Dissertation

Dynamics of Academic Leadership in Research Groups

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The **Rathenau Institute** shows the influence of science and technology on our daily lives and reveals the dynamics of this process through independent research and debate.

Dynamics of Academic Leadership in Research Groups

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Dynamics of Academic Leadership in Research Groups

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Content

1 Introduction

In order to solve highly complex scientific and societal problems (such as climate change, the economic crisis and infectious diseases), we cannot just wait for the answers coming from smart, intelligent scientists working in their ivory towers. These challenges necessitate a multi- inter- or transdisciplinary approach where more and different specialties and skills of researchers are combined in larger teams (Borner et al., 2010; Stokols, Hall, Taylor, & Moser, 2008; Stokols, Misra, Hall, & Taylor, 2008). Dick Swaab, professor of neurobiology, explains the increased complexity in neurosciences and what he would do if he started an academic career in 2011: "*I would first realise that brain science now consists of various disciplines that often have difficulty understanding each other's language. Those worlds need to be bridged in order to do research. It has become incredibly complex; the equipment has developed enormously. I would first learn a few techniques from good academics. I would check the CVs of people and visit their laboratories anywhere in the world. I would wish to learn the language of the techniques that you will need later. Functional scanning is important, as is molecular biology and cognitive neuroscience.*" (HP/De Tijd, februari 2011). The lonely genius who is inventing smart solutions in his or her own world is becoming, or already is, an extinct species. Academic research is increasingly conducted in teams, especially in the medical and health sciences (the focus of this study).

To conduct excellent research that contributes to solving complex scientific and societal issues, the availability of talented, creative, innovative and enthusiastic researchers is, of course, crucial. However, researchers can excel only if adequate conditions are provided by the environment they operate in (e.g. Allison & Long, 1990; Andrews, 1979; Heinze, Shapira, Rogers, & Senker, 2009; Hemlin, Allwood, & Martin, 2008; Pelz & Andrews, 1966). The work environment for researchers is the research group. Research groups are organisational units embedded in a research organisation (i.e. a university, research institute or university medical centre) with researchers and support staff as group members, with a research agenda and a research budget, and headed by an academic group leader (e.g. Andrews, 1979; Beaver, 2001; Cohen, Kruse, & Anbar, 1982; De Haan, 1994; Laredo, 2001; Laredo & Mustar, 2001; Rey-Rocha, Martin-Sempere, & Garzon, 2002, Stankiewicz, 1976). Academic group leaders are the core of a research group. In particular, their leadership and management practices are important for achieving high research performance, because group leaders affect the conditions for a productive research environment (Bland & Ruffin, 1992). Their challenge is to create adequate conditions that help meet individual as well as collective research goals, such as high research performance.

Obviously, research performance is not only the result of the behaviour of academic leaders; it is also influenced by several bottom-up and top-down processes. Bottom-up processes concern group dynamics, such as how individual researchers with different activities and skills interact. Top-down processes concern conditions created at a higher level in the organisation, such as the management practices of heads of departments, deans, and the board of the research organisation. In this study, I will focus on the leadership and management practices of academic group leaders, who operate at the intersection of these processes.

Academic group leaders fulfil an intermediary role, as they are positioned somewhere between the individual researchers within the group and the higher level management of the research organisation. This intermediary position seems to have become more important over the last decades. Recent changes in the science system are affecting the role of academic group leaders, such as a higher emphasis on academic excellence, increased competition for research funding, an increased need for access to expensive, large-scale research facilities, a tendency to organise research into large collaboration networks, and a call for conducting social relevant research. These developments put extra weight on the traditional tasks of group leaders and extend these with entrepreneurial activities, which, in turn, also ask for new skills (Hansson & Monsted, 2008). More specifically, the internal role of leaders in the workplace – where, among other things, they facilitate research meetings, supervise junior researchers and generate exiting new ideas – is increasingly extended with the external role of acquiring resources, maintaining collaboration networks and disseminating knowledge to society at large. It is this development that raises the research question of this study: *How does academic leadership affect the performance of research groups?*

The following quote illustrates to the topic of this study; what does the life of an academic group leader look like and how does leadership behaviour affect a research group's performance?

"As a professor… Yes, you have to teach things to many people, but also do a lot of research. So, part of my time I'm in the lab, I discuss research, I plan research, we analyse the results. We consider: what may have gone wrong? What can we learn from this experiment? How do we want to proceed with the research? So, it is a lot of collecting, seeing and discussing results. Of course, as a junior researcher you do the experiments. You have all these little pots and pans and dishes. You make what I eventually see, so we still look through the microscope a lot. When my analyst comes and says, 'look, I've got something interesting, what do you think it is?' we go and look through microscope together and say, 'well, that looks like a blood vessel cell. What can we do to prove it?' And, naturally, the first time we saw heart cells, well, it goes without saying: we all looked through the microscope and there was this thing, beating.

It was wonderful to see, but seeing a beating cell does not mean that it is a heart cell. So we needed follow up with all kinds of tests. You can add all kinds of dyes to see if it really is a heart cell. Or you can take an electrode: can you measure an electrical current in that cell? Does it work like a real heart cell? And then you can do all these things. But in practice, my life consists of collecting data, reading a lot on the internet, reading articles. What does the competition do? Are we the first? What are the chances of a good publication? A lot of data analysis. And keeping in contact with colleagues, especially those abroad." (Christine Mummery, professor in developmental biology, Leiden University Medical Centre, on the life of a professor in the Spinoza Debate).

1. Academic leadership

The vital contribution of the academic leader to research performance is undisputed (Babu & Sing, 1998; Bland & Ruffin, 1992; Harvey, Pettigrew, & Ferlie, 2002; Knorr, Mittermeir, Aichholzer, & Waller, 1979; Mumford, Scott, Gaddis, & Strange, 2002; Smith, 1971; Spangenberg et al., 1990; Stankiewicz, 1976). These studies focus on the importance of leadership in general rather than on the type of management activities and leadership practices that relate positively to research performance. In most empirical studies, only one or a few management activities, leadership practices or contingencies[1] are included. Van der Weijden et al. (2007; 2008) conducted one of these rare studies[2] where a diverse set of management and leadership determinants of research performance were included. The study concluded that group leaders have different (combinations of) research goals and each research goal calls for a different strategy. Van der Weijden's study shows the complexity of steering a research group. Yet, it is unclear how various academic leadership determinants of research performance are interrelated and how they affect group performance. My research aims to disentangle these questions and examine what the main factors of academic leadership are that influence performance of research groups.

To understand how academic leadership influences performance, a clear definition is needed. In this study, academic leadership of research groups is defined as: the management and leadership of researchers and the research group; it refers to the variety of opinions, tasks and practices of academic group leaders. Based on a literature review presented in chapter two, I will distinguish four components of academic leadership. According to Zaleznik (1977), the leadership role that requires an open spontaneous attitude to developing creative and innovative ideas is rather different from the management role that requires a well-structured organisation. For research groups this means that *leadership* refers to how individual researchers are directed and encouraged by the

1 Examples of contingencies are scientific discipline, activity profile and characteristics of the group leader.

2 One of the first studies on this topic was conducted by Pelz & Andrews (1966).

inspiration and vision of the leader, and *group management* concerns the tools that leaders use to manage and coordinate the research process. In addition to their internal role, leaders have an external role which is currently intensified as described above. The activities undertaken to position the research group in the academic and societal environment so as to obtain legitimacy, reputation and visibility is the so-called *network management* task. Finally, *resource strategy* is the task to acquire and combine the resources for the research group, which are needed to conduct research in the first place.

2. Research performance

As argued by Merton (1957), the highest priority of scientists is to be the first to present new knowledge and to get rewarded for this by the scientific community. Although this seems to be a clear goal of science, the way to measure the originality of ideas is heavily debated. Given the multidimensional nature of research output, this is not surprising at all (Jansen et al., 2007). New knowledge claims can be presented in publications, reports, presentations, technical contributions, contributions to public debates, education, patents and innovations. Also, assessment of the quality of newly produced knowledge has a multidimensional nature. Quality can be measured in terms of productivity, impact, innovativeness, creativity, social relevance and recognition. Due to the multidimensional character of research performance, it is hard to construct an objective definition of research performance, let alone an objective definition of 'excellent' research performance. This study aims to contribute to the debate on the measurement of research performance by formulating a workable definition of performance, by constructing a multidimensional performance index, and by investigating how academic leadership influences the various goals of research. In addition to traditional indicators such as publication and citation counts, this study addresses new indicators that refer to the social relevance of knowledge produced.

3. The Dutch science system[3]

How academic leaders influence the performance of research groups is also determined by the context in which a leader and his or her group operate. To inform the readers who are not familiar with the Dutch science system, this section begins with a general overview of the Dutch science system. I will then look more specifically at the external factors that an academic leader has to take into account, namely funding and human resource management (resources), quality control (management) and agenda setting (leadership).

3.1 Research organisations and intermediary organisations

Data for my research on academic leadership have been collected in the Netherlands. The Dutch science system is characterised by a complex landscape of organisations with various roles and goals. First, there are research organisations: universities, university medical centres, research institutes, private non-profit research institutes[4] as well as companies. Also, there are numerous intermediary organisations that allocate funding, stimulate research and innovation, coordinate large-scale collaborations between research organisations, and fulfil an advisory role.

Research is conducted by the universities including the university medical centres (UMCs), research institutes including the private non-profit (PNP) institutes, and companies[5].

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3 This section is a summary of the following reports: Versleijen, A. (eds) (2007) *Dertig jaar publieke onderzoeksfinanciering in Nederland 1975-2005* (Thirty years of public research funding in the Netherlands 1975-2005); Ministry of Education, Culture, and Science (2009) *Het Nederlandse wetenschapssysteem* (The Dutch science system); Dawson, J., Van Steen, J., & Van der Meulen, B. (2009) *Science systems compared: A first description of governance in innovations in six science systems*; Van Steen, J. (2011) *Feiten en cijfers: Overzicht Totale Onderzoeksfinanciering* (TOF) 2009-2015 (Facts and Figures: Overview of Total Research funding 2009-2015); Van Balen & Van den Besselaar (2007) *Universitaire onderzoeksloopbanen. Een verkenning van problemen en oplossingen* (University research careers. An exploration of problems and solutions); Van Balen (2010) *Op het juiste moment op de juiste plaats. Waarom wetenschappelijk talent een wetenschappelijke carrière volgt* (Being in the right place at the right time. Why academic talent follows an academic career); Van den Besselaar, P., & Horlings, E. (2011), Focus en massa in het wetenschappelijk onderzoek: de Nederlandse onderzoeksportfolio (Focus and mass in academic research: the Dutch research portfolio); Van den Besselaar, P. (2011), Een kwantitatieve analyse van de besluitvorming over aanvragen in de Vernieuwingsimpuls 2009 (A quantitative analysis of grant decisions on submissions in the Innovational Research Incentives Scheme 2009).

4 This is a very small sector in the Netherlands.

5 Most of the research is conducted in companies. In 2007, there were approximately 2,700 companies conducting R&D with more than ten employees in the Netherlands.

There are 14 public research universities, including one university for distance learning (Open Universiteit). In addition to conducting research, universities provide education and disseminate knowledge to society. Since 1999, the eight Dutch UMCs have become independent from the universities; the medical faculties of the universities have formalised their collaboration with the medical centres. UMCs conduct research, provide education and supply patient care.

Research institutes include:
- The institutes of NWO and KNAW that conduct research in various scientific fields
- The Dutch organisation for applied research (TNO) that services both the government and companies in strengthening their innovative capabilities
- The Large Technological Institutes (GTI's) that function as centres of technological knowledge and develop technology for companies as well as for the government
- DLO institutes that conduct agricultural research and are part of the Wageningen University and Research Centre which focuses on the life sciences and natural resources
- Departmental institutes are knowledge institutes that are part of a specific ministry, such as Statistic Netherlands (CBS) that is part of the Ministry of Economy, Agriculture and Innovation
- Technological and Social Top (virtual) institutes that aim to stimulate public-private collaborations

In between government and research organisations there is a complex landscape of intermediary organisations for the allocation of funding, coordination of research, stimulation of research and innovation, collaboration of research and advice.

NWO is the Dutch research council. In general, NWO funds basic research. NWO provides various subsidies for programmes and projects, for specific research fields or specific goals (e.g. the encouragement of individual academic careers). It has developed into an intermediary body with a range of different responsibilities and organisational divisions:
- NWO owns nine research institutes
- NWO has eight disciplinary bodies and foundations to allocate competitive funding and manage research programmes
- NWO has two separate divisions for funding: engineering sciences by the division STW and medical research by the division ZonMw
- NWO manages three of the national coordinating bodies (i.e. genomics) for strategic funding
- NWO has two foundations (WOTRO – Science for Global Development and NCF – national computer facilities)

Agentschap NL is a government agency that provides research consortium funds and research subsidy schemes intended for companies and research institutes. It focuses on strategic technological research in innovation, energy, climate and environment.

