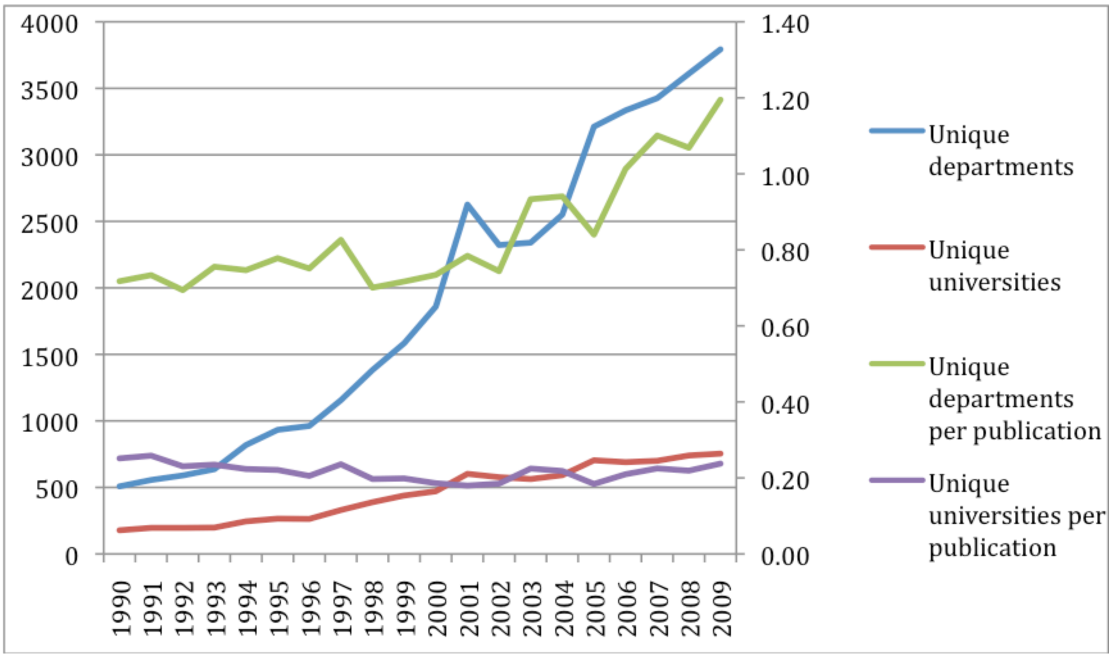


Figure 9: Number of unique affiliated departments and universities in total and per publication

All interviews confirm these results of the first three hypotheses. The interviewees experience an increase in the collaboration with researchers from the same discipline as with researchers from other disciplines and with researchers from other countries. There are a number of reasons behind these increases.

One reason is that not all researchers have the necessary technique at one's disposal. Next, brain and cognition research has become much more complex; the 'low hanging fruit' has already been harvested over the years. The more complex research questions require collaboration to get the field further. Partly because of this increased complexity, a wider range of perspectives and points of view are taken to look at the research questions. Brain and cognition research thus became interesting for a more divers group of researcher, and interdisciplinair knowledge and collaboration became required. The increase of international collaboration has also a financial reason. International collaboration is preferred for many grants, sometimes even required. The motivation for this preferrence is that it stimulates a researcher to involve the global experts in the field.

The goal of collaboration is improving the quality of research and to lift the brain and cognition research to a higher level. Due to the increased complexity research activities are very expensive and require high investments. Researchers with the necessary expertise, no matter their disciplinairy or geographical origin, are recruited to increase the quality of research, and with that the efficiency of the investments. Collaboration has no cosmetic goal in itself; researchers do not collaborate just to generate more publications. However, a researcher's own publication score does play a role in the decision process to collaborate. The interviewees agree that they are willingly to accept invitations for collaboration; with only a small time investment their name is related to many (potential) publications. On the other hand, due to collaboration the quality of the research increases, resulting in a higher chance on publication of the results. (International) Collaboration is also important for a researchers carreer. Of course, collaboration has some (minor) disadvantages. According to the interviews there is always a risk on sponging, in particular in very large research consortia. Furthermore, collaborating may be aggravating and all needed consultation may hamper the knowledge production process. However, when the balance between these disadvantages and the eralier mentioned advantages is right the collaboration is desired and positive for the researchers themselves as well as for the brain and cognition science field.

H2a: The number of organizations involved in scientific activities in the brain and cognition search regime is increasing.

The previous results showed that the collaboration between researchers has increased. The next section will tell whether this development holds true for the organizational level. Following the theoretical framework it is expected that the knowledge production process is increasingly organizational heterogeneous. To analyse if this applies to the brain and cognition search regime the number of organizations per publication as well as the share of publications with two or more contributing organizations is determined. The results of these analyses are presented in Figure 10.

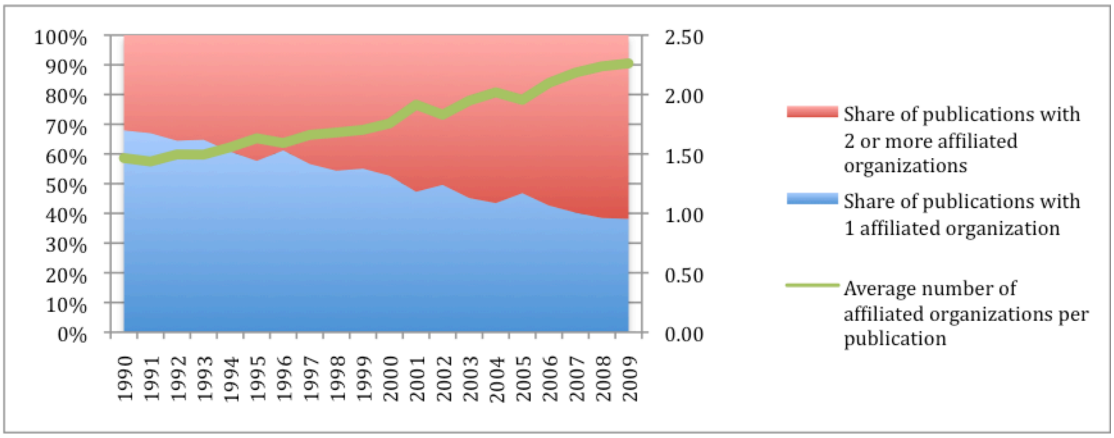


Figure 10: Number of organizations per publication and share of publications with 2 or more affiliated organizations

As becomes clear from the chart in Figure 10 the average number of organizations that are affiliated per publication has increased from almost 1.50 to over 2.25. Furthermore, the chart shows that the share of publications with 2 or more affiliated organizations gained almost 30% at the cost of the share of publications that affiliate only 1 organization. These results confirm hypothesis H2a and state that the number of organizations involved in scientific activities in the brain and cognition search regime and their mutual collaboration are indeed increasing.

H2b: The variety of organizations involved in scientific activities in the brain and cognition search regime is increasing.

This hypothesis states that the brain and cognition search regime is characterised by an increase in the variety of contributing organizations and an increase in non-university contributions to research activities. This hypothesis is analysed by determining the share of publications that affiliate the different types or organizations. All organizations in the bibliometric dataset are labelled as university, academic hospital, hospital, research institute or industry (the syntax used for this labelling is presented in Appendix D – SPSS syntax for coding affiliated organisations). Figure 11 and Table 11 present the share of publications per type respectively per year and per 5-year period (the extensive table with the data per year is in Appendix F – Extensive Table 11: Share of publications that affiliate each type of organisation). The results show that all types are increasingly affiliated to a publication, with a minor increase for industrial organizations and (academic) hospitals, a moderate increase for research institutes and a major increase for universities. So hypotheses H2b holds partly true: an increase of non-university contribution can be noticed, though universities provide the largest and increasing contribution to the knowledge production process. The variety is thus not strongly increasing.