KNAW (The Royal Netherlands Academy of Arts and Sciences) is an independent and high quality advisory body for the government, but it also owns seventeen research institutes that conduct research and preserve collections. With regard to their advisory role, KNAW has some advisory bodies on various scientific disciplines. Also, there are some advice committees on specific topics such as ethics and global change.

Other advisory organisations are: the Advisory Council for Science and Technology Policy (AWT) which provides independent advice to the government concerning the policy for academic research, technological development and innovation; 'knowledge chambers' to intensify interaction between ministries and research organisations; the Scientific Council for Government Policy (WRR), which, using an academic approach, aims to advise the government about future developments of great public interest; the Social and Economic Council for the Netherlands (SER), which aims to help create social consensus on national and international socio-economic issues, and the National Bureaus for Policy advice (Planbureaus).

Furthermore, there are some other organisations that support research but do not conduct research themselves. EG liaison is part of Agentschap NL and it is the expertise centre for European Framework Programmes in the Netherlands; it supports potential applicants with information and advice, information meetings, training days and partner search. Stichting SURF is a collaboration network between universities, professional education institutes and research institutes for frontier ICT innovation to improve the quality of education and research. Finally, the academic libraries and the Royal Library (KB) provide access to academic information.

3.2 Funders and funding types

Research is funded by companies (private sector), the government, other national sources and foreign countries. The Netherlands spends 1.76 percent of the GDP on R&D, which is a relatively low amount compared to other countries in the European Union (EU) and is caused by the low private funding for R&D. Nevertheless, private funding is the most important source for R&D and amounts to approximately 50 percent. Public research funding amounts to 36 percent in the Netherlands, which is similar to other EU countries. Since 1997, foreign funding – including the EU funds – has increased until over ten percent of the total R&D funding. Other national sources are mainly the charity funds which are an important funding source especially for the medical sector.

Most (meaning 80 percent) of the public research funds from the government are allocated to universities, university medical centres (UMCs) and public research institutes. The Ministry of Education, Culture and Science (73 percent) and the Ministry of Economic Affairs[6] (12 percent) provide the highest proportion of funding. The remaining government funding comes from the other ministries (15 percent). The highest proportion of the total public research funds is institutional funding (60 percent), which research organisations get for their research mission; they are autonomous as to how they spend this money. Part of the institutional funding is goal-directed and is meant for research organisations with a specific mission (so-called earmarked funds). A very small part is predetermined for the infrastructure and equipment of the research institute, but since the mid-1990s most of these funds have been included in institutional funding or consortia funding. The remaining part of the institutional funding goes to international research collaborations (e.g. CERN).

In addition, NWO allocates public research funds via project funding. Project funds are intended to fund research with a specific goal and they are allocated through competitions. Open competitions are project funds where researchers can choose their own theme; these competitions are meant to stimulate excellence and innovation in general. An important incentive, for example, is the Innovational Research Incentives Scheme (Vernieuwingsimpuls) which was implemented in 2000 to support excellent researchers in different phases of their careers: *Veni* for researchers who have recently obtained their PhDs and who are allowed to develop their own ideas; *Vidi* for researchers who want to develop their own innovative research line with one or more researchers, and *Vici* for senior researchers, enabling them to build their own research group. The competition for the 'Verniewingsimpuls' is relatively strong; the average chance to obtain a grant is 17 percent but varies between scientific disciplines. For medical sciences the success rate is 18 percent, and especially for the social sciences the success rate is quite low: 12.5 percent. Thematic competition includes funds for a specific field or theme to increase research capacity, to stimulate interaction between researchers and practitioners or to stimulate innovation. Consortia competition has emerged since the 1990s and is meant to unite resources and to encourage strong coordination in a specific field, for example top research schools and technological top institutes. This type of funding also resulted in specific coordination bodies, which are temporary organisations that coordinate specific themes such as genomics, nanotechnology and climate research. Funds from contract research are meant to solve a specific research question from a ministry or company in mainly short-term projects. For the medical sector, charity funds are another important funding source. These charities[7] have their own

6 Because of the recent reclassification of departments, the Ministry of Economic Affairs has now changed into the Ministry of Economic Affairs, Agriculture and Innovation.

7 The largest charity funds are KWF kankerbestrijding (Dutch Cancer Society) and the Hartstichting (Dutch Heart Foundation).

assessments and allocation procedures for funding academic excellence research that focuses on a specific disease. Increasingly important is funding from the European Framework Programmes. For research groups in the medical sector, this has increased from three percent in 2002 to about 11 percent in 2007 of the total research funding (Van der Weijden, Verbree, Braam, van den Besselaar, 2009). Finally, other funding sources are coming from foreign companies. Since 1975, the organisation of project funding has steadily extended. As a result, the intermediary level of organisations increased extensively.

3.3 Human resource management

There are surprisingly few efforts in systematic Human Resource Management (HRM) to attract and retain talented researchers. Anyone wishing to pursue an academic career after obtaining a PhD will find that he or she is highly dependent on coincidences. For instance, there has to be a professor or senior researcher who provides supervision and mentorship in one's next career step. An academic career most likely results in an accumulation of temporary postdoctoral positions with little job security and unclear agreements about career perspectives. One of the causes is the inflexible, hierarchical career system. Applying for a full professorship is only possible when there is a vacancy; you have to wait until your predecessor has left. Assistant and associate professors have relatively little autonomy too, since they reside under the research programme of a leading professor. A remarkable characteristic of the Dutch academic career system is the position of PhD students; they are not students but employees and therefore make the system quite expensive. The number of positions for PhDs has increased over the last years but it is still low in comparison to the size of the Dutch science system.

Recently, several local initiatives have been implemented in research organisations to encourage talented researchers. Some universities have started to implement the tenure track system. Tenure track aims to offer assistant or associate professors a permanent position as associate or full professors respectively, provided that they have come up to some specific expectations within a five-year period. Another example is the principal investigator system that provides possibilities for (young) talented researchers to develop their own research line and group.

In particular, talented women are supported in their careers. All universities signed the 'Charter Talent to the Top', which aspires to increase the proportion of women in higher level positions. Still, however, nowadays only 12 percent[8] of the full professors are female. In comparison, the average percentage of female professors in other European countries is 19 percent. A specific example of a

8 Monitor Women Professors 2009: an initiative of the De Beauvoir Foundation and a product in collaboration with the Association of Dutch Universities (VSNU), the Dutch Network of Women Professors (LNVH) and the Social Fund for the Knowledge Sector (SoFoKleS).

programme that stimulates female researchers is the Rosalind Franklin Fellowship Programme of the University of Groningen (RUG), which focuses on helping more women to obtain a full professorship. Van den Brink (2009) showed that such initiatives for female researchers are needed, since recruitment and selection for a professorship are usually not public and not transparent. She also showed that half of the assessment committees consists of males only, which decreases the chance of female candidates being appointed.

Searching for the most talented researchers already starts during bachelor and master education with so-called honours courses. Very recently, (medical) graduate schools have been established to create a stronger connection between bachelor and master education and the PhD phase. The organisation of education in graduate schools provides opportunities for coherence between education and research, joint use of facilities, an increase of quality and return of investments (higher proportion of PhDs), and an option to offer interdisciplinary education. UMCs also provide opportunities that stimulate young, talented researchers. For example, specific scientific committees have been founded to supervise young researchers in writing research proposals to obtain grants[9]; some special fellowships are available that attract external talent to the organisation, and there are internal opportunities (with internal assessment procedures) to get funding for highly innovative and creative research pilots. Despite some local initiatives for stimulating talented researchers, research organisations do not have general career policies.

3.4 Quality control

There is one joint Standard Evaluation Protocol (SEP)[10] to control quality in Dutch research organisations. Evaluations focus on either the institute (faculties or research schools) or on the individual research groups or programmes. The focus at institute level is on policy and strategy, with the accent on future prospects. The focus at group level is on performance and deals with scientific achievements as well as social relevance. These 'once in six years' evaluations are organised by research organisations themselves through the appointment of external committees. It is unclear whether different committees use comparable standards. The outcomes of the assessments have no direct effect on funding allocations, and limited effects on research policies of the organisations. The SEP has two main objectives with regard to the evaluation of research (including PhD training) and research management:

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9 Research organisations are especially eager to obtain the so-called Innovational Research Incentives Scheme (Vernieuwingimpuls).

10 SEP 2009-2015 is available on the internet only: www.knaw.nl/Content/Internet_KNAW/publicaties/pdf/20091052.pfd.

1 Improvement of research quality based on an external peer review, including scientific and societal relevance of research, research policy and research management.
2 Accountability both to the board of the research organisation and to funding agencies, the government and society at large.

Assessment is based on four criteria: quality (i.e. academic reputation, resources and PhD training); productivity (i.e. the number of scientific publications, PhD-theses, professional publications and output for audience outside the academic community); relevance (i.e. interactions with stakeholders as well as products for and use by stakeholders), and vitality and feasibility (i.e. strategic planning, research facilities and financial resources). The evaluation committee clarifies its most important considerations and presents its conclusions on a five-point scale from unsatisfactory (below acceptable standards) to excellent (world-class research). Three years later, the external recommendations of the committee are evaluated internally by a mid-term review; future actions, too, will be formulated then.

3.5 Agenda setting

Characteristic for the Dutch science system is the absence of a long-term national research agenda with set priorities. Instead, agenda setting occurs at various levels (universities, public research organisations, intermediary organisations, research groups and individual researchers) in the science system. On the whole, research organisations (universities, UMCs and public research institutes) have a large degree of autonomy with respect to their strategy. There is no strong competition between research institutes; instead they tend to collaborate internally (and do so increasingly) by setting up inter-organisational graduate schools, virtual research institutes and research consortia. This is partly stimulated through several funding instruments (such as consortia competition) and top institutes as described above in 'funders and funding types'. Perhaps this is why there is hardly any reputational and quality differentiation between research organisations. The most recent development in higher education policy is that universities need to develop more distinctive research profiles[11]. University medical centres (UMCs) are already setting priorities for specific research themes in which they aim to focus and to excel.

11 Advies van de Commissie Toekomstbestendig Hoger Onderwijs Stelsel (Advisory committee Future-proof Higher Education) (2010) *Differentiëren in drievoud omwille van kwaliteit en verscheidenheid in het hoger onderwijs* (Differentiate in threefold because of quality and diversity in higher education); Ministry of Education, Culture and Science & Ministry of Economy, Agriculture and Innovation (2011) *Kwaliteit in verscheidenheid. Strategische Agenda Hoger Onderwijs, Onderzoek en Wetenschap* (Quality in diversity. Strategic Agenda Higher Education, Research and Science).

3.6 Medical and health research in the Netherlands[12]

In this study, the dynamics of academic leadership in research groups will be investigated in the medical and health research fields in the Netherlands. There are a number of reasons why it is these fields that are particularly interesting. The total output covers approximately 40 percent of public research in the Netherlands. Also, the Netherlands contributes a high proportion of medical and health research to the world output (Van den Besselaar & Horlings, 2011). From an international perspective, this output is of high quality (NOWT, 2010). Furthermore, the medical and health sciences consist of many different specialties. Based on the relation to patients, these specialties can be classified into three domains (Van der Weijden, 2007, p. 19). In para-clinical research, researchers have an advisory relationship with patients and their research; therefore, it often has a social sciences perspective. In pre-clinical research, researchers have no direct contact with patients, since their type of research is often basic, usually laboratory-based. In clinical research, researchers have direct contact with patients and their research; therefore, it is application-oriented. Table 1 gives an overview of disciplines in medical and health research that are classified according to these three domains.

12 Information in this paragraph is partly based on interviews with four experts from the field: Prof. Dr. Rune Frants, Prof. Dr. Frits Koning, Prof. Dr. Pancras Hogendoorn and Prof. Dr. Eduard Klasen. Furthermore, the website of the NFU and the various UMCs provided information.

Table 1 Classification of medical and health disciplines in three domains

Para-clinical research (health care research)	Pre-clinical research (basic medical research)	Clinical research (applied research)
Medical psychology	Pharmacology and toxicology	Oncology
Environment, work and health	Genetics	Cardiovascular system
Youth and health	Cell and development biology	Nephrology
Social medicine	Immunology	Respiration
Public health	Microbiology	Dermatology
Bioinformatics and epidemiology[13]	Virology	Musculoskeletal disorders
	Haematology	Gastroenterology and hepatology
	Medical technology	Neurology
	Endocrinology	Psychiatry
	Metabolism	Gerontology and geriatrics
	Neurosciences	General practice
	Bioinformatics and epidemiology[1]	Bioinformatics and epidemiology[1]

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13 Bioinformatics and epidemiology can be characterised as a method rather than a discipline. It depends on the topic in which discipline it should be classified, i.e. genetic epidemiology (para-clinical), molecular epidemiology (pre-clinical) or clinical epidemiology (clinical).

Note: This table is based on Van der Weijden (2007, p. 20) and adjusted in consultation with Eduard Klasen (dean of Leiden University Medical Centre).

In addition to the output, quality and diversity of the medical and health sciences, the field has a leading position as far as the implementation of new developments in the organisation and institutionalisation of research is concerned. Inherent in medical and health research is the relevance for society at large; eventually research aims to improve patient care. To strengthen the relationship between basic medical science and clinical health care, the cooperation between medical faculties and university hospitals has been formalised in the establishment of University Medical Centres (UMCs) since 1999.This development has benefitted the organisation of research in two ways. Firstly, the transition from two organisations (medical faculty and university hospital) to one (UMC) has reduced the complexity of the organisation. As a result, management and administrative issues like funding and human resource management have been more efficiently organised. The second benefit is related to why UMC were established in the first place: to bring research closer to patients. Translational research that brings research from bench to bedside is intensified by pre-clinical and clinical collaboration. Clinical researchers benefit from faster access to basic medical knowledge for patient care, while pre-clinical researchers benefit from the availability of patient populations and materials to test fundamental knowledge.

Since 2004, the Netherlands Federation of University Medical Centres (NFU) has been representing the collaboration of the eight UMCs[14]. NFU policy has led to nationwide agreements on 'which UMC provides which care'. This so-called referral care aims to take care of patients with orphan diseases, with diseases difficult to diagnose or with diseases difficult to treat *(topreferente zorg)*. Patients are referred to the particular UMC that can provide the best health care based on its excellent research within a specific domain. This development relates to different research themes that a specific UMC aims to focus on and excel in.

The choice for specific research themes is an ongoing development. Traditionally, research is organised within departments. Recently, thematic research themes have emerged between various departments with overlapping research topics, resulting in a multidisciplinary approach of research problems. For example, depression, epilepsy and migraine are all episodic syndromes that call for basic research of biological rhythm and have direct relevance for patient care. These multidisciplinary collaborations are not limited to the walls of one UMC. In the last years, research institutes have emerged that combine research on a specific theme by several UMCs, (technical) universities and public and private research institutes. In these collaborations, medical knowledge is linked to knowledge from other disciplines such as engineering sciences, mathematics, natural sciences, humanities or social sciences. Furthermore, large international collaborations are being supported by research funding from the EU Framework Programmes.

The increased collaboration of research in the medical and health sciences is caused by an interaction between bottom-up and top-down processes. One driving factor is evidently the increased research funding that stimulates these collaboration initiatives, such as the abovementioned increase in funding of EU projects. Also, the amount of goal-directed funding for consortia and thematic programmes has increased. For the medical sector, this development has been taking place since the mid-1970s; since 2005, consortia funding has become more important (figure 1).

These type of large-scale collaborations are being intensively encouraged by higher management policies, such as NFU, the Board of Directors of UMCs, deans, and department managers who aim to create "focus and mass" in research. Interviews with experts indicated that academic group leaders are also willing to cooperate because of the benefits that are generated: increases in scale lead to new knowledge, expertise and technologies, possibilities for large-scale infrastructures, acquirement of visibility, and attractiveness for talented and excellent researchers.

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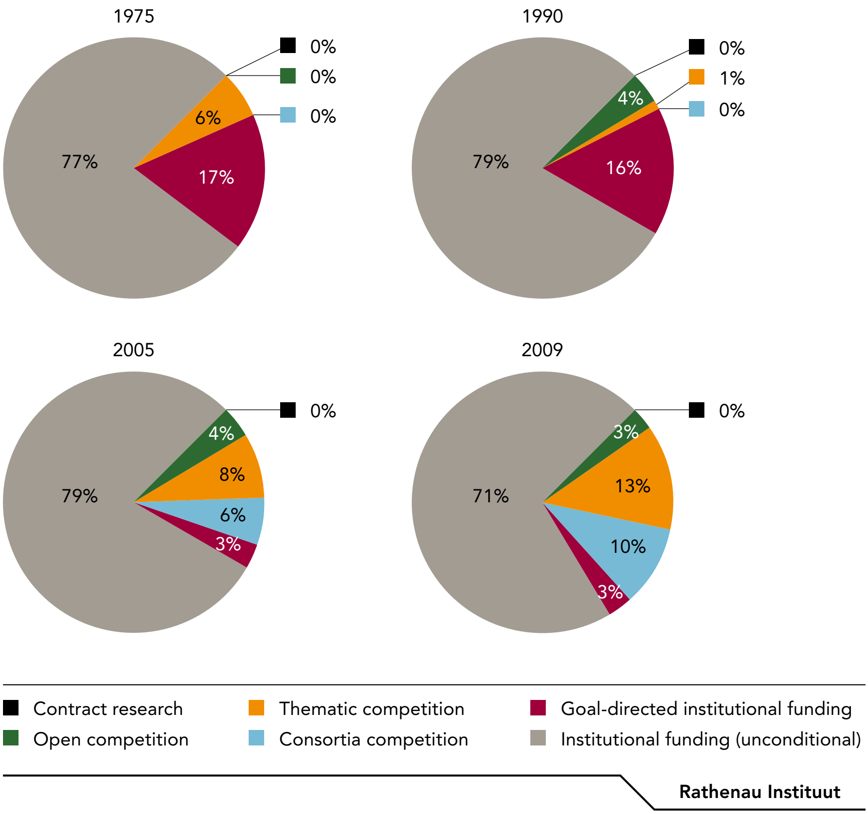
14 The predecessor of the NFU was the Association of Academic Hospitals (VAZ).

In short, the medical and health sciences are particularly suitable to study the dynamics of academic leadership. They account for a high proportion of academic leaders in the Dutch science system. The diversity in research types – para-clinical research with a social science perspective, pre-clinical research with a fundamental orientation and clinical research focused on application – provide opportunities for generalising the findings to other scientific fields. Finally, the high degree of research coordination in this field explicitly challenges the role of academic group leaders who no longer manage research and researchers on the shop floor (or laboratory) only, but do so increasingly on inter-institutional, national and international levels too.

Figure 1 Proportion of different funding types for the medical sector in 1975, 1990, 2005, and 2009 (source: Van der Meulen & Horlings, 2010). Note: Industry funding, European funds and charity funds are not included in the figures. Contract research refers to specific research projects funded by ministries.



4. Methods

This research is a quantitative study that examines how academic leadership influences performance of research groups. In order to collect data about academic leadership practices, a survey was sent out in 2002 and 2007 among para-clinical, pre-clinical and clinical group leaders in the Netherlands (see table 2). The population in 2002 was defined by interviews with research policy staff from medical faculties that provided lists of academic group leaders. In 2007, all medical professors of the Dutch Research Database (NOD) were included in the study. This provided a larger population, but it may have also resulted in a larger proportion of professors that are not academic group leaders (i.e. they do not have their own research group). This may explain why the response rate in 2007 was somewhat lower. In both years, the response was evenly distributed among (sub-)disciplines and organisations.

Table 2 Response rate academic group leaders

	2002	2007
Para-clinical	12	26
Pre-clinical	68	80
Clinical	57	82
Total	**137**	**188**
Response rate	**38%**	**27%**

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The survey design was based on interviews and a literature review (Van der Weijden, 2007; 2008). Items addressed in the survey refer to various components of academic leadership, i.e. resource strategy (proportion of funding from various sources), leadership (research commitment and time allocation), group management (rewards and communication) and network management (conference attendance and participation in committees)[15]. The survey of 2007 included some additional items on the topic of societal impact of health care research. Performance data (publication and citation counts) were collected from PubMed (US National Library of Medicine's search service) and Thomson Reuters (formerly ISI) Web of Knowledge. For more details about the methods, I refer to the separate chapters.

In addition to the quantitative data, preliminary results were presented in a four-hour expert meeting with 27 participants. The goal of this meeting was to get feedback on the results and policy recommendations. Participants were academic group leaders and experts from various organisations such as UMCs, non-university

15 The survey of 2002 is printed in Van der Weijden (2007, p. 201) and the survey of 2007 is printed in appendix 1.

research institutes, NFU, ZonMw, NWO, KNAW, RGO, QANU and charity funds (see appendix 2). Furthermore, results were presented to and discussed (1) with about 150 academic leaders of five UMCs, (2) with participants (academic leaders) from various disciplinary backgrounds at a large conference about academic leadership, organised by Sofokles, and (3) with policy makers of the Medical and Health research council (ZonMw). Finally, four interviews were held with experts from the field to gather information about recent developments in the organisational context of medical and health sciences in the Netherlands.

5. Overview

In order to investigate how academic leadership influences performance of research groups, four separate studies were conducted that are presented in the following four chapters (Chapters 2-5). Chapter two, 'Academic Leadership of High-performing Research Groups'[16], provides an extensive literature review of the relationship between academic leadership and research performance. Here, I construct a workable definition of academic excellence. For the period 2004-2006, a multidimensional academic performance index was constructed and used to identify high-performing research groups. Academic leadership of high-performing research groups (n = 34) was compared to other (average performing) research groups (n = 151) from the 2007 survey. Also, the issue of weak-performance is addressed. Based on the differences found in academic leadership, I provide suggestions to improve the leadership, management and organisation conditions that facilitate excellent research performance.

In the next chapter, the focus is on the characteristics of academic leaders such as age, experience and generation. More specifically, the question in chapter three, 'Generation and Life Cycle Effects on Academic Leadership'[17], is how generation and life cycle influences academic leadership. This study is the first to address academic leadership development and discuss generational challenges. With cross-sectional analysis of the data from the 2002 survey[18], academic group leaders at varying points in their life cycles (starting n = 22, experienced n = 69, leaving n = 45) were compared in order to investigate differences in their behaviour. Generations were defined based on a natural experiment that was based on changes in research evaluation and funding in the Dutch science system. Behaviour of academic leaders (n = 105) who were socialised in the time period before these changes took effect were compared with academic leaders (n = 30) who were socialised after these changes took

16 Chapter two is submitted as book chapter for S. Hemlin, C. M. Allwood, B. Martin, & M. Mumford (Eds.), *Creativity and Leadership in Science, Technology, and Innovation*.

17 Chapter three is accepted as book chapter for S. Hemlin, C. M. Allwood, B. Martin, & M. Mumford (Eds.), *Creativity and Leadership in Science, Technology, and Innovation*.

18 The survey in 2002 provided information about the year a PhD was obtained. This enabled us to define cohorts of academic group leaders. This information was not included in the 2007 survey

effect. The implications for academic career policy and the organisation of research in groups are discussed.

Chapter four, 'Addressing Complexity in Leadership and Management of Research Groups'[19], introduces a conceptual model of the relationship between academic leadership and research performance. The model is based on the two preceding chapters, on Gladstein's (1984) inputs-process-outputs model of group effectiveness, and on insights of the resource dependence theory (Pfeffer and Salancik, 1978). The model combines various variables of academic leadership in order to examine how various academic leadership practices are interrelated and simultaneously influence resource performance. Combining data from both surveys enlarges the sample (n = 325), which provides opportunities for more advanced model testing with negative binomial regressions. The results show which specific academic leadership practices lead to different research goals, i.e. achieving high output, securing high visibility, reaching high productivity and attaining high quality. Finally, implications are discussed for research evaluation, the relations between research groups and higher level management, and disciplinary differences.

The last empirical study in chapter five, 'From Bench to Bedside: The Societal Orientation of Research Leaders'[20], addresses the topic of societal impact as included in the 2007 survey. With respect to the increasing emphasis on societal relevance of scientific research, the following question was posed: what is the societal orientation of leaders and how is it related to scientific productivity? More specifically, what is its effect on the research agenda, communication with stakeholders and knowledge dissemination to stakeholders? Also, the diversity and quantity of societal output is investigated and subsequently how this relates to scientific productivity. Finally, results are presented about the relationship between funding, group size and experience and societal output. The chapter is finished with a discussion about the incentives that are needed to stimulate societal impact.

In the final chapter, the conclusions of the four empirical studies will be summarised. Also, the theoretical implications as well as the science policy implications following from the main conclusions will be discussed.

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19 Chapter four is submitted for *Research Policy*.

20 Chapter five is accepted for *Science and Public Policy*.

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2 Academic Leadership of High-Performing Research Groups

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Abstract
This study investigates whether leaders of high-performing academic research groups differ in academic leadership from leaders of research groups with 'average' performance. We constructed a multidimensional academic performance index using data from PubMed, the Web of Knowledge, and our own survey on academic leadership of 185 biomedical and health care research group leaders in the Netherlands. The research groups cover the various main types of research in the biomedical and health sciences: pre-clinical (fundamental research in natural and life sciences), clinical (application-oriented clinical research), and para-clinical (social sciences-oriented research). We investigated the effects of group size, funding sources, research involvement, time allocation, research communication and other relevant issues. Our results show that the leaders of high-performing groups differ from the leaders of the other groups, as they possess a stronger research commitment, put more effort in group management and spend more time on network management. In sum, leaders of high-performing research groups tend to be all-rounders.