The interviewed researchers recognize an increase in the number of organizations involved in brain and cognition research activities, however this concerns mainly universities and their departments. The interviewed researchers do not recognize an obvious increase in the number of collaborations with non-academic organizations in the knowledge production process; an increase in the variety of organizations that are collaborated with is not noticed. Some collaboration occurs with research institutes, though not to a noteworthy increased degree. The researchers from the categories cognitive neurology and cognitive psychology seem to have the most collaboration with these institutes, in particular with those active in the development of interventions. Collaborations with industry are rare. Occasionally a researcher collaborates with an ICT company, pharmaceutics or an educational publisher, however the interviewees make clear that they are reserved in entering such collaborations due to a risk on confusion of interests. Although it mainly regards to universities, an increase in the number of organizations involved in scientific activities is noticed, thus the interviews confirm hypothesis H2a. The results from the interviews are also more or less in line with the results of hypothesis H2b.

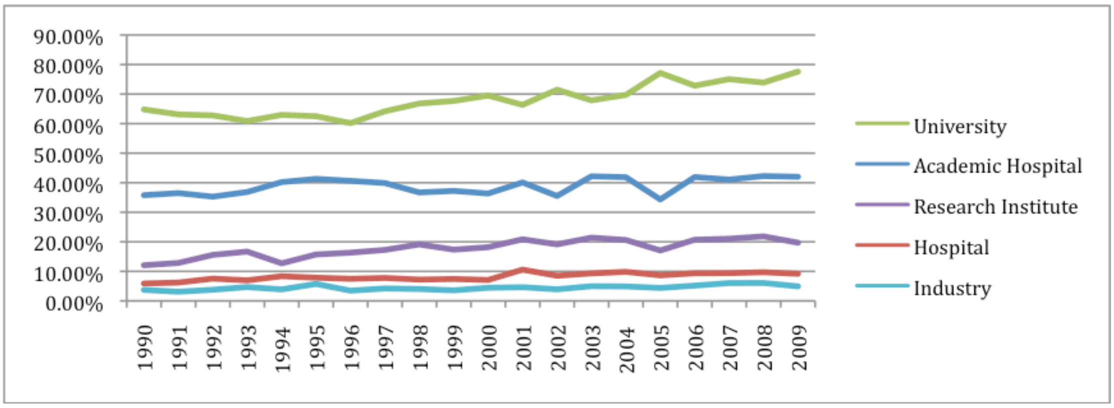


Figure 11: Share of publications that affiliate each type of organization in the bibliometric dataset

Table 11: Share of publications that affiliate each type of organization in the bibliometric dataset

	1990-1994	1995-1999	2000-2004	2005-2009	*Change*
University	62.90%	64.27%	68.98%	75.30%	*12.40%*
Academic Hospital	36.92%	39.15%	39.20%	40.31%	*3.39%*
Research Institute	13.98%	17.16%	20.04%	20.07%	*6.09%*
Hospital	6.99%	7.55%	9.07%	9.26%	*2.27%*
Industry	3.84%	4.20%	4.58%	5.32%	*1.48%*

6.3 Science level

H3a: The brain and cognition search regime is characterised by a high growth rate.

The science level is analysed on two characteristics: the rate and direction of growth. Following the theory on new science fields the rate is expected to be high and the direction divergent. The first analysis is about the rate of growth, the subject of the first hypothesis of the science level, H3a. The research field is operationalized as an evolving set of related publications. Thus, the bibliometric dataset represents the research field and the number of publications can function as the indicator for the growth rate. Figure 12 shows the chart of the number of publications in the dataset per year, Table 5 contains the corresponding numbers. The results show a high growth rate until 2005 (with peaks in 2001 and 2002) to over 3800 publications that year, whereupon the quantity of publications decreases somewhat and fluctuates around 3200 publications a year. These figures suggest that the brain and cognition search regime experienced a high growth rate to 2005 after which some stabilization occurred. Therefore, hypothesis H3a is partly confirmed.

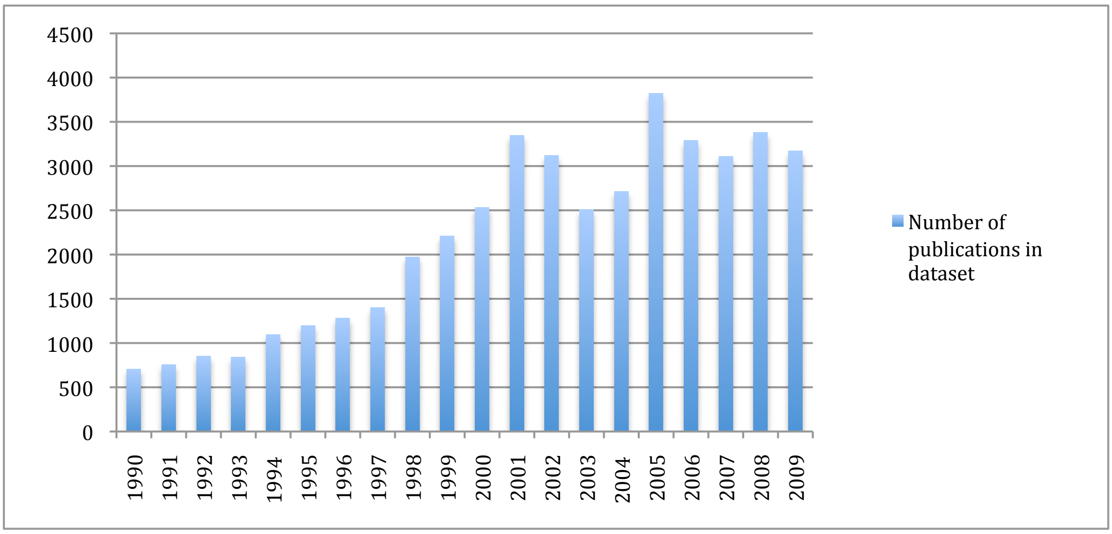
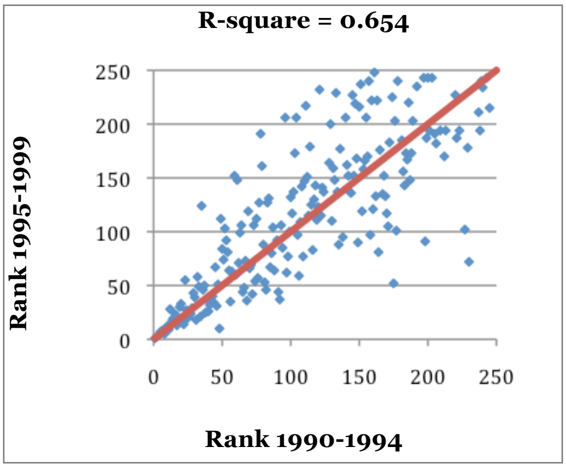


Figure 12: Number of publications in the bibliometric dataset

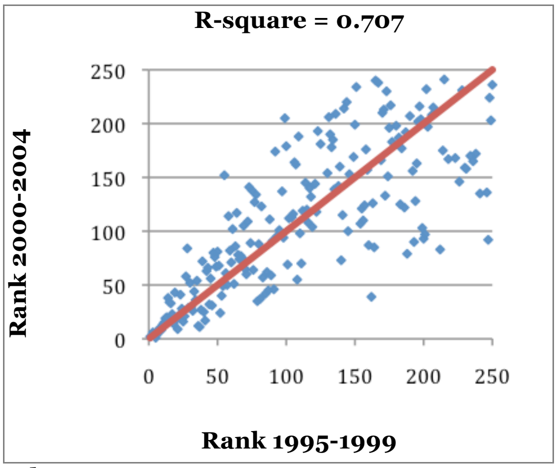
H3b: The brain and cognition search regime is characterised by divergent growth.

The second hypothesis for the science level tests the direction of growth of the brain and cognition search regime. As discussed in the theoretical framework section this direction is expected to be divergent. The correlation between ranks of keywords, that represent the topics of scientific activities, is the indicator for this analysis.