Keywords
Research performance, research groups, academic leadership

1. Introduction
Academic excellence depends not only on the availability of creative, innovative and enthusiastic researchers, but also on the opportunities provided by the environment they operate in (e.g. Allison & Long, 1990; Andrews, 1979b; Heinze, Shapira, Rogers, & Senker, 2009; Hemlin, Allwood, & Martin, 2008; Pelz & Andrews, 1966). The work environment of most researchers is the research group. We focus on research groups as organisational units embedded in a research organisation with researchers and support staff as group members, a research agenda, a research budget, and headed by an academic group leader (e.g. Andrews, 1979b; Beaver, 2001; B. P. Cohen, Kruse, & Anbar, 1982; De Haan, 1994; Laredo, 2001; Laredo & Mustar, 2000; Rey-Rocha, Martin-Sempere, & Garzon, 2002; Stankiewicz, 1976). The job of an academic group leader is to manage his or her group by motivating the researchers, by creating

the necessary facilities, by defining and implementing the mission and strategy, and by positioning the group internally and externally (Sousa & Hendriks, 2008), but also by acquiring resources. Management of research groups is particularly important for achieving high performance because group leaders affect the conditions for a productive research environment (Bland & Ruffin, 1992). Although a number of scholars underscore the positive influence of leadership and management on research performance (e.g. Babu & Sing, 1998; Bland & Ruffin, 1992; Harvey, Pettigrew, & Ferlie, 2002; Knorr, Mittermeir, Aichholzer, & Waller, 1979; Mumford, Scott, Gaddis, & Strange, 2002; Mumford, Peterson, & Robledo, 2010; Stankiewicz, 1976), studies in which specific management activities and leadership practices have a positive relation with performance are scarce. In a previous study, one of the current authors investigated the relation between specific management activities and performance, and showed that a diverse constellation of management activities positively relates to the performance of research groups (Van der Weijden, 2007; van der Weijden, de Gilder, Groenewegen & Klasen, 2008).

Research groups are increasingly expected to perform excellent research. This emphasis on excellence by science policy is reflected, for instance, in specific funding programmes for individual top researchers and in the concentration of the best researchers in 'centres of excellence'. In this paper, we address the question whether research groups with outstanding academic performance – termed high-performing research groups – have group leaders with particular academic leadership characteristics. Our approach is innovative as we do not conduct correlation analyses between variables; instead, we compare groups with different performance levels in order to identify the leadership and management characteristics of high-performing research groups. If high-performing research groups differ from other research groups, we may be able to improve the leadership, management and organisation conditions that facilitate an excellent research performance.

2. Academic leadership

We define academic leadership as organising, managing and leading researchers and the research group; it refers to a variety of opinions, tasks and practices of academic group leaders. We distinguish four components of overall academic leadership. The first component, *resource strategy*, is the task of acquiring and combining resources for the research group. According to Zaleznik (1977), the leadership role that requires an open and spontaneous attitude for developing creative and innovative ideas is rather different from the management role required for a well-structured organisation. *Leadership* in a narrow sense, as second component of academic leadership, refers to how researchers are directed and stimulated by the inspiration and vision of the leader. The third component, *group management*, concerns the tools that are used to manage and coordinate the research process. In addition to their internal role, leaders have external tasks. More specifically, the activities undertaken to position the research group in the academic and societal environment to obtain legitimacy, reputation, and visibility is what we call *network management*.

A research group is a heterogeneous set of people with varying capabilities and preferences, interests and priorities, which have to be reconciled by the group leader. Hackett (2005) identified six areas of tension that academic leaders have to deal with in managing and leading their groups. Firstly, leaders have to find an appropriate balance between autonomy and coordination. Secondly, leaders have to deal with the paradox of risk: working on a research line that seems low risk can be very risky when it is not innovative. A third area of tension can be found in role-induced conflict. For instance, leaders educate the new generation of researchers and want to give them the freedom to choose what to explore. However, this freedom may have to be limited as leaders are responsible for attaining both group goals and the strategic goals of the organisation. Fourthly, leaders have to determine when to share information both within and between groups, and when further time is needed for more in-depth research. The fifth area of tension can take place when leaders are personally active as a *researcher* in the lab, doing experiments and analysing data. Simultaneously, however, they need to *manage* their groups, build external networks for collaboration, and position their group in the environment. Finally, there is the accumulation of advantage within groups. Past decisions about research technologies and research directions partly determine later performance and group recognition. This is the tension between continuity and innovativeness.

Leaders have to cope with these six tensions to stimulate creativity within their group. In the following sections we review several aspects of the academic leadership, addressing the abovementioned areas of tension. We provide an overview of previous empirical studies about the relationship between academic leadership and research performance.

2.1 Resource strategy

From the perspective of resource-based theory, one of the main goals of a research group is to achieve a productive combination of resources as inputs for research (Grant, 1996; Pfeffer & Salancik, 1978). In the eyes of research leaders, it is also one of the most challenging goals (Mets & Galford, 2009). Examples of resources required for scientific research are: human capital, physical capital, technology, accumulated knowledge and experience, and social networks (Horlings & Versleijen, 2009). Research groups must have access to tacit knowledge, skills, social relations, information (access to journals, databases and libraries), equipment, (large-scale) facilities, and technology (e.g. Babu & Sing, 1998; Bozeman & Corley, 2004; Crewe, 1988; Dundar & Lewis, 1998; Horlings, Gurney, Somers, & Van den Besselaar, 2009; Melin, 2000). How research leaders deal with these resources is a matter of administrative control (Omta & De Leeuw, 1997). Administrative control includes, for instance, administrative procedures for the appointment of staff, for the procurement of equipment, and for reallocating personnel and material resources to a new research line. Resource strategy is the group leader's management task undertaken to acquire and combine resources for his or her group. We address two key resources for conducting research, viz. funding and human capital.

Research groups need *funding* to perform in the first place, and lack of funding is clearly harmful (e.g. Babu & Sing, 1998; Creswell, 1985; Culpepper & Franks, 1983; Meltzer, 1956; Pruthi, Jain, Wahid, & Nabi, 1993). The more intriguing question is whether the available funding sources, rather than the amount of the funding, influence the performance of research groups. In addition to traditional institutional funding, external funding sources have become increasingly important. External funding and its availability can be seen as an opportunity for new initiatives (Auranen & Nieminen, 2010). This is especially the case for international funding (Geuna, 2001; Van der Weijden, Verbree, Braam, & Van den Besselaar, 2009), where external funding sources seem to increase research output (Gulbrandsen & Smeby, 2005; Johnes, 1988). A comparison of various external funding sources provides evidence that funding by National Research Councils is positively related to research performance, whereas third-party funding (contract research) has no or even a negative relationship with performance (Carayol & Matt, 2006; Cherchye & Abeele, 2005; Groot & García-Valderrama, 2006). This difference could be explained by the fact that applied research for third parties is not always translatable into academic output (Groot & García-Valderrama, 2006). Conversely, Gulbrandsen and Smeby (2005) show that professors who receive funding from the industry publish more than their colleagues who receive other types of external funding. Yet here the causal relation may run in the opposite direction. As Carayol (2003) argues, researchers with a high reputation can pick and choose industry collaborations that suit their own research aims. In other studies, no relation was found between the productivity of graduate students and post docs and financial support from industry (Louis et al., 2007). Despite the possible positive effect of competitive research council funding on performance, an increase in this funding source can hamper creative science when stable institutional funding is not guaranteed (Heinze et al., 2009). It should be noted that, although funds acquired in competitions may be important for stimulating the academic careers of talented young researchers, they are not necessarily related to their research performance (Bornmann, Leydesdorff, & Van den Besselaar, 2010; Hornbostel, Böhmer, Klingsporn, Neufeld, & Von Ins, 2009; Van den Besselaar & Leydesdorff, 2009). In addition, Auranen and Nieminen (2010) showed that that the notion of competition for funding as a driver of productivity in university research is not self-evident. Another intriguing question is whether more funding sources lead to higher research output, or the other way around; whether higher output attracts more funding sources. Sandstrom (2009) could not confirm this, either way.

Concerning *human capital*, we introduce two aspects. Firstly, what is the relation between the size and performance of research groups? Secondly, which combination of researchers and support staff is required for research groups to achieve a good performance? According to Von Tunzelmann, Ranga, Martin and Geuna (2003), both small and large groups have different benefits for research performance. On the one hand, 'big is better', because it leads to 'economies of scale' (i.e. greater output per unit input) and 'economies of scope' (i.e. synergies arising from conducting allied activities). On the other hand, the advantage of smaller groups is 'dynamic scale economies' through greater agility and responsiveness to change. Urwick (1956) argues that smaller groups have a narrower span of control, that is, coordination costs are reduced for group leaders. This leads to better cooperation, greater efficiency, improved morale and a sense of unity. The two opposing views on large versus small groups are both supported by studies on size and performance. Several studies find support for the positive influence of a small group size (Carayol & Matt, 2004, 2006; Heinze et al., 2009). Other studies demonstrate the positive influence of a large group size (Louis, Holdsworth, Anderson, & Campbell, 2007; Pineau & Levy-Leboyer, 1983; Spangenberg et al., 1990). A third view suggests that size, small or large, does not play a key role in achieving high performance (J. E. Cohen, 1991; Crewe, 1988; Hoare, 1995; Kyvik, 1995; B. Martin, Skea, & Ling, 1992). An alternative perspective on size is that its positive effect diminishes as size increases (Dundar & Lewis, 1998; Jordan, Meador, & Walters, 1988, 1989; Omta, 1995). Blackburn et al. (1978) argue that a minimum size (between 11 to 15 group members on average) is necessary to facilitate communication with and stimulation from colleagues. However, there seems to be an upper limit for group size, above which having more staff does not lead to a proportional increase in the groups' research output. The critical mass threshold appears to be quite low (Stankiewicz, 1979; Von Tunzelmann et al., 2003). The review by Von Tunzelmann et al. (2003, p. iii) concludes that "productivity seems to rise as the team size increases to about six or eight persons, above which there is usually little or no extra gain per capita." The threshold can vary among scientific fields. For arts and humanities, no threshold was found. In fields where applied subjects dominate (e.g., clinical medicine), the threshold is somewhat higher, while the threshold is lower in more theoretical fields (mathematics). Earlier studies also note that the effect of size on performance depends on the discipline (Baird, 1986; Kyvik, 1995).

The second human capital issue we address here is the optimal group size. Research groups should be composed in such a way that the full set of knowledge and capabilities needed to achieve the groups' aims are available (Harvey et al., 2002; Heinze et al., 2009; Jones, 2010; Stevens & Campion, 1994). This requires heterogeneity that can be obtained from many sources (Carayol & Matt, 2004; García-Romero, 2006; Hemlin, 2006; Smith, 1971), including a mix of disciplines, functional areas, types of research and methods, as well as a mix of researchers in terms of educational specialisation, experience, position and gender (Baird, 1986; Carayol & Matt, 2004, 2006; De Haan, 1994; Dundar & Lewis, 1998; Fox & Mohapatra, 2007; García-Romero, 2006; Groot & García-Valderrama, 2006; Keller, 2001; Pelz, 1956; Pineau & Levy-Leboyer, 1983; Rey-Rocha, Garzon-Garcia, & Martin-Sempere, 2006; Rey-Rocha et al., 2002; S. J. Shin & Zhou, 2007; Smeby & Try, 2005). Heterogeneity in membership provides research groups with divergent perspectives, different expertise, knowledge and skills, and access to external (communication) networks (for an overview, see the meta-analysis of Hülsheger, Anderson, & Salgado, 2009).

An essential goal of research groups is to educate the next generation of researchers. This means that research groups need to attract PhDs, but they also need to have more experienced researchers to supervise the new generation. The best publication of scientists, i.e., with the highest impact, tends to appear between their late 30s (in the case of mathematicians) and early 40s (for medical scientists), while on average their last major contribution is published in their fifties (Simonton, 2004, p. 69, figure 3.5). Recent research shows that the age at which researchers make their most important contributions has risen over time. On average, the rise has been about eight years over the last century. This may be due to the increasing complexity of science, which therefore requires longer training, and the collaboration with others who have different competences (Jones, 2010). Longer training increases the need for intensive and high-quality supervision of young researchers. Several studies show the importance of sponsorship or mentorship for the performance and development of young researchers (Anderson & Shannon, 1988, p. 40). The sponsor or mentor roles in research groups are provided by the more experienced members (i.e. senior researchers and group leaders), who supply supervision. Supervision can be important for stimulating creativity, (pre-doctoral or early-career) research productivity, self-efficacy, grants, collaboration and the professional networking of young researchers (Bozeman & Corley, 2004; Cameron & Blackburn, 1981; Cronan-Hillix, Gensheimer, Cronan-Hillix, & Davidson, 1986; Green, 1991; Hemlin & Olson, 2011; Long & McGinnis, 1985; Paglis, Green, & Bauer, 2006; Reskin, 1979; J. C. Shin & Cummings, 2010; Van Balen, 2010). Affiliation to a prestigious department seems to be of even more importance for the research performance of new generation researchers, probably because these departments can provide better access to eminent researchers for sponsorship (Cameron & Blackburn, 1981; Crane, 1965; Reskin, 1979).

2.2 Leadership

Leaders try to lead and inspire their researchers. *Research involvement*, or *motivation*, is dedication to one's work. Pelz and Andrews (1966) were the first to thoroughly study the relation between motivation and individual research performance. They discovered a mildly positive relationship, which was also confirmed by later studies (Andrews, 1979a; Babu & Sing, 1998; Fox, 1983; García-Romero, 2006; Harris & Kaine, 1994; Ramsden, 1994). Researchers can be motivated by internal as well as external sources (Amabile, 1993). Tien (2000) showed that both internal sources (e.g. curiosity) as well as external rewards (e.g. promotion) tend to increase productivity (measured in terms of published articles). Amabile (1993) found that both intrinsic motivators – autonomy, challenges and excitement about the work – and extrinsic motivators – rewards, clear project goals and feedback – are important for research performance and creativity. In addition, Tien also showed that different sources of motivation lead to different types of research performance. The more researchers are motivated by a desire to show their scholarly excellence, the higher the probability that they will publish books. The more researchers see an increase in their personal income as important, the more likely it is that they will apply successfully for research grants (Tien, 2000). Although both internal and external motivation are important for research performance, Pelz and Andrews (1966) found that researchers who are internally stimulated by their own ideas are more productive, while researchers who are externally stimulated by a supervisor are less productive. However, Pelz and Andrews (1966) stipulate that self-motivated researchers are not isolated. Their internal motivation is stimulated by a variety of external sources, such as practical problems, technical literature, colleagues and previous research. Specific sources of motivation do not seem to relate positively to performance, but to an underlying factor of 'intellectual self-reliance', that is, confidence in one's own ideas.

If internal motivation is generated by confidence in one's own ideas, can it be externally stimulated by an academic group leader? According to Pelz and Andrews (1966), it can. First, it is important to enable researchers to demonstrate their contributions through presentations of their own ongoing work, the publication of reports or papers, registering patents or reviewing progress on (technical) designs. Second, researchers should have the freedom to define and pursue individual scientific interests. Third, commitment to one's own work can be reinforced by enthusiastic feedback from supervisors and colleagues. The academic group leader has a special role and should show strong commitment to his or her members' research by, for example, contributing technical competence, showing an interest in the projects, remaining informed, and participating in the research (Andrews & Farris, 1967). In addition, scientists will be more involved when the leader encourages participation in defining the problems to be pursued and the approaches used in addressing these problems (Mumford et al., 2002). Andrews (1979a) demonstrated that motivation is not only a characteristic of individual researchers, but it can also be considered a characteristic of the research group. He found that researchers' motivation levels can vary between research groups. Research groups with highly motivated group members (group leader, senior researchers and technical staff) have higher performance, that is, these groups are evaluated by their members as more productive and innovative.

Research activities, besides conducting experiments and analyses, include attending research meetings, participating in (external) research projects, supervising PhDs, publishing papers, giving presentations and participating in the national and international scientific community. Time for research activities is scarce because it is constrained by other tasks that research groups have to accomplish, particularly teaching in universities (Gottlieb & Keith, 1997; Leisyte, Enders, & de Boer, 2009). A stronger preference for research and a lower preference for teaching is positively associated with performance, as are other research activities such as obtaining grants, supervising Master's or PhD students, participating in informal discussions, acting as a reviewer or editor, presenting papers at conferences, maintaining influential gatekeeping roles in national and international scientific communities, and frequent contact with national and international colleagues (Blackburn et al., 1978; Fox, 1992; Gottlieb & Keith, 1997; Harris & Kaine, 1994; Porter & Umbach, 2001; Prpic, 1996; Ramsden, 1994; J. C. Shin & Cummings, 2010).

It is often questioned whether research and teaching are mutually reinforcing or competing tasks. Empirical evidence refers to research and teaching as different dimensions, which implies a trade-off between these activities (Bellas & Toutkoushian, 1999; Fox, 1992; Porter & Umbach, 2001). As Fox says, "Good – or at least more productive – researchers have less classroom contact with students, spend fewer hours preparing for courses, and consider teaching much less important than research" (Fox, 1992, p. 301). Time spent on research and time spent on teaching is negatively correlated as shown in a meta-analysis and follow-up study by Hattie & Marsh (1996; 2002). However, they found no relationship between teaching and research. Good researchers can either be good or bad teachers and good teachers can either be good or bad researchers. Likewise, Harris and Kaine (1994) found that high-performing researchers do not regard their teaching commitments as a constraint on their research activities. Too much time spent teaching tends to be negatively related to research performance, but teaching as such does not seem to constrain research performance. In fact, too much time spent on research is not favourable for research performance either. Pelz and Andrews (1966) found that lesser performing researchers tend to have a '9-to-5' mentality, while researchers working one or two hours extra a day performed somewhat better. Nonetheless, more hours does not necessarily mean better performance. Highly involved researchers are not obsessed by their work 24 hours a day. They have periods of relaxation when they spend time on activities unconnected to work. Indeed, the more effective researchers do not spend all their working hours on research. It seems to be more productive to also spend some time on teaching and administration (Pelz & Andrews, 1966). Interestingly, extra research time does not necessarily translate into higher research and user- effectiveness, as Omta (1995) found. He compared the research time of researchers from pre-clinical and para-clinical units with researchers from clinical units. Clinical researchers spent half as much time on research, due to patient-care duties, but on average they published a similar number of scientific papers as pre-clinical and para-clinical researchers.

2.3 Group management

Leaders can use various tools to manage the research process. The balance between *academic freedom* and *coordination* is one of the main issues of internal management (Barnowe, 1975; Hackett, 2005; Pettigrew, 1979). In general, coordination and academic freedom are both necessary for performance. Freedom is needed to enhance creativity in approaching research problems. Coordination is needed since interaction with academic leaders stimulates researchers, especially the young (Pelz, 1956; Pelz & Andrews, 1966). Coordination of research through standard procedures (such as lab protocols) is positively related to the performance of medical PhD students (Van der Weijden, De Gilder, Groenewegen, & Geerling, 2008). However, too much coordination can hamper innovation (Andrews & Farris, 1967). In high-performing biomedical laboratories, Pineau and Levy-Leboyer (1983) found a management approach where supervisors gave researchers moderate freedom but still formally controlled their researchers' work. Formal control can be done in assessment procedures such as the annual individual job evaluation or the preliminary evaluation of research proposals before these are submitted for external funding (Mets & Galford, 2009; Van der Weijden, 2007), although little is known about the effects on the performance of academic groups (van der Weijden, de Gilder, Groenewegen, & Klasen, 2008).

Gaston (1975, p. 228) argues that "the generally accepted model of a scientist as a person who goes about his work virtually free to choose the scientifically relevant research problems that he wants to attack with few if any major constraints is, if not erroneous, at least an exaggeration." He remarks that the autonomy of researchers in British university departments is related to academic rank. Professors, as heads of a department, have influence in many decision areas, such as staff appointments and promotion, financial support of research activities and the purchase of equipment. Scientists of lower ranks have far less influence in decisions, but they are satisfied with this lack of voice because of socialised expectations: young scientists do not expect to have any influence on departmental affairs as long as their research needs are met and their work load is reduced by not involving them in decision-making processes (Gaston, 1975). Additionally, Leisyte, Enders and De Boer (2008) note that individual freedom is restricted by 'collective' freedom of choice. To be more precise, the individual freedom of researchers is bound by the research agenda of the research unit and by the thematic choices of the academic group leader, although there is still room for individual choice and consultation. This 'collective freedom of choice' stimulates creativity (Heinze et al., 2009). An early study by Haraszthy and Szántó (1979) found some significant positive correlations between the perceptions of researchers on the effectiveness of the research group and their perceptions on the adequacy of research planning and the coherence of the research programme. Junior researchers mainly follow the professor's preferences (Leisyte et al., 2008). Particularly for junior researchers, supervision is an important way to motivate and improve performance. For instance, Van der Weijden et al.

(2008) showed that medical PhD students who were more satisfied with their supervision received more prizes with a higher total value. In line with this, Katz (1978a, 1978b) found autonomy to be negatively related to job satisfaction for employees just starting a new job or entering the organisation (i.e. junior researchers). He argues that new employees first need to discover the relevance of their work within the group before issues like autonomy become more important. It seems that young researchers first need to get socialised in research before their need for supervision decreases.

The *reward system* is an important management tool for motivating researchers. As Merton (1957) pointed out long ago, the institution of science has developed a reward system designed to give recognition and esteem to those scientists who have best fulfilled their roles; to those who have made genuinely original contributions to the common stock of knowledge. Incentive mechanisms can be used to motivate researchers with both material and intangible forms. The presence of a reward system positively influences research performance (Omta & De Leeuw, 1997; Spangenberg et al., 1990). Examples of material rewards are financial bonuses, a salary increase or promotion, and fringe benefits. Examples of intangible rewards are additional opportunities for career planning, facilities for developing skills (courses and conferences), support in achieving recognition through publishing, presentations and fellowships, flexible working hours and locations, possibilities for gaining experience in foreign research groups and receiving public recognition. Above a certain income level, material incentives are only important in limited circumstances, for example, if researchers have low salaries compared to others (Gustad, 1960). McKeachie (1979) argues that salary has a relative meaning for researchers; it is compared with past raises and those of one's peers. Salary symbolises the achieved level of competence in the eyes of respected peers. Rewards that motivate a researcher can change over time in the development of a career, and especially in the early years of one's career, the symbolic meaning of a salary raise could be important. A meta-analysis showed that financial incentives can be important in encouraging employee performance, but only for the quantity and not the quality of the output (Jenkins, Mitra, Gupta, & Shaw, 1998). In line with the modest role of material incentives in enhancing performance, academic research leaders seldom use them and concentrate more on intangible incentives. (Van der Weijden et al., 2009). Intangible rewards, especially praise and prizes, positively correlate to several aspects of performance, namely the number of publications, the proportion of external research funding, and the number of submitted and granted research proposals (Van der Weijden, 2007; van der Weijden, de Gilder, Groenewegen, & Klasen, 2008). Hagstrom (1971) found that honouring scientists for their accomplishments is important; together with memberships of advisory committees, honorific awards account for 44 per cent of the variance in departmental prestige. Researchers seem to value material incentives less than intangible incentives.

Academic group leaders emphasise *communication* with their researchers as a prime task. Indeed, the frequency of interaction within groups has a positive relationship with different aspects of performance (Allen & Sloan, 1970; Harris & Kaine, 1994; Kretschmer, 1985; Ramsden, 1994; Visart, 1979). Internal communication includes group meetings, retreats, research meetings on ongoing projects and feedback on results, meetings to discuss long-term research policy, and an internal website (e.g. Frederiksen, Hemlin, & Husted, 2004; Mets & Galford, 2009; Van der Weijden, 2007). As early as the 1960s, Pelz and Andrews (1966) found that the more communication is sought and received, the better researchers perform, as communication is important for intellectual stimulation, the generation of new ideas, catching errors, coordination and reflection. Hamming's 'open doors' quotation nicely illustrates the role of interaction with colleagues: "If you have the door to your office closed, you get more work done today and tomorrow, and you are more productive than most. But 10 years later somehow you don't quite know what problems are worth working on; all the hard work you do is sort of tangential in importance. He who works with the door open gets all kinds of interruptions, but he also occasionally gets clues as to what the world is and what might be important. There is a pretty good correlation between those who work with the doors open and those who ultimately do important things, although people who work with doors closed often work harder. Somehow they seem to work on slightly the wrong thing – not much, but enough that they miss fame" (Erren, 2008, p. 475).

It is easier to establish contact and collaboration with colleagues in a more consolidated research group. A consolidated research group has attained a certain size, composition, duration, autonomy, funding, member involvement, cohesiveness, intra- and inter-team collaboration and competitiveness. Consolidation increases with group age. Being a member of a consolidated research group fosters participation in funded projects and develops the potential to publish in international, mainstream journals (Martin-Sempere, Garzon-Garcia, & Rey-Rocha, 2008; Martin-Sempere, Rey-Rocha, & Garzon-Garcia, 2002; Rey-Rocha et al., 2006; Rey-Rocha, Garzon-Garcia, & Martin-Sempere, 2007; Rey-Rocha et al., 2002). Consolidation must be balanced by an open attitude towards external sources (e.g., asking an expert), because too much consolidation leads to conservation and insulation ('group think': see Janis, 1972), which lowers creativity. For example, Moorhead and Montanari (1986) showed that groups that felt most insulated from outsiders tended to have lower performance.