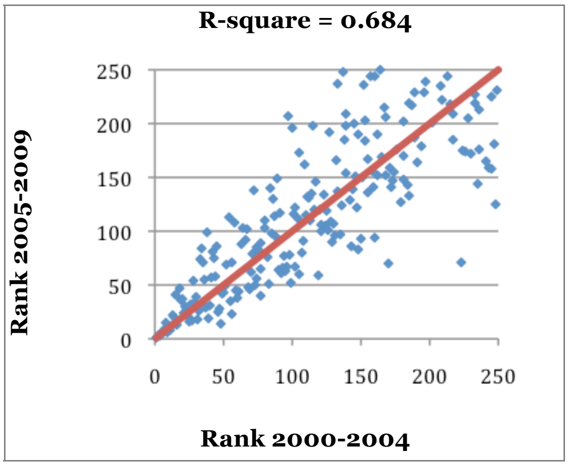
To be able to reveal some possible trends and changes over time, the correlation between keyword ranks is compared over the 5-year periods. The rank of the top 250 keywords per period is determined and subsequently compared to the rank of the next period. Figure 13a/d show these comparisons. When the ranks are identical, the dots will be on a straight line, like the red line in the charts. This line represents a perfectly convergent search regime, where the same keywords are of the same importance overt time. The R-square values (between 0-1) at the top of each chart represent the deviation from this red line, with the lower the value the higher the deviation and thus the higher the variance in keyword ranks. Hence, the lower the R-square value the higher the divergence of the growth of the search regime.



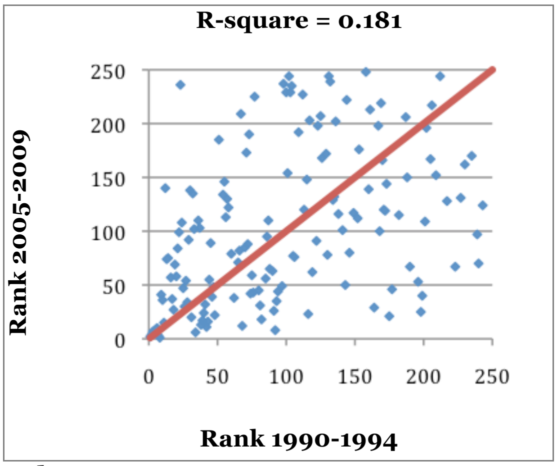
13a



13b



13c



13d

Figure 13a/d: Correlation between keyword ranks in the brain and cognition search regime

The results in Figure 13a/c show a rather stable progression with relatively high R-square values (0.68 on average) when two consecutive 5-year periods are compared. This would suggest that the brain and cognition search regimes develops gradually in a rather convergent way. However, research projects often cover a number of years and consequently the variance in keywords may be limited in short-term comparisons. Therefore, the rank of the first 5-year period (1990-1994) is compared with the rank of the last period (2004-2009). This analysis has a very different outcome, see Figure 13d. The R-square value is now only 0.18, pointing at a large variance in keywords and thus a divergent growth. The knowledge production in the brain and cognition search regime over the period 1990-2009 was a divergent process. In consequence, hypothesis H3b is confirmed.

The interviews confirm the results of the analyses for hypotheses H3a and H3b. The researchers experience a high and divergent growth rate of the brain and cognition research field. The main reason mentioned is the technological development, in particular of imaging techniques. It seems that these developments in the first instance stimulated the 'pure' brain and neuroscience, and the cognition research grew along with that category of brain and cognition science. Furthermore, these imaging techniques become more easily accessible for other groups of researchers, for example psychologists. And because more and more is known about the functioning of the human brain, and its relation to human behaviour and emotion, brain and cognition research has become interesting for a larger and more divers group of researchers.

6.4 Society level

H4a: The direct communication between knowledge producers and their socio-economic context is increasing.

H4b: The indirect communication between knowledge producers and their socio-economic context is increasing.

The first two hypotheses of the society level are about the communication between scientists in the brain and cognition search regime and their socio-economic context, which is expected to have increased according to the theory. A substantial part of the data for analyzing these hypotheses comes from the interviews alone. For practical reasons, these hypotheses are tested in combination.

Nearly all interviewees experience an increase in the communication with society, both in a direct and indirect way. The common notion that scientists have left their ivory tower seems to account also for the brain and cognition search regime. The researchers and/or their affiliated organizations increasingly organise or participate in activities to exhibit their research and the accompanying knowledge: conferences, symposia, discussion forums, public (science) days and lectures are forms of events where direct communication takes place. The most common forms of activities with indirect communication, which are increasingly noticed, are: popular-media publications (including newspapers and popular scientific magazines), TV- and radio appearances, (chapters in) books and websites. For example, almost all researchers or their organizations send out a press release when a research project resulted in interesting outcomes or when it has finished. The analysis of the public media articles in the Lexis Nexis database emphasizes this notion. With specific search queries (Appendix C – LexisNexis search queries) all relevant media articles were recorded. The results, presented in Figure 14, show an obvious increase in public media articles related to brain and cognition research. Both hypotheses 4a and 4b are confirmed by these analyses.

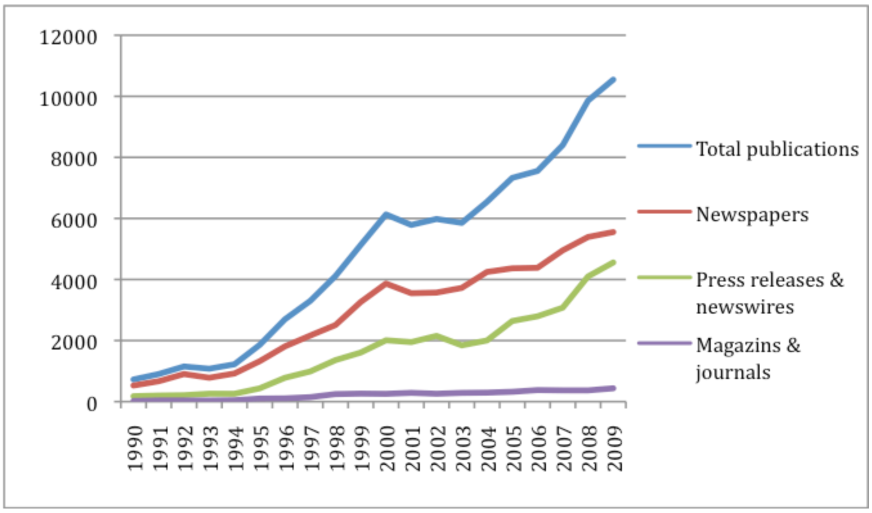


Figure 14: Public media articles related to brain and cognition research in the Lexis Nexis database

The reasons behind these increases are threefold. As the previous results point out the brain and cognition search regime and its number of research activities has increased vigorously. Scientific activity has always received some attention and when the number of activities increases, the media attention logically will do the same. Second, the grant provider, from first, second as well as third flows of funding, nowadays often demands the applicant to exhibit their research activities and the accompanying results. According to the interviews, the first and second flow funders (respectively government and research councils) demand this exhibition because they perceive it as an element of valorization and legitimising governmental expenses (Spaapen et al., 2007), while the third flow funders (private funds, foundations) perceive it as good publicity. Third, the interviewees agree that brain and cognition is a hot topic in society and popular topics automatically receive much attention from popular / public media. Possible reasons for the popularity of brain and cognition science are the increasing knowledge about the functioning of our brain and its relation with human behaviour and wellbeing; and a large affinity as it is related to well known phenomena like the aging population, Alzheimer disease, dementia and strokes. Although this type of publicity is more often demanded by the grant providers, the researchers do not receive any credits for these activities. Researchers are judged by their employer mainly on scientific publication activity and not on their appearance in public media.

Noteworthy, the interactions with society are unilateral in nature; Society does not influence the research agenda or activities directly. Social or societal problems may function as a source of possible research ideas, though the research topics originate from existing knowledge and ideas and interests of researchers. Occasionally, researchers respond to current situations. However, due to the long duration of research activities this is scarcely the case.

H5: The role of industry and institutes is increasing in the brain and cognition search regime.

Due to globalization, increased competition and responding innovation policies, and an increase in interdisciplinarity the interactions between academic scientists and extra-academic actors is expected to increase (Barnes et al., 2002; van Rijnsoever et al., 2008; Viale & Etzkowitz, 2010). Extra-academic actors like research institutes and industry are expected to play an increased role in the brain and cognition knowledge production process. Analyzing the contribution of these actors to the scientific activities can test this hypothesis. Therefore, the share of each type of actor, university, academic hospital, research institute, hospital or industry, in the bibliometric dataset is calculated. More specific, the calculated figures represent the share of each type in the total amount of organisations, as the focus is on the role of each type of organization in the knowledge production process. Figure 15 and Table 12 show the results of this analysis (the corresponding extensive table is given in Appendix G – Extensive Table 12: Share of each type of organization in the brain and cognition knowledge production process). The shares of each type of organization do not show much variation and remain almost unchanged over time. Minor increases in the share of universities and research institutes can be noticed, as well as minor decreases in the share of academic hospitals and industry. These results contradict the hypothesis.

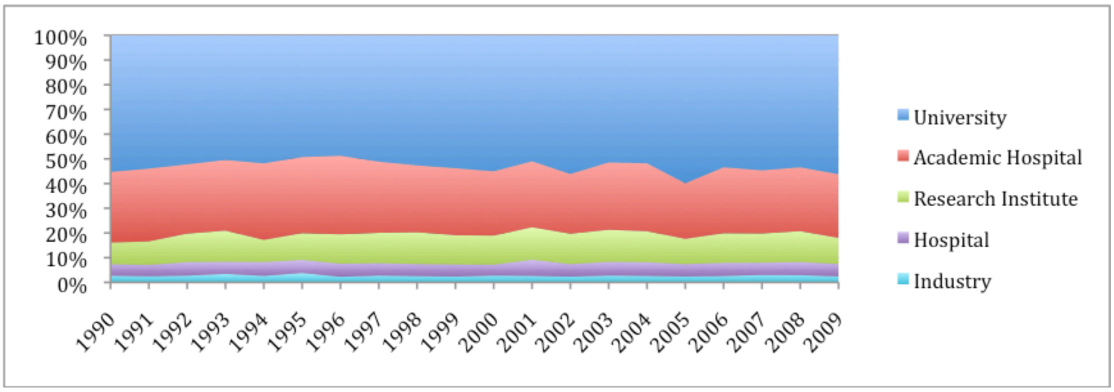


Figure 15: Share of each type of organization in the brain and cognition knowledge production process

Table 12: Share of each type of organization in the brain and cognition knowledge production process per 5-year period

	1990-1994	1995-1999	2000-2004	2005-2009	*Change*
University	52.74%	51.10%	53.07%	55.51%	*2.77%*
Academic Hospital	29.14%	29.12%	26.34%	25.27%	*-3.87%*
Research Institute	10.26%	11.93%	12.54%	11.41%	*1.15%*
Hospital	5.06%	5.08%	5.42%	5.14%	*0.09%*
Industry	2.81%	2.76%	2.64%	2.67%	*-0.14%*

The share of each type in the total number of organizations does not suffice to draw conclusions on the interactions between the different types of organizations; an indispensable element of the role an organization can fulfil in the knowledge production process. Therefore, the role of collaborations in the knowledge production process will function as the second indicator for testing hypothesis H5. The share of publications (i.e. research activities) resulting from collaborations is determined to determine the role of each type of organization in knowledge production. For practical matters, the number of distinguished types is reduced to three: university, research institutes and industry, where hospitals are included as public research institutes. This indicator is proved to be a proper measuring method for these social dynamics (Heimeriks, 2011). The results of this analysis are presented in Figure 16 and Table 13 (Appendix H – Extensive Table 13: Share of publications resulting from collaborations among universities, public research institutes and industry contains the extensive table).

Table 13: Share of publications resulting from collaborations among universities, public research institutes and industry

	1990-1994	1995-1999	2000-2004	2005-2009	*Change*
University-public	18.86%	23.69%	30.34%	35.97%	*17.11%*
University-industry	1.54%	1.97%	2.88%	3.97%	*2.43%*
Public-industry	1.37%	2.40%	2.78%	3.38%	*2.01%*
University-public-industry	0.40%	0.93%	1.60%	2.40%	*2.00%*

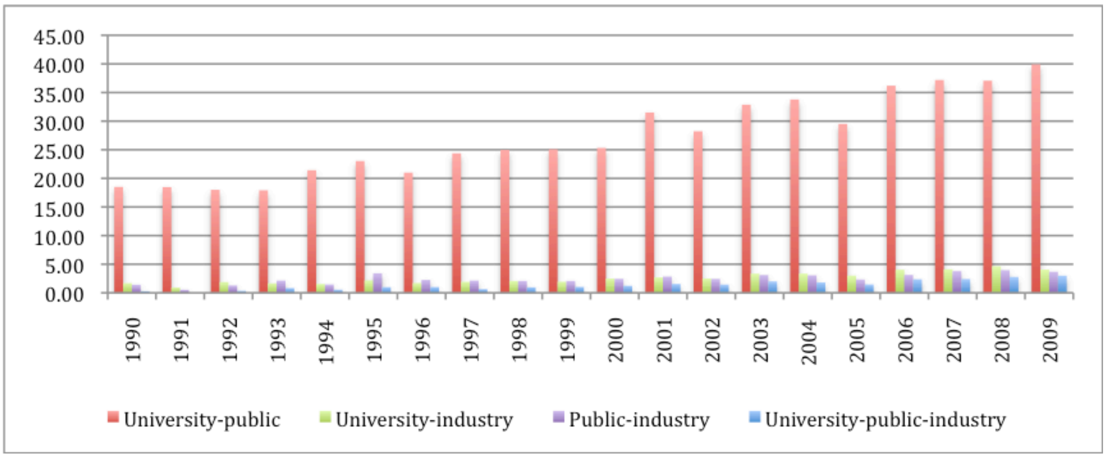


Figure 16: Percentage share of publications resulting from collaborations among universities, public research institutes and industry

The results show a large increase of 17% in the share of publications resulting from collaboration between universities and public research institutes (including hospitals). As the share of hospitals in the knowledge production has decreased while the share of research institutes increased (Figure 15 and Table 12) it is quite possible that the collaboration between universities and research institutes have increased. All other collaborations only show a minor increase. Although some increases are of low impact, these results support hypothesis 5.

The related results of the interviews are almost the same as those discussed for hypotheses H2a and H2b. The researchers do not recognize an obvious increase in the collaborations with and between universities, research institutes and industry in the knowledge production process. In line with the previous results (Table 13 and Figure 16), some collaboration occurs with research institutes, though not to a noteworthy increasing degree. The cognitive neurology and cognitive psychology researchers seem to have the most collaboration with these institutes, mainly with those active in the development of interventions. Collaborations with industry are rare. Occasionally a researcher collaborates with an ICT company, pharmaceutics or an educational publisher, however the interviewees make clear that they are reserved in entering such collaborations due to a risk on confusion of interests. Furthermore, the researchers perceive that the industry is not itching to contribute to or participate in brain and cognition research, most likely due to the risks and uncertainty of science. The results of the bibliometric analyses and the interviews are not unambiguous, hence hypothesis 5 is neither confirmed, nor rejected.

H6: The share of industry and social organisations in the composition of funding sources for brain and cognition research projects is increasing.

According to the theoretical framework the composition of funding is changing due to an increasing budgetary stringency that researchers encounter (Guena, 1999). It is expected that researchers seek for alternative external income and therefore hypothesized that industry and social organizations will take a larger share in the composition of funding. All interviewees perceive a distinct shift in money flows. Funds from the first flow have decreased drastically. Governmental expenses on scientific activities are increasingly distributed via second flow organisations. Second flow grants are provided after the evaluation of proposals, which is called for by the funding provider. The latest years there have been large investments in brain and cognition research in terms of second flow grants. However, as the first money flow vanished away while the number of researchers in the field increased, the competition for these grants has obviously also increased. Notably, some researchers experience the evaluation of the proposals and the assigning of grants as a real tombola. Only a part of the researchers receives funding from third money flow organizations: foundations and (private) funds. The funding from industry is nil. The Dutch research council remains the largest funding provider. So, as long as it concerns funding from social organizations the hypothesis is confirmed, though to a low degree. When it comes to industrial funding, the hypothesis is rejected.