2.4 Network management

Group leaders need to manage their groups but also their external relationships. *Network management* is the dependence on the environment for gaining access to resources and acquiring visibility and a reputation for the research group (Bozeman & Corley, 2004; Oh, Chung, & Labianca, 2004; Oh, Labianca, & Chung, 2006; Reagans, Zuckerman, & McEvily, 2004; Reagans & Zuckerman, 2001). The social capital of group leaders is often crucial to attaining high performance (Mehra, Dixon, Brass, & Robertson, 2006). The smaller the group, the more important it is to build a wide network (Von Tunzelmann et al., 2003, p. 15). Relationships can be built by collaborating with research groups located in the same research institute, in other domestic research institutes, or in research institutes abroad[1]. Especially interactions with the scientific community have a positive influence on research performance (e.g. Spangenberg et al., 1990). They offer an intellectual exchange that stimulates creativity (Melin, 2000; Wagner, 2005).

3. Methodology

We designed a survey (section 3.2) that is based on the literature summarised above as well as on several open interviews with group leaders. Additionally, we created a performance index to identify the excellent groups (section 3.1).

3.1 Performance index

A performance index was constructed to differentiate between high-performing research groups and other, average performing research groups. For this differentiation it is crucial to define high, or excellent, research performance. However, there is no consensus on an objective definition of research excellence due to its multidimensional character. One way to clarify the concept of excellence is to use it comparatively (Tijssen, 2003). The comparative approach evokes two main issues. The first concerns the set of comparable entities, or, in other words, which frame of reference to use for the comparison. The second issue concerns which indicators to use for comparing academic performance.

The first issue about the frame of reference is important because excellence can only be evaluated in an appropriate context (Bornmann, Mutz, Neuhaus, & Daniel, 2008; Van der Meulen, 1995). We have to deal with two frames of reference that determine the comparison of our set of Dutch health research groups: the international context and the disciplinary context. From an international perspective, overall Dutch health research is judged to be of high quality (NOWT, 2010). Basic and experimental medicine and health care sciences in the Netherlands score slightly above the global average impact; Dutch biomedical science scores approximately 15 per cent above global average impact, and Dutch clinical medicine about 30 per cent (NOWT, 2010). In other words, Dutch high-performing groups are also excellent from an international perspective.

The disciplinary context was used to distinguish between different types of research in the health research field, since disciplines differ heavily in publication and citation patterns (e.g., Baird, 1986; Martin & Irvine, 1983; Neuhaus & Daniel,

1 See Katz & Martin, 1997, for a conceptualisation of research collaboration and its different forms.

2009; Schubert & Braun, 1996; Van Raan, 2004; Whitley, 2000; Wouters, 1999). In the health sciences, the relation to patient care provides a good framework for discipline classification (Van der Weijden, 2007; van der Weijden, de Gilder, Groenewegen, & Klasen, 2008). Group leaders were asked to classify their groups' research in terms of one or more of 28 (sub)disciplines in health research (e.g., public health, immunology or oncology; for an overview see Van der Weijden (2007, p. 202)). On this basis, we classified the research groups in three categories distinguished by the relation to the patients[2]:

- *pre-clinical research* is basic (life sciences) research, usually laboratory-based; for example: immunology, micro-biology and neurosciences;
- *clinical research* is application-oriented, with direct patient contact; for example: dermatology, nephrology and psychiatry;
- *para-clinical research* into healthcare systems often has a social sciences perspective: researchers have an advisory relationship with patients; for example: social medicine, public health and medical psychology.

The issue of research excellence indicators is more complicated as it involves the multidimensional character of excellence. Academic performance consists of various aspects that can be measured with different indicators (e.g., King, 1987; Martin, 1996; Schubert & Braun, 1996; Tijssen, 2003). Commonly used indicators that measure academic performance are publication and citation counts (e.g., King, 1987; Martin, 1996; Van Raan, 2004, 2008). We use four types of publication and citation indicators over a three-year time span (2004 to 2006). Each indicator measures a different aspect of performance. The first indicator is the publication count of the group leader; it reflects the *quantity* of knowledge produced. The second indicator is the citation count of the group leader; it reflects the *visibility* of the output. The third indicator is the publication count divided by the number of researchers in the group; it reflects *productivity* and normalises output for group size. When a group attracts a lot of citations for each publication, they tend to work at the research front and publish innovative ideas that their colleagues consider interesting (Wouters, 1999). Therefore, we take as a final indicator the number of citations per publication, which reflects the *creativity* of the group.

Data about academic performance of the research groups were collected from three databases. PubMed (US National Library of Medicine's search service) was used to obtain the *publication counts* of research groups over the given three-year period (2004-2006). Thomson Reuters (formerly ISI) Web of Knowledge was

2 Our classification is similar to the NOWT classification: para-clinical research (health sciences). pre-clinical research (basic and experimental medicine, biomedical science) and clinical research (clinical medicine).

used to obtain publication counts for the same period[3]. Finally, the 'Nederlandse Onderzoeks Databank' (Dutch Research Database) was used to check whether research group leaders were affiliated to more than one organisation; if so, we included their publications from both affiliations[4]. We collected publication counts from both databases by searching for the group leaders' surname and first two initials. In addition, we collected *citation counts* and the number of citations per publication from the Web of Knowledge[5] over the publications published in the specific three-year period with a citation span of 2004-May 2008[6]. The last performance indicator was calculated by normalising the number of *publications by group size*.

Our definition of high performance was based on the assumption that the best research groups would have outstanding performance in all four aspects of academic performance. It appeared, however, that some groups had many publications but not an outstanding number of citations, while other groups had many citations but not an outstanding number of publications. This can be explained by a difference in publication and citation strategies (Hemlin & Gustafsson, 1996; Moed, 2000; Whitley, 2000; Wouters, 1999). The four indicators correlate moderately strongly (see Table 1).

3 PubMed differs from Web of Knowledge in that it also contains Dutch publications. It is important to include Dutch publications because some group leaders focused mainly on a national level and rarely published in international journals. But PubMed is limited by its less advanced search options; it is not possible to select a particular organisation, which was a problem with very common names. Web of Knowledge differs from PubMed in that it holds a more varied set of documents, such as conference abstracts, notes and letters. With Web of Knowledge, it is also possible to connect the names of group leaders to their organisation or affiliation. The two databases sometimes gave dissimilar publication counts for the same research group, caused by errors in either database or by a difference in content. After a test for research groups with large differences between the two databases, the lower publication count proved to be the more accurate.

4 Sometimes group leaders were affiliated to two organisations, either because they had moved to another organisation in the selected three-year period or because they actually held two positions.

5 These data were not available in PubMed.

6 This was the biggest time span as possible at the moment of collection (12-26 May 2008).

Table 1 Spearman's rho for performance indicators

		Citations	Publications/ Group size	Citations/ Publication
Publications	Spearman's rho Sig. (2-tailed) N	.848*** .000 184	.782*** .000 184	.337*** .000 184
Citations	Spearman's rho Sig. (2-tailed) N	1.000 184	.688*** .000 183	.722*** .000 184
Publications/ Group size	Spearman's rho Sig. (2-tailed) N		1.000 184	.294*** .000 183

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Note: *** $p < 0.01$

The first two unweighted indicators measure the absolute performance of research groups: total output and impact. Of course, the larger the group, the more that can be published and the more citations that can be gained; hence these indicators favour larger groups. The third and fourth indicators measure relative performance: publications per FTE (fulltime equivalent) researcher and citations per article. These indicators favour the more efficiently operating groups. As coordination costs increase with size, a key management goal is to combine the benefits of size (high absolute output, visibility and creativity) with managing the coordination costs in order to remain efficient (low costs per unit of output and impact). Thus excellence is multidimensional and we attempt to measure it by combining the four indicators. This opens up the possibility for smaller (but not too small) groups that are excellent, as well as for large groups that are not too inefficient. Indeed, in our selection of high-performing research groups we found both large and small groups. Similar findings are reported in a study about innovation published by West and Anderson (1996), who reported that group size in hospitals is not important for predicting team innovation.

The four indicators were standardised on the maximum score for each indicator and then weighted into an aggregate performance index, separately for each discipline (para-clinical, pre-clinical and clinical). The performance index formula is:

$$\text{(1)} \qquad \text{performance index} = \frac{\left[\frac{P}{P_{max}} + \frac{C}{C_{max}} + \frac{X}{X_{max}} + \frac{Y}{Y_{max}}\right]}{4}$$

where *P* is the number of publications; *C* is the number of citations; *X* is *C/P* and *Y* is *P*/group size; P_{max} is the maximum value of *P* within the sample, which varies by discipline; C_{max} is the maximum value of *C* within the sample, which varies by discipline; X_{max} is the maximum value of *C/P* within the sample, which varies by discipline, and Y_{max} is the maximum value of *P*/group size, which again varies by discipline[7]. The resulting performance index is the skewed distribution represented in Figure 1[8].

The figure shows that the natural cut-off point that separates excellent performing groups from other groups is 0.4. This point corresponds to the 'elbow' visible in the graph. Below the threshold of 0.4, the data points form a more continuous line and the curves become flatter. Research groups below the threshold are more similar in their academic performance than the top-performing groups with relatively higher scores. The top of the skewed distribution – above the 0.4 threshold – results in a very small selection of top-performing research groups and is unevenly distributed among the domains: there are 7 para-clinical, 4 pre-clinical and 13 pre-clinical groups. The sum total of the top selection – 24 research groups – is too small for detecting significant differences between top-performing and other research groups. For statistical reasons, we therefore decided to select a larger proportion of groups. This ensures that the high-performing groups account for a similar proportion of all groups in each domain[9]. The selection of high-performing research groups includes five para-clinical (19.2%), 16 pre-clinical (20.3%) and 13 clinical research groups (16.3%). The difference between high-performing and average groups is indicated by the dashed lines in Figure 1 which show a gap between high-performing and other research groups[10].

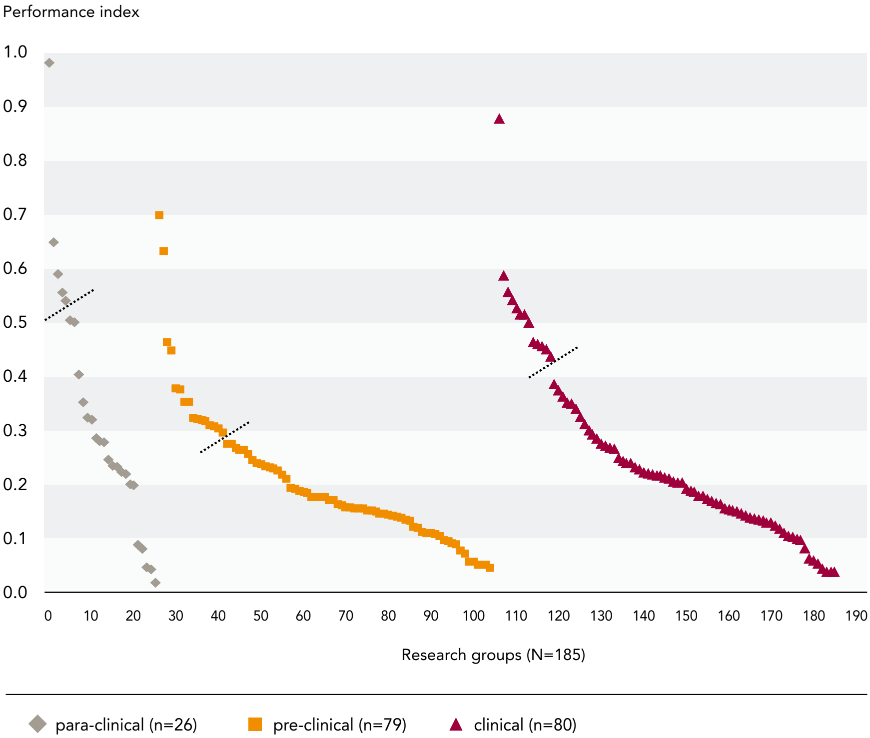
7 The specific maximum values are not given in order to protect the anonymity of the research groups. In addition, maximum values of citation counts vary by date of collection – these data were collected within a specific time period (12-26 May 2008) – and are thus not comparable with recent data. Some citation data were corrected after this period but this had no consequences for the selection of high-performing research groups.

8 None of the high-performing groups scored a 1 on the performance index, which means that none of the high-performing groups scored the maximum in all four performance indicators.

9 By using the larger proportion of high-performing groups, we found the same differences between leaders of high-performing and other groups and a few more than with the smaller top-selection, but with the smaller selection the statistical power is not sufficient (the probability of Type II errors increases).

10 By selecting a similar proportion of high-performing groups of each domain, we can be sure that the differences between high-performing and other research groups are not a domain effect.

Figure 1 Sample distribution



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To test that we had selected an appropriate set of high-performing research groups, we conducted four analyses. First, we examined whether groups that were not among the selected high-performing groups still had outstanding scores on two or more indicators. This was not the case. In addition, we asked experts in the Dutch biomedical and health care fields to evaluate some high-performing research groups (not in our sample) and compare the publication and citation scores of their groups with our selected high-performing groups. Analysis shows similar publication and citation scores. Thirdly, we compared the publication and citation scores of group leaders who had won the Spinoza Prize (the most prestigious Dutch award) in all three disciplines with our selection of high-performing groups, and these totals were comparable in both cases. Finally, we conducted a sensitivity analysis: a comparative analysis between all high-performing and other research groups, again excluding the weak-performing groups (the 18 lowest scoring groups on the performance index). This had no consequences for the results. It seems that weak-performing groups were headed by less experienced group leaders; we will return to this issue in the results section.

3.2 Survey

The data were collected in 2007 through a survey of health research group leaders employed by university medical centres or by biomedical public research institutes in the Netherlands (Van der Weijden, 2007; van der Weijden, de Gilder, Groenewegen, & Klasen, 2008; Van der Weijden et al., 2009). Names and addresses of group leaders (mainly chaired professors) were obtained from administrative records. We approached 832 group leaders, of whom 131 were ineligible because they had only been involved with their groups for a short period of time (less than six months); or they had not been able to complete the questionnaire because the group did hardly any research (a focus on patient care); or they had filled in the questionnaire as a department head instead of as a group leader – we verified this by checking the reported group size (>40 group members) and, if available, their organisation's website; or they had just left the research group (emeritus professors). The participating group leaders (N = 188) returned the completed questionnaires with an overall response rate of 27 per cent. To maximise the response rate we used the tailored design method (Dillman, 2000). Due to incomplete data, only 185 research groups were used in the analysis.

Non-response analysis shows that the respondents can be regarded as a representative sample of the Dutch biomedical and health research groups. Firstly, we checked whether the respondents were evenly distributed among the various research institutions and the disciplines, and this proved to be the case. Secondly, we compared the scholarly performance of respondents and non-respondents. Since publication counts are highly skewed, a Mann-Whitney test was used. Respondents did not significantly differ (Mdn = 25.0) from non-respondents (Mdn = 23.0), U = 62315.0, p = 0.365, r = -0.03. The mean difference between the two groups was also small (33 publications for respondents versus 31 for non-respondents).

The questionnaire was designed on the basis of unstructured interviews with experienced research leaders and a literature review. Interview partners were asked to reflect on a list of management activities that might contribute to a group's research performance. We used both interview and literature data to develop and design survey questions and possible answer categories. The questionnaire was composed with the assistance of survey experts and it was pretested. The final version of the questionnaire was constructed using the comments and suggestions of the pretesters on both individual questions and the questionnaire as a whole.

The survey questions dealt with academic leadership practices (see Table 2).

Table 2 description and descriptive statistics of academic leadership practices

		Descriptive statistics				
Variables	**Description**	**Mean**	**Median**	**Standard deviation**	**Minimum**	**Maximum**
Resource strategy						
Funding sources	Percentage of total funding from: – Institutional funding – Competitive funding – Contract funding – Charity funding – European funding – Other funding sources	 32.18 20.72 17.08 17.67 7.78 4.57	 30.00 20.00 10.00 10.00 0 0	 22.49 18.55 19.93 19.82 14.33 10.99	 0 0 0 0 0 0	 100 80 89 100 85 90
Number of funding sources	Measure the total number of funding sources	3.57	4.00	1.9	1	6
Group size	Number of scientific and support staff (fte)	16.59	16.00	8.39	3	40
Scientific staff	Number of scientific staff (fte)	13.23	12.0	6.76	3	34
Staff constellation	Percentage of total scientific staff: – Professors – Senior staff – PhDs – Other scientific staff – Support staff (analysts and technicians) Presence of co-leader	 11.03 30.96 51.31 6.70 18.32	 10.00 30.77 50.00 0 18.18	 6.64 13.61 15.11 10.66 14.79	 0 0 14 0 0 yes: 73.9%	 33 75 88 55 60 no: 26.1%
Supervisory capacity	Measure the number of PhDs per professor	5.75	5.0	3.83	0.5	23
Leadership						
Co-researcher versus manager	Measure degree of research involvement of the leader where 1 is totally disagree and 5 is totally agree: "I feel more like a researcher than like a manager"	3.32	3.0	1.0	1	5
Highly skilled scientist	"My staff think of me as a highly skilled scientist"	3.69	4.0	0.82	1	5
Importance of visibility	Measure degree of importance to obtain visibility in top journals, like Nature, Science and the Lancet, where 1 is not important at all and 5 is very important	3.31	3.0	1.0	1	5
Importance of preliminary evaluation of research proposals	Measure importance of quality control for acquiring funding where 1 is totally disagree and 5 is totally agree: "Internal pre-assessments of research proposals generally result in major changes to receiving external funding"	4.03	4.0	0.86	1	5
Time allocation	Percentages of time spent on: – research – education – group management – patient care – percentage of groups – external management tasks (network management)	 44.52 13.62 16.53 16.74 8.15	 42.95 10.00 16.70 11.05 6.20	 16.19 10.61 8.39 18.87 8.15	 11.00 0 0 0 yes: 56.4% 0	 87.40 55.50 48.60 78.00 no: 43.6% 40.60

		Descriptive statistics				
Variables	**Description**	**Mean**	**Median**	**Standard deviation**	**Minimum**	**Maximum**
Group management						
Preliminary evaluation of research proposals	Dummy variable measuring whether or not leaders evaluate research proposals before they are submitted to funding agencies				yes: 80.2%	no: 19.8%
Research agenda	Percentage of considerations[11] that are valued as important to set the research agenda: 100 means that a group leader values all 8 considerations as important, that is; more freedom for researchers to fit their individual goals within the research agenda	48.96	50.0	22.80	0	100
Research policy meetings	Dummy variable measuring whether or not leaders organise meetings where their group members can participate in discussing the long-term research policy of the group				yes: 82.6%	no: 17.4%
Intangible reward	Dummy variable measuring whether or not leaders provide intangible rewards (i.e. special honours)				yes: 57.8%	no: 42.2%
Feedback meetings	Measure intensity of feedback meetings (meetings to discuss research, concept papers, or research proposals) where 1 is never or occasionally; 2 is at least once a year; 3 is at least once in six months; 4 is at least once a month; 5 is at least once a week	3.40	3.33	0.58	2.0	5.0
Project meetings	Dummy variable where 1 is project meetings at least once a week and 0 is project meetings less than once a week				yes: 48.9 %	no: 51.1%
Network management						
Network activities	Intensity of network activities in days per year where network activities are the sum of days spent on: – lectures – attending conferences – participation in editorial boards – participation in assessment committees	40.19	40.00	19.03	10	100
Characteristics of the leader						
Age	Age of leader	52.78	54.00	6.86	36	67
Experience	Years of experience as group leader in current research group	11.80	10.00	7.20	0.50	34

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11 Considerations were: research themes of international interest, theoretically challenged and innovative research themes, possibility for new research lines, PhDs interests and possibilities, opinion of colleagues, interest of international research programs, application possibilities in health care, and the possibility of obtaining visibility in top journals.

3.3 Analysis

As the data were not distributed normally (Kolmogorov-Smirnov test), we conducted Mann-Whitney tests and Chi-Square tests to compare differences in academic leadership between high-performing and other research groups. Where we find disciplinary differences, we report separate results for the three domains.

4. Results

4.1 Characteristics of the group leader

The performance of the research groups generally did not seem dependent on their leaders' years of experience, age or gender. No differences were found in years of experience as group leader in high-performing research groups (Mdn = 12.0) compared to other groups (Mdn = 10.0), U = 2150.0, p = 0.35, r = -0.07; or in age (resp. Mdn = 49.5, and Mdn = 54.0), U = 2140.0, p = 0.13, r = -0.11. Concerning gender, the percentage of groups headed by women did not differ by performance: $\chi^2(1, N = 185) = 1.040$, p = .31. It should be noted that most groups are headed by men (87.6%).

4.2 Resource strategy

Funding sources

Research groups obtain funding from various sources among others institutions, research councils and industry or companies. High-performing research groups from the pre-clinical and clinical domain obtain their funding from more sources (Mdn = 4.0) compared to the other groups (Mdn = 3.0), U = 1178.5, p = 0.007, r = -0.22. Also, leaders of high-performing groups – including para-clinical groups – acquire a higher percentage of competitive funding from research councils (resp. Mdn = 25.0 and Mdn = 20.0), U=1913.0, p = 0.067, r = -0.14.

Human capital

All the groups showed a variance in group size; there are big and small groups in both high-performing and other research groups. The size of most groups varies between 15 and 18 FTE[12]. Approximately three-quarters of the research groups have a second group leader[13]. We corrected size for the presence of a second group leader. Also, no significant differences were found between high-performing (Mdn = 10.0 FTE) and other research groups for size per group leader (Mdn = 8.5 FTE), U = 2133.0, p = 0.137, r = -0.11. Research groups have, on average, 9.8 FTE per group leader and 7.9 FTE scientific staff per group leader.

The group composition – regarding the proportions of scientific and support staff – varies between research groups but not between high-performing (Mdn = 0.83) and other groups (Mdn = 0.82), U = 2470.0, p = 0.774, r = -0.02. All groups have approximately 82 per cent scientific staff (professors, senior

12 Based on a 95% confidence interval for the mean.

13 The second group leader may have a formal or informal leadership position.

researchers, PhD students and other scientific staff) and 18 per cent support staff (analysts and technical staff). No differences were found between the three disciplines. For most of the groups (76 per cent), the composition had been stable over a number of years. Other groups have had a yearly change in composition (18 per cent), and some groups have changed even more often (6 per cent). The predominance of composition stability as well as the variety in composition between groups may relate to the type of research conducted in particular groups. For example, some groups need a high proportion of support staff to carry out lab experiments or analyses.

Finally, concerning supervisory capacity, we did discover significant differences between high-performing (Mdn = 6.0) and other research groups (Mdn = 5.0), U = 1838, $p = 0.084$, r = -0.13. Professors in high-performing research groups supervise more junior researchers (an average of 6.7 PhDs) per professor compared to leaders of other groups (5.5 PhDs per professor). Leaders of high-performing research groups tend to attract more young researchers.

4.3 Leadership

Research involvement

Research involvement was measured by the degree in which group leaders felt committed to the research on the shop floor. Leaders of high-performing groups perceived themselves to be more like researchers than managers (*Mdn* = 4.0) compared to leaders of other research groups (*Mdn* = 3.0), *U* = 1826.5, $p = 0.012$, *r* = -0.19. Moreover, leaders of high-performing groups were more convinced that they are seen as high-skilled scientists (*Mdn* = 4.0) than leaders of other research groups (Mdn = 4.0)[14] 13, U = 1261.0, $p < 0.001$, r = -0.32.

Leaders of high-performing groups, except for para-clinical groups, also attach more importance to quality. They strive for visibility in top journals (Mdn = 4.0) more so than leaders of other groups (Mdn = 3.0), U = 1229.0, $p = 0.003$, r = -0.24. In addition, it appears that leaders of high-performing research groups attached more value to the preliminary evaluations of research proposals for acquiring external funding (*Mdn* = 4.0) compared to leaders of other research groups (*Mdn* = 4.0)[15], *U* = 1166.5, $p = 0.014$, *r* = -0.20.

Time allocation

Intuitively, you would expect leaders of high-performing research groups to spend more time on research, given that they also feel more involved with the research. Indeed, leaders of high-performing clinical groups do spend more time on research (*Mdn* = 43.9%) than leaders of other clinical groups (*Mdn* =

14 Note that the medians of high-performing and other research groups are similar, but that the distribution is significantly different. Mann-Whitney test differences in (mean) ranks and not in medians.

15 See note 14.

39.3%), $U = 295.5$, $p = 0.068$, $r = -0.20$. However, this does not apply for pre-clinical and para-clinical groups. Concerning leaders of high-performing pre-clinical groups, they spend less time on education (*Mdn* = 5.8%) than leaders of other groups (*Mdn* = 9.0%), $U = 307.0$, $p = 0.016$, $r = -0.27$. For para-clinical groups, no significant differences were found between leaders of high-performing and those of other groups. Apparently, the optimal time allocation among tasks varies between disciplines. But it seems to be that leaders of high-performing groups are less distracted by other tasks and focus more on research tasks. In the clinical domain where patient care takes a lot of time, leaders of high-performing groups spend more time on research. In the pre-clinical domain, leaders of high-performing groups spend less time on education, which thus also allows them to spend more time on research.