Related to the funding of research activities some interesting remarks are observed during the interviews. Due to the increased competition the writing of research proposals has become a time-consuming core business. An evolvement that is expected to increase, as the interviewed researchers expect an upcoming decrease of available funding due to political changes. The funding organizations influence the research direction in an indirect way. Many calls for proposals are issued within a certain research theme. The research proposal has to fit between the boundaries of such a theme. When the calls come from governmental related organizations (first and second money flows), these research themes can be influenced by the political agenda. Though, no funding organization has any influence on the outcome and results of the research. The independence of the researchers is guaranteed.

H7: Brain and cognition research programmes are increasingly aimed at serving social and/or economic goals.

It is expected that socio-economic demands are increasingly taken into account within research programmes and funding organizations are increasingly expressing social and/or economic goals in their calls for proposals. The studied research programmes and calls for proposals from the Dutch research council (Table 6) confirm this expectation. The first six documents from the Dutch research council NWO do not express obvious social goals but are mainly scientifically orientated. Only one programme description (*NWO Programme Cognition*) mentions a social tinted goal: 'Establishing a solid level of public acceptance and support for the cognitive sciences.' However, this cannot be marked as a social and/or economic goal in itself. The subsequent documents from the research council show a changeover. Social demands, besides the always important scientific aims, are of great importance in the 2009 programme description and calls. Social innovation, relevance and implementation and solutions to social issues are specifically asked for. The *Smartmix BrainGain* programme from NL Agency (part of the Dutch Ministry for Economic Affairs, Agriculture and Innovation) also serves an economic goal: their ultimate goal is to use their results to develop concrete products and applications that improve the quality of life and performance of patients and healthy people, in combination with bringing about an economic stimulus. The third money flow funding organizations do not express such goals and demands. Their programmes and grant specifications (still) mainly address scientific issues. The interviewees do experience a shift in the rationale for funding research activities. Although the degree somewhat depends on the type of grant or funding, the social relevance has gained importance and is specifically asked for nowadays. These results confirm the hypothesis as long as it concerns public funding and social goals. The hypothesis cannot be confirmed when it concerns economic goals (apart from one exception) and when it concerns private funding organizations.

Worthwhile to mention here are the concerns the more fundamental oriented researchers express about the current value of social relevance. It may be a threat to fundamental research as it is hard to determine some direct social relevance for this type of research. However, fundamental research is essential to get the field of brain and cognition further.

H8: The set of criteria for quality control researchers and research activities are judged on is getting broader.

The hypothesis on the characteristics of the quality control is the last hypothesis and related to the fifth and last attribute of the Mode 2 theory. This theory states that the quality of researchers (and its activities) is assessed on a more divers range of criteria besides the system of peer-review.

The criteria in the programme descriptions and the calls for proposals show the same trend as the results of the analysis of hypothesis H7 as the scientific activities are judged whether they will contribute to the main goal(s) of the research programmes. The scientific quality control is always present. The researchers are judged on their experience, expertise and competence, usually by their Curriculum Vitae and track record. Almost all documents from the Dutch research council judge the research group on multi- or interdisciplinarity. Further scientific criteria are originality, innovativeness and scientific output. These criteria are not time-bound and expressed in nearly all documents. Again, the 2009 research council documents show a changeover; social criteria are added to the judgement of research activities. Specific attention is paid to social relevance, social application and implementation of the results (put them into practice), knowledge dissemination, valorization and communication with society. The *HCMI* call furthermore pays specific attention to the participation of third parties, private or public social partners. Also here, the third money flow funding organizations do not have the same standard as the research council has. Their judgement is based on mainly scientific criteria, like experience and expertise of the researchers and scientific relevance and output.

The interviews describe a somewhat different situation. All interviewees agree that currently the main criterion for determining a researcher's performance and quality is the scientific publication-score. In fact, publications are gaining more and more importance, both in appraisal and application procedures at the employer, as well as in evaluating proposals for funding. Consequently, publications are the most important products resulting from a researcher's activities. Some other output, like interventions, guidelines and Dutch publications, is also delivered, as it is sometimes demanded by the grant provider. However, this type of output does not have any priority at all, as it has no value for the quality, appraisal or career of the researcher, as one researcher said: "The relation between publications and interventions is 10 to 1."

As long as it concerns public funding from research councils the hypothesis can be confirmed, though the importance of the added non-scientific criteria is open to debate. The hypothesis cannot be confirmed when it concerns the judgement by private funding organizations or by the researchers' employer.

As the publication-score plays an important role in assigning grants and the competition for grants has increased (as discussed before at hypothesis H6), the urgency to publish has also increased. Due to the role a publication-score plays in the evaluation of proposals, a researcher may enter a positive, virtuous circle: once a grant is received, the researcher can conduct activities resulting in publications by which the researcher's publication-score increases, leading to a higher change on getting assigned another grant.

The increasing importance of publications has different consequences: a positive outcome is that researchers are forced to write everything down properly and to draw some conclusions. Possible disadvantages are less profundity and the willing to publish as much as possible as soon as possible, and consequently publishing articles with less (theoretical) contribution.

Table 14 provides an overview of the confirmation or rejection of the hypotheses.

Table 14: Overview of the status of the hypotheses

Level	**Attribute**	***Hypothesis***	***Status***
Research	Transdisciplinary	*H1a: Research in the brain and cognition search regime is characterised by an increase in collaboration.*	*Confirmed*
		H1b: The brain and cognition search regime is becoming more international.	*Confirmed*
		H1c: The brain and cognition search regime is becoming increasingly trans- or interdisciplinary.	*Confirmed*
	Heterogeneity	*H2a: The number of organizations involved in scientific activities in the brain and cognition search regime is increasing.*	*Confirmed*
		H2b: The variety of organizations involved in scientific activities in the brain and cognition search regime is increasing.	*Confirmed, but low impact increase*
Science		*H3a: The brain and cognition search regime is characterised by a high growth rate.*	*Partly confirmed*
		H3b: The brain and cognition search regime is characterised by divergent growth.	*Confirmed*
Society	Reflexivity	*H4a: The direct communication between knowledge producers and their socio-economic context is increasing.*	*Confirmed*
		H4b: The indirect communication between knowledge producers and their socio-economic context is increasing.	*Confirmed*
	Heterogeneity	*H5: The role of industry and institutes is increasing in the brain and cognition search regime.*	*Neither confirmed, nor rejected*
	Context of application	*H6: The share of industry and social organizations in the composition of funding sources for brain and cognition research projects is increasing.*	*Confirmed for social organisations, rejected for industry*
		H7: Brain and cognition research programmes are increasingly aimed at serving social and/or economic goals.	*Confirmed for public funded programmes and calls, rejected for private grant providers*
	Quality control	*H8: The set of criteria for quality control research activities are judges on is getting broader.*	*Confirmed for research council, rejected for private grant providers and researchers' employers*

7. Conclusions and Discussion

The research question of this thesis was:

> *What changes took place in the knowledge production process in the field of brain and cognition in the period 1990-2009?*

This question was accompanied by two goals:

1. Delivering a contribution to a better understanding of the changes and interactions involved in the brain and cognition knowledge production process.
2. Delivering a contribution to the development of innovation theory on the changing knowledge production process as well as to the methodology for analyzing this process.

In order to meet the first objective, this chapter will first reflect on the results of the analyses and draws conclusions about the changing knowledge production process. The changing patterns that are observed in the brain and cognition research field between 1990 and 2009 will be discussed. Where possible and necessary policy recommendations will be given. Subsequently, there will be reflected on the theory and methodology used in this thesis to meet the second goal of this thesis. The contribution of this thesis' conceptual framework to innovation theory and methodology is discussed, followed by a critical note on the used concepts of Mode 2 and the bibliometric analysis.

7.1 Patterns of change and policy recommendations

The brain and cognition research field is characterized by a strong and divergent growth in the period 1990-2009. At the bottom of this growth lies mainly the technological development of brain imaging techniques. Subsequently, the number of research activities has increased, as well as the variance in points of view with which is looked at brain and cognition related research questions. These research questions and activities have become increasingly complex and have two requirements: (1) interdisciplinary collaboration with the global experts in the field and (2) increasingly extensive funding. International and interdisciplinary collaboration occurs increasingly, which might be induced by the past large investments in second flow funding. These second flow grants are assigned after an evaluation of the research proposals. Furthermore, only a (small) part of the researchers finds its way to private funds. In combination with the decrease of first money flow funding, these evolvements have led to an intensification of the competition for obtaining funds and writing research proposals has become a core task of researchers. A situation that is expected to intensify as the amount of available resources is expected to decrease in the near future. Thus, the first general pattern of change observed is the intensified struggle for funding, a struggle that is expected to further intensify. Though, resources are needed to find solutions for the acknowledged brain and cognition related problems in healthcare, education and social safety. Without the required funding it is impossible to conduct the needed research activities to overcome these social issues. For a further development of brain and cognition science it is recommended to maintain (or improve) the processes needed for international, interdisciplinary collaboration and to at least not further decrease the amounts of available funding. Next, it is recommended to support researchers in attracting additional private funding.

A second trend is the tightening of the relationship between science and society. Society is demanding social accountability for public funded research. This research must result in social or economic value. Hence, public grant providers are increasingly aiming at social (and economic) goals. More weight is given to valorization. The tightening relationship between science and society is also visible in the communication patterns. The communication from the brain and cognition scientific world to society has intensified. Brain and cognition science is leaving the ivory tower, a trend that is generally observed in science-society relationships. In turn, society is interested in the developments in brain and cognition science. The social contract between brain and cognition science and society has indeed become tighter. The valorization need may push researchers to conduct less risky and more applied research. Risky and fundamental research is subsequently threatened, while this form of research is useful, valuable and necessary. Fundamental knowledge forms the vital basis for further (more applied) research and is needed to push the scientific field forward. Furthermore, fundamental research is important to preserve the quality of higher education (Hessels, 2010). And last, it is not excluded that fundamental research leads to outcomes with (high) social or economic value. Therefore it is recommended to maintain a reasonable share of public funding available for fundamental research.

The third observed pattern of change is related to the second one. The results point at a rise of a mismatch between the performance evaluation criteria of the researchers' employers and those of the public grant provider. Due to the tightening social contract social and economic goals are increasingly aimed at and assessment and advice committees increasingly use social quality criteria in the evaluation of research proposals. Nevertheless, a researcher's performance is evaluated mainly on scientific output, by his employer and remarkably also by the grant provider. It seems that this use of bibliometric indicators, and thus the importance of publishing, is increasing. The researchers themselves do not get credits for social or economic outputs. Consequently, for the researchers scientific output is much more important than social accountable outcomes, as one said: "The relation between publications and interventions is 10 to 1". Real incentives for social accountable research activities are lacking. The researchers experience a tension between meeting the grant providers' requirements and maintaining or improving their own scientific career. A situation that hampers practical orientated and/or social accountable research. To overcome this mismatch it is recommended to adjust and synchronize personal performance criteria and the social quality criteria for research activities. The incentives for meeting the social criteria should be improved, while the importance of scientific criteria can be reduced.

Fourth, it is observed that the role of industry in the brain and cognition research field is almost nil, both in research activities and in funding. In a recent study Technopolis Group mapped the stakeholders of the Dutch brain and cognition field over the three areas of application (Chapter 2) (Zuijdam et al., 2011). This study confirms these results of this thesis; industry is little present among the stakeholders. Researchers are reserved in collaborating with industry due to the risk on confusion of interests, while industry is not itching to collaborate due to the uncertainties of science. Another reason for the lack of contribution by industry might be the focus on social goals and the creation of social, and not economic or industrial, value. The surplus value of brain and cognition science is particularly social in nature and leads to a failure in co-operative behavior between public and private organizations. Public-private partnerships may function as an appropriate tool to overcome this failure (Pongsiri, 2002). Therefore, it is recommended to bring forth specific programs with which public-private partnerships can be formed.

When the results of this thesis are compared to the results of somewhat equivalent studies (Heimeriks & Leydesdorff, 2012; Hessels et al., 2010a; Hessels et al., 2010b; Hessels & Van Lente, 2011) differences in the knowledge production process can be identified across scientific fields. Although these other studies do not use exactly the same method as is done in this thesis, there is some overlap and the differences can be revealed. These field specific differences seem to be present across all three levels. Consequently, 'one size fits all' policy interventions and instruments should not be applied. Policies that do not take field-specific "characteristics, dynamics and requirements" into account "may be ineffective or even harmful" (Heimeriks, 2009). Instead, disaggregated, field specific science policy is recommended.

This thesis analysed to what extend the knowledge production process in the field of brain and cognition science changed based on the Mode 2 attributes. The Mode 2 theory functioned as an entrance point for determining the characteristics where the science field was analysed on. The results of the analyses of these characteristics may indicate to which extend the Mode 2 attributes have changed. The findings in this thesis support 4 out of 5 Mode 2 trends of change, but not to the same extend. These results are presented in Table 15.

Table 15: Results in terms of Mode 2 attributes (based on Hessels, 2010)

Attribute	Trend in the field of brain and cognition science
Context of application	Increased, but competed by scientific accountability
Transdisciplinary	Increased
Heterogeneous	No clear increase of non-scientific institutions
Reflexivity	Increased
Divers quality control	Increased only in public funding mechanisms

7.2 Reflection on theory and methodology

In this thesis a framework was developed to analyze the changing patterns in the knowledge production process in a scientific field, in this case the field of brain and cognition. This framework was primarily based on the Mode 2 theory of Gibbons et al. (1994) and the complex adaptive system as formulated by Heimeriks and Leydesdorff (2012). The Mode 2 theory, in particular the patterns of change related to the 5 major attributes, functioned as the entrance point for determining the characteristics where the brain and cognition search regime was analyzed on. As discussed before (section 4.2) this theory has the widest scope and takes cognitive, organizational and societal changes into account (Hessels & Van Lente, 2008). The transformations of the process of knowledge production discussed in the Mode 2 theory, distributed over the five major attributes, formed the basis for the conceptual framework. Next, the complex adaptive system with the 3 levels of research, science and society was added. This model takes the complete system of knowledge production into account. It pays attention to global, local and contextual dimensions (Heimeriks, 2009). Hence, it treats the mutual relationships between researchers, as well as their relations with the scientific community and with society (Heimeriks, 2009). Beside to these theories the framework used the search regime concept to demarcate the scientific field under study and the science-society contract as a heuristic for analyzing the interactions between science and society. Combined, the two theories, assisted by these two concepts, resulted in a framework with which a complete, multidimensional picture of the changing knowledge production process can be created. In total 13 hypotheses were formulated distributed over the research, science and society levels. These hypotheses were tested with a comprehensive dataset. All publications, which represent research activities, from 7 selected core journals that represent the scientific field under study, were analysed. As these scientific publications did not provide sufficient insights for the dynamics on the society level popular media publications, research programme descriptions and calls for proposals were also analysed. Additionally, 13 semi-structured in-depth interviews were held with researchers in the field. The interviews dealt with all three levels of the complex adaptive system. With this combination of both quantitative and qualitative data it was possible to make a complete and multidimensional analysis, as it covers both global and local dynamics. Thus, the conceptual framework and methodology developed in this thesis provide a useful way of analyzing the changing knowledge production process by taking the whole system of knowledge production, including its dynamics and interactions, into account.

Of course, some discussion about and criticism on the used theoretical and methodological concepts does exist. The Mode 2 theory is subject to very diverse criticism. Hessels and Van Lente (2008) elaborate on the objections that range from empirical validity to conceptual strength and political value. Their main conclusion on these critics is that attention has to be paid to differences between scientific fields, national contexts and the limited coherence of the five attributes. Within this thesis only one scientific field is analyzed, attention is paid to the local context of application and the attributes are studied separately. Actually, this thesis contributes to the debate on the coherence between the Mode 2 attributes. In agreement with the discussion in Hessels & Van Lente (2008) this thesis shows that there is no entire shift in the science system from Mode 1 to Mode 2 knowledge production (Table 15) and that the coherence is limited. Therefore, these claims of the Mode 2 theory are challenged. Though, when using the attributes in the way as is done in this thesis they are a useful heuristic for analysing the knowledge production process and the critics are overcome. The Mode 2 attribute *transdisciplinary* asks for some special attention here. Van den Besselaar & Heimeriks (2001) define the different forms of non-disciplinary research: multi-, inter- and transdisciplinary research (p. 2). However, researchers do not make this distinction and do not assign such type of non-disciplinarity to their activities. Therefore, throughout the analysis the terms multi-, inter- and transdisciplinary refer to non-disciplinary research in general and not to a specific form of non-disciplinarity.

The use of bibliometrics is also open to debate. This thesis uses publications as valuable indicators of research practices, a proven method following the success of the field of scientometrics/bibliometrics (Hessels & Van Lente, 2010). However, bibliometric data doesn't provide a complete view of the actual situation. For example, not all collaboration activities are represented by co-authorships (Laudel, 2002). Subsequently, the number and rate of collaboration might by underrepresented in this thesis. Furthermore, bibliometric data does not provide information on motives underlying the results. As far as possible, this gap is corrected via the in-depth interviews. For example, knowledge created by the industry is often not published (in order to maintain a competitive advantage). Subsequently, the role of industry might be poorly represented in the analysis. However, the interviews indicated a minor role for the industry in the brain and cognition field. Within the bibliometric study only formal communication through scientific publications is analyzed. It is arguable that in more application oriented research activities other forms of communication are also important. These more fluid forms include "conferences [...] and practical collaboration in applied projects"

(Van den Besselaar & Heimeriks, 2001, p8). Again, this gap is filled by the interviews as far as possible. Though, the completions by the interviews take only the local context into account.

7.3 Closing remarks

The knowledge production process is subject to change, and so the knowledge production process in the field of brain and cognition. The observed patterns of change are in line with the commonly acknowledged trends of research that is conducted in an interactive, interdisciplinary and international way; that is closely related to society; and that must be socially relevant and accountable. The increased importance of economic relevance and accountability and the industrial participation are still hardly present in the field of brain and cognition. These observations emphasize the field-specificity of the changes in knowledge production. The theoretical framework and methodology developed in this thesis are useful for an empirical analysis of the changing patterns and interactions in the knowledge production process in scientific fields. Analyses that are needed for two reasons: (1) empirical studies to the changing knowledge process are lacking, and (2) the different scientific fields with their field-specific dynamics ask for field-specific science policy.

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Appendix A – List of consulted experts

The experts in the field of brain and cognition research that are consulted in order to indentify the core journals in the field:

1. XXXXXXXXXXXXX
2. XXXXXXXXXXXXX
3. XXXXXXXXXXXXX

Appendix B – List of interviewees

XXXXXXXXXXXX
XXXXXXXXXXXX
XXXXXXXXXXXX
XXXXXXXXXXXX
XXXXXXXXXXXX
XXXXXXXXXXXX
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Appendix C – LexisNexis search queries

(((brain OR cognition) W/S (science OR research Or study) AND HLEAD (brain OR cognition) AND ATLEAST2(brain OR cognition) AND ATLEAST2(science OR research Or study))
OR
((hersen! OR cognitie) W/S (wetenschap! OR onderzoek! Or studie) AND HLEAD (hersen! OR cognitie) AND ATLEAST2(hersen! OR cognitie) AND ATLEAST2(wetenschap! OR onderzoek! Or studie))
OR
((hirn! OR kognition!) W/S (wissenschaft OR untersuch! Or studie OR forschung) AND HLEAD (hirn! OR kognition!) AND ATLEAST2(hirn! OR kognition!) AND ATLEAST2(wissenschaft OR untersuch! Or studie OR forschung))
OR
((cerveau OR cogniti!) W/S (science OR recherche Or étudier OR étude) AND HLEAD (cerveau OR cogniti!) AND ATLEAST2(cerveau OR cogniti!) AND ATLEAST2(science OR recherche OR étudier OR étude))
OR
((cerebro OR encéfalo OR cognición) W/S (ciencia! OR investigación OR estudion) AND HLEAD (cerebro OR encéfalo OR cognición) AND ATLEAST2(cerebro OR encéfalo OR cognición) AND ATLEAST2(ciencia! OR investigación OR estudion)))

Appendix D – SPSS syntax for coding affiliated organisations

Academic hospital

```
COMPUTE ACAD_HOSP=0.
IF  ((CHAR.INDEX(cs,"UNIV") > 0 AND CHAR.INDEX(cs,"HOSP") > 0) OR
(CHAR.INDEX(cs,"ACAD") > 0 AND CHAR.INDEX(cs,"HOSP") > 0)
OR (CHAR.INDEX(cs,"ACAD") > 0 AND CHAR.INDEX(cs,"MED") > 0) OR
(CHAR.INDEX(cs,"MED") > 0 AND CHAR.INDEX(cs,"SCH") > 0)
OR (CHAR.INDEX(cs,"MED") > 0 AND CHAR.INDEX(cs,"UNIV") > 0) OR
(CHAR.INDEX(cs,"MED") > 0 AND CHAR.INDEX(cs,"COLL") > 0)
OR (CHAR.INDEX(cs,"OSPED") > 0 AND CHAR.INDEX(cs,"UNIV") > 0) OR
(CHAR.INDEX(cs,"COLL") > 0 AND CHAR.INDEX(cs,"HOSP") > 0)
OR CHAR.INDEX(cs,"CHU") > 0 OR CHAR.INDEX(cs,"CHRU") > 0 OR
CHAR.INDEX(cs,"ERASMUS MC") > 0 OR CHAR.INDEX(cs,"CANC CTR") > 0)
ACAD_HOSP=1.
```

University

```
COMPUTE UNIV=0.
IF  ((CHAR.INDEX(cs,"UNIV") > 0 OR CHAR.INDEX(cs,"ACAD") > 0 OR
CHAR.INDEX(cs,"COLL") > 0 OR CHAR.INDEX(cs,"ECOLE") > 0
OR CHAR.INDEX(cs,"CALTECH") > 0 OR CHAR.INDEX(cs,"MIT") > 0 OR
CHAR.INDEX(cs,"CHU") > 0 OR CHAR.INDEX(cs,"UCL") > 0
OR CHAR.INDEX(cs,"NYU") > 0 OR CHAR.INDEX(cs,"ETH") > 0 OR
CHAR.INDEX(cs,"GEORGIA INST") > 0 OR CHAR.INDEX(cs,"KAROLINSKA INST") >
0
OR CHAR.INDEX(cs,"KOREA ADV INST") > 0 OR CHAR.INDEX(cs,"OKINAWA INST
SCI") > 0 OR CHAR.INDEX(cs,"CHARITE") > 0
OR CHAR.INDEX(cs,"FAC MED") > 0 OR CHAR.INDEX(cs,"GRAD SCH") > 0) AND
ACAD_HOSP = 0) UNIV=1.
```

Non-academic hospital

```
COMPUTE HOSP=0.
IF  ((CHAR.INDEX(cs,"HOSP") > 0 OR CHAR.INDEX(cs,"MED CTR") > 0 OR
CHAR.INDEX(cs,"AZIENDA") > 0 OR CHAR.INDEX(cs,"ZIEKENHUIS") > 0
OR CHAR.INDEX(cs,"KRANKENHAUS") > 0 OR CHAR.INDEX(cs,"OSPED") > 0 OR
CHAR.INDEX(cs,"CLIN") > 0 OR CHAR.INDEX(cs,"INFIRM") > 0
OR CHAR.INDEX(cs,"HOP") > 0 OR CHAR.INDEX(cs,"HEALTHCARE SYST") > 0 OR
CHAR.INDEX(cs,"HLTH SYST") > 0 OR CHAR.INDEX(cs,"OSP") > 0
OR CHAR.INDEX(cs,"AP HP") > 0 OR CHAR.INDEX(cs,"HOP") > 0 OR
CHAR.INDEX(cs,"CURA") > 0 OR CHAR.INDEX(cs,"IRCCS") > 0
OR CHAR.INDEX(cs,"RICOVERO") > 0) AND ACAD_HOSP = 0 AND UNIV = 0)
HOSP=1.
```

Research institute

```
COMPUTE INST=0.
IF  ((CHAR.INDEX(cs,"INST") > 0 OR CHAR.INDEX(cs,"NEUROSPIN") > 0 OR
CHAR.INDEX(cs,"NIA") > 0 OR CHAR.INDEX(cs,"NIAAA") > 0
OR CHAR.INDEX(cs,"NICHHD") > 0 OR CHAR.INDEX(cs,"NIDA") > 0 OR
CHAR.INDEX(cs,"NIH") > 0 OR CHAR.INDEX(cs,"MIND") > 0
OR CHAR.INDEX(cs,"NIMH") > 0 OR CHAR.INDEX(cs,"CNR") > 0 OR
CHAR.INDEX(cs,"CNRS") > 0 OR CHAR.INDEX(cs,"INRA") > 0
OR CHAR.INDEX(cs,"INSERM") > 0 OR CHAR.INDEX(cs,"LAB") > 0 OR
CHAR.INDEX(cs,"CEA") > 0 OR CHAR.INDEX(cs,"NINDS") > 0
OR CHAR.INDEX(cs,"RES CTR") > 0 OR CHAR.INDEX(cs,"MED RES") > 0) AND
ACAD_HOSP = 0 AND UNIV = 0 AND HOSP = 0) INST=1.
```

Industry

```
COMPUTE CORP=0.
IF  ((CHAR.INDEX(cs,"CORP") > 0 OR CHAR.INDEX(cs,"INC") > 0 OR
CHAR.INDEX(cs,"GMBH") > 0 OR CHAR.INDEX(cs,"INCORP") > 0
OR CHAR.INDEX(cs,"LTD") > 0 OR CHAR.INDEX(cs,"CO") > 0 OR
CHAR.INDEX(cs,"LLC") > 0 OR CHAR.INDEX(cs,"AG") > 0 OR
CHAR.INDEX(cs,"SPA") > 0
OR CHAR.INDEX(cs,"BV") > 0) AND ACAD_HOSP = 0 AND UNIV = 0 AND HOSP = 0
AND INST = 0) CORP=1.
```

Appendix E – Extensive Table 8: Share of each continent in bibliometric dataset

CONTINENT	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
NORTH AMERICA	79.19%	79.20%	77.41%	76.94%	75.69%	68.51%	70.47%	67.58%	66.27%	66.47%
EUROPE	16.62%	15.84%	17.87%	18.70%	18.84%	24.52%	23.40%	25.11%	27.02%	25.23%
ASIA	2.88%	3.87%	3.29%	3.61%	4.40%	5.33%	4.94%	5.91%	4.71%	6.33%
OCEANIA	1.05%	0.97%	1.10%	0.53%	0.57%	1.35%	0.91%	0.85%	1.00%	1.27%
SOUTH AMERICA	0.26%	0.12%	0.33%	0.21%	0.41%	0.28%	0.28%	0.55%	1.00%	0.69%
AFRICA	0.00%	0.00%	0.00%	0.00%	0.08%	0.00%	0.00%	0.00%	0.00%	0.00%

CONTINENT	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Change
NORTH AMERICA	63.28%	46.83%	57.73%	54.48%	55.79%	55.88%	51.73%	50.01%	48.67%	50.57%	-28.62%
EUROPE	28.35%	42.32%	33.57%	34.88%	33.58%	34.47%	37.43%	38.60%	39.00%	38.24%	21.62%
ASIA	6.18%	8.56%	6.71%	8.02%	8.45%	7.51%	8.63%	8.52%	9.87%	8.37%	5.49%
OCEANIA	1.53%	1.83%	1.36%	1.75%	1.45%	1.63%	1.58%	1.85%	1.73%	1.90%	0.85%
SOUTH AMERICA	0.63%	0.44%	0.63%	0.88%	0.73%	0.52%	0.58%	0.94%	0.68%	0.88%	0.62%
AFRICA	0.03%	0.02%	0.00%	0.00%	0.00%	0.00%	0.05%	0.07%	0.04%	0.05%	0.05%

Appendix F – Extensive Table 11: Share of publications that affiliate each type of organisation

Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Academic Hospital	35.78%	36.49%	35.28%	36.85%	40.20%	41.30%	40.63%	39.88%	36.70%	37.23%
Hospital	5.89%	6.22%	7.54%	6.96%	8.36%	7.85%	7.48%	7.76%	7.22%	7.42%
University	64.80%	63.11%	62.77%	60.86%	62.95%	62.50%	60.18%	64.18%	66.80%	67.67%
Research Institute	12.07%	12.84%	15.57%	16.69%	12.72%	15.71%	16.33%	17.26%	19.12%	17.35%
Industry	3.74%	3.11%	3.77%	4.68%	3.90%	5.74%	3.46%	4.21%	4.02%	3.57%

Type	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Change
Academic Hospital	36.35%	40.09%	35.51%	42.17%	41.86%	34.33%	41.92%	41.07%	42.25%	42.01%	6.23%
Hospital	7.09%	10.58%	8.51%	9.32%	9.84%	8.64%	9.36%	9.41%	9.71%	9.18%	3.28%
University	69.50%	66.34%	71.48%	67.87%	69.70%	77.14%	72.84%	75.04%	73.89%	77.59%	12.79%
Research Institute	18.17%	20.85%	19.13%	21.41%	20.61%	17.07%	20.71%	21.04%	21.84%	19.69%	7.62%
Industry	4.44%	4.63%	3.92%	4.98%	4.90%	4.39%	5.18%	6.04%	6.07%	4.92%	1.19%

Appendix G – Extensive Table 12: Share of each type of organization in the brain and cognition knowledge production process

Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
University	55.29%	53.93%	52.20%	50.45%	51.81%	49.26%	48.73%	51.11%	52.63%	53.78%
Academic Hospital	28.60%	29.46%	28.05%	28.59%	30.99%	30.83%	31.81%	28.81%	27.04%	27.12%
Research Institute	8.76%	9.50%	11.54%	12.57%	8.94%	10.81%	11.88%	12.29%	12.87%	11.82%
Hospital	4.63%	4.61%	5.48%	4.93%	5.63%	5.30%	5.29%	5.03%	4.89%	4.90%
Industry	2.72%	2.50%	2.74%	3.45%	2.63%	3.81%	2.28%	2.76%	2.56%	2.38%

Type	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Change
University	55.03%	50.97%	56.12%	51.42%	51.79%	59.87%	53.42%	54.62%	53.42%	56.20%	0.91%
Academic Hospital	26.04%	26.71%	24.15%	27.28%	27.51%	22.50%	26.68%	25.57%	25.82%	25.79%	-2.81%
Research Institute	11.75%	13.14%	12.30%	12.96%	12.52%	10.21%	11.96%	11.81%	12.50%	10.56%	1.80%
Hospital	4.41%	6.52%	5.08%	5.55%	5.54%	5.02%	5.35%	4.98%	5.32%	5.04%	0.41%
Industry	2.77%	2.66%	2.35%	2.78%	2.64%	2.40%	2.59%	3.01%	2.94%	2.41%	-0.31%

Appendix H – Extensive Table 13: Share of publications resulting from collaborations among universities, public research institutes and industry

YEAR	University - public	University - industry	Public - industry	University - public - industry
1990	18.50%	1.69%	1.41%	0.28%
1991	18.47%	0.92%	0.53%	0.00%
1992	18.00%	1.88%	1.29%	0.35%
1993	17.91%	1.66%	2.14%	0.83%
1994	21.42%	1.55%	1.46%	0.55%
1995	23.02%	2.17%	3.42%	1.00%
1996	21.00%	1.72%	2.26%	1.01%
1997	24.37%	1.93%	2.14%	0.64%
1998	24.97%	2.08%	2.08%	0.96%
1999	25.07%	1.95%	2.08%	1.04%
2000	25.32%	2.49%	2.45%	1.22%
2001	31.51%	2.69%	2.84%	1.55%
2002	28.23%	2.50%	2.44%	1.44%
2003	32.87%	3.35%	3.11%	1.99%
2004	33.78%	3.36%	3.06%	1.81%
2005	29.51%	3.01%	2.33%	1.46%
2006	36.19%	4.04%	3.13%	2.37%
2007	37.18%	4.11%	3.79%	2.41%
2008	37.06%	4.65%	3.97%	2.78%
2009	39.92%	4.06%	3.69%	2.99%
Change	*21.42%*	*2.37%*	*2.27%*	*2.71%*