4.4 Group management

Coordination versus autonomy

Leaders of high-performing research groups highly value quality. But despite the fact that leaders of high-performing groups regarded preliminary evaluations as very important to obtain external funding, they did not conduct more of these evaluations. Preliminary evaluations of research proposals are very common in 80% of the research groups.

To set the group's research agenda, a group leader draws on strategic considerations such as visibility, possibilities for applications in health care, and innovation. When we examine the percentage of strategic considerations that is valued as important, we found that leaders of high-performing research groups – except for the para-clinical groups – attached a statistically significant higher value to the various strategic considerations (*Mdn* = 62.5) than leaders of other groups (*Mdn* = 50.0), U = 1183.5, p = 0.008, r = -0.22. They seem to take a broader set of considerations into account when setting their research agendas, which may create more freedom for group members to place their individual research interests on the group's programme.

Finally, we analysed whether researchers participate in meetings to discuss the long term research policy of the group. The percentage of leaders of high-performing research groups (93.1%) that organise these meetings for their group members is higher than leaders of other research groups (80.0%), $\chi^2(1, N = 159) = 2.806$, p = 0.094. That is, it is 3.4 times more likely that researchers can express their views on long-term research policy in high-performing research groups than in other research groups. As an overall conclusion, the emphasis is more on autonomy than on coordination in high-performing research groups.

Reward system

No significant differences were found between groups that did or did not award non-financial prizes, $\chi^2(1, N = 184) = 0.709$, p = 0.400. A little bit more than half of the group leaders (57%) use this management tool to motivate their researchers.

Research communication

Research communication stands for the organisation of internal meetings for giving feedback on research presentations, concept papers, or research proposals. In particular, high-performing research groups hold significantly more feedback meetings (Mdn = 3.7) than other groups (Mdn = 3.3), U = 2004.0, p = 0.092, r = -0.12. Also, leaders of high-performing groups are 2.7 times more likely to organise meetings about ongoing projects at least once a week (viz. 70.6% of the groups) than other research groups (viz. 47.0% of the groups), $\chi^2(1, N = 185) = 6.171$, p = 0.013.

4.4 Network management

Network activities refers to the number of days a year that are spent on positioning the research group in the academic and societal environment by giving lectures, attending conferences, participating in editorial boards and participating in assessment committees. The highest network activity is shown in leaders of high-performing research groups – with the exception of para-clinical groups – (*Mdn* = 50 days) in comparison with leaders of other groups (*Mdn* = 40 days), *U* = 1200.0, *p* = 0.002, *r* = -0.24. The amount of time spent on external management tasks in proportion to the total work time is also higher for leaders of high-performing groups (*Mdn* = 7.1%) than for leaders of other groups (*Mdn* = 5.9%), *U* = 663.0, *p* = 0.078, *r* = -0.17. This does not apply for leaders of clinical groups, which might be an effect of the higher proportion of time they spend on patient care duties.

4.5 Weak-performing research groups

Now we have examined the differences between leaders of high-performing and other research groups, let us come back to the issue of weak-performing groups. Leaders of weak-performing groups did indeed have some different characteristics in academic leadership. Most interestingly, leaders of weak-performing research groups have less experience as group leaders than leaders of high-performing and other research groups. The difference in years of experience suggests that these research groups may be in early phases of development, rather than just harbouring weak performers. This phase is characterised by a different group composition: they have fewer junior researchers. Also, they spend less time on network activities. In other words, their activity in the (international) scientific community is less well-developed (see Table 3).

Table 3 Academic leadership by high-, other-, and weak-performing research groups

		No.	Median	Bottom quartile	Top quartile	Mean	Std deviation
Experience in years	High	32	12.0	10.0	15.0	12.5	6.14
	Other	132	10.0	6.0	17.0	12.1	7.59
	Weak	18	6.3	4.9	11.3	8.6	5.95
Percentage of junior researchers	High	34	55.8	46.1	66.7	54.6	14.4
	Other	132	50.0	40.2	63.5	51.7	15.0
	Weak	18	46.4	27.7	52.2	41.5	15.3
Network activities in days per year	High	34	45.0	30.0	70.0	49.9	24.2
	Other	133	40.0	25.0	50.0	38.8	17.0
	Weak	18	30.0	20.0	40.0	31.4	14.4

	J	z	R
Experience in years	3011.0	-1.801*	-0.13
Percentage of junior researchers	2904.5	-2.533**	-0.19
Network management in days per year	2719.5	-3.176***	-0.23

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Note: Jonkheere's test with effects reported at *p < 0.10, **p < 0.05, ***p < 0.01.

Before summarising our conclusions in the next section, let us discuss several (potential) limitations of this study. Firstly, we focussed on one set of research fields: the biomedical and health care sciences. However, these fields cover about 40 per cent of all public research in the Netherlands. In addition, the biomedical and health care sciences are rather heterogeneous and consist of fundamental pre-clinical research, application-oriented clinical research, and health care research with an approach comparable to the social sciences. Nevertheless, the situation may be different in the technical sciences, for instance, and in parts of the humanities. Secondly, the study focussed on one medium-sized, high-impact science country: the Netherlands. Leadership and management practices may of course differ between countries, so comparative studies are needed as a next step. Thirdly, as the research system changes over time, leaders may need to adapt their behaviour. In Chapter X of this book (Verbree, Van der Weijden, & Van den Besselaar, forthcoming), we report these changes over time. Finally, the sample was not very large, and this prevents us from conducting more advanced model testing. We hope to be able to do that after a new survey.

5. Conclusion and discussion

In this study, we searched for the main organisational, management and leadership factors that are expected to influence performance. Our survey of research leaders included key factors identified by the relevant literature. Our research method adds to the current state of knowledge in that we do not focus on bivariate relations between academic leadership variables and performance, but aim at identifying the productive characteristics of academic leadership by comparing leaders from high-performing and average performing, i.e. good, research groups. From the comparison between high-performing and other research groups, we conclude that leaders of high-performing research groups emphasise both leadership practices and management tools. They are better able to combine diverse activities. Leaders of high-performing research groups are more research-oriented; they perceive themselves as highly involved in research as a co-researcher rather than a manager, and as highly-skilled scientists; they set a high quality standard, and they are less distracted by non-research tasks. Furthermore, these leaders are also more devoted to their group management, as they organise internal communication on research more intensively, and provide researchers the freedom to develop their individual research interests. In addition to group management, leaders of high-performing groups spend more time on network management. These activities are focused both on obtaining visibility and a reputation in the scientific community as well as on obtaining resources from various sources, especially from competitive funding agencies. As a general conclusion, leaders of high-performing research groups are versatile: they are *all-rounders*. They set an example by showing strong research commitment and they are able to manage their group both internally and externally.

5.1 Implications

If high-performing and other research groups differ in academic leadership, it might be possible to identify opportunities to improve organisational, management and leadership conditions for excellent performance. On the one hand, it is important for a research leader to have internal and external managerial skills in order to acquire and combine the necessary resources and to direct the research process. On the other hand, successful research leaders need to be committed to research. More specifically, they should be involved in the research of their group by generating ideas, participating in meetings, carrying out analyses, and motivating their researchers. These two tasks may be at conflict. Managing both the *research process* and the *resources* calls for an ability to organise the group in a well-structured way, while leading *researchers* requires an ability to handle the open, spontaneous processes needed to develop creative and innovative ideas. Although leaders of high-performing research groups appear to be capable of both, these qualities may be difficult to find in a single person. This may explain why the trend in increasingly larger research groups is to have co-leaders; this is a pattern we clearly observed in our population (Van der Weijden et al., 2009; Verbree, Horlings, Van der Weijden,

& Van den Besselaar, in preparation). Based on recent interviews with research leaders, we observed that co-leaders are young and direct their own research line under the management of the principal group leader. Co-leaders provide opportunities for task specialisation in order to deal with the possible tension between the leading of *researchers* and the managing of *research inputs and processes*.

Our conclusions about the importance of versatility in academic leadership also apply to the researchers in the group. Previous research by Pelz and Andrews (1979a; 1966) showed that diversity in work activities is weakly but positively related to research performance. They distinguished eight types of diversity, including the allocation of time over several tasks such as teaching and administration, interdisciplinary orientation where one makes use of methods, theories and other specific elements developed in other fields, and the obtainment of funding from multiple sources. When different aspects of diversity are aggregated, the effect of diversity becomes stronger, and explains roughly ten per cent of the variance in performance (Andrews, 1979a). This implies not only that group leaders should carry out wide-ranging activities; they also need to promote versatility in the work activities for their group members. This paper indicates that leaders of top-performing and weak-performing research groups have different characteristics, and this also has implications for research evaluation. The findings on weak-performing research groups demonstrate that assessment based solely on bibliometric indicators can disadvantage younger, less experienced group leaders. Our analysis suggests that these groups are generally in an early phase of development rather than simply weak performers. Research evaluation should not overlook the time necessary to develop both a research group and the leadership and management qualities needed for high performance (Braam & Van den Besselaar 2010). Finally, assessing only output and impact is clearly not sufficient in evaluating research. In order to come up with useful recommendations for improving performance, evaluation protocols should include the quality of organisation, management and leadership. This paper indicates what to focus on in evaluation protocols; for instance, an intensive communication structure, diversity in funding sources and the research focus of the group leader.

In this paper, we defined high-performing research groups based on multiple performance indicators, viz. quantity, visibility, productivity and creativity. These four indicators measure different aspects of performance, and correlate moderately strongly (Table 1). An open question remains whether leaders of top-creative groups behave differently from leaders of top-productive, top-visible or top-quantity groups. We will investigate this in a follow-up study using multivariate analyses.

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Appendix

Table 4 Descriptive statistics of academic leadership by performance

		No.	Median	Bottom quartile	Top quartile	Mean	Std deviation
Number of funding sources (pre-clinical and clinical)	High	28	4.0	3.3	5.0	4.1	0.9
	Other	123	3.0	3.0	4.0	3.5	1.1
Percentage of competitive funding	High	33	25.0	10.0	32.5	24.9	16.9
	Other	143	20.0	0	30.0	19.6	18.9
Supervisory capacity	High	33	6.0	4.0	7.5	6.7	4.4
	Other	138	5.0	3.0	7.0	5.5	3.7
Co-researcher versus manager	High	33	4.0	3.0	4.0	3.7	0.8
	Other	151	3.0	2.0	4.0	3.2	1.0
High-skilled scientist	High	31	4.0	4.0	5.0	4.3	0.6
	Other	151	4.0	3.0	4.0	3.6	0.8
Importance of visibility (pre-clinical and clinical)	High	29	4.0	4.0	4.0	3.9	1.0
	Other	129	3.0	2.0	4.0	3.2	1.1
Importance of preliminary evaluation of research proposals (pre-clinical and clinical)	High	26	4.0	4.0	5.0	4.4	0.6
	Other	124	4.0	4.0	5.0	4.0	0.8
Time spent on research (clinical)	High	13	43.9	36.2	59.0	49.0	16.3
	Other	67	39.3	27.1	46.4	39.7	14.3
Time spent on education (pre-clinical)	High	16	5.8	4.9	7.5	7.9	5.3
	Other	63	9.0	5.9	17.5	13.0	9.8
Importance of considerations for research agenda (in percentage) (pre-clinical and clinical)	High	28	62.5	40.6	75.0	58.9	24.0
	Other	124	50.0	37.5	62.5	47.3	21.7
Participation in research policy meetings (% yes)	High	29	93.1				
	Other	130	80.0				
Frequency of feedback meetings	High	33	3.7	3.0	4.0	3.6	0.6
	Other	149	3.3	3.0	3.7	3.4	0.6
Project meetings at least once a week (% yes)	High	34	70.6				
	Other	151	47.0				
Network activities (pre-clinical and clinical)	High	29	50.0	32.5	70.0	53.3	24.4
	Other	130	40.0	25.0	50.0	38.4	16.5
Time spent on external management tasks (para-clinical and pre-clinical)	High	21	7.1	5.6	18.1	11.5	9.0
	Other	84	5.9	1.0	12.2	8.4	8.6

3 Generation and Life Cycle Effects on Academic Leadership

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Abstract

Academic leadership has an influence on the creativity and the productivity of researchers. Due to changes in the science system and how research is organised, the tasks of academic leaders have been extended over time to include external management and networking activities in addition to traditional internal leadership. The intention of this study is to first investigate whether different generations of academic leaders have contrasting leadership practices in response to contextual changes in the science system. Generation differences are not the only factor influencing academic leadership. Of course, leadership practices are also influenced by the skills and experiences of academic leaders, which are expected to change during their careers. Therefore, the second question we address in this paper is whether academic leaders within different life cycle stages (viz. less experienced, experienced and old academic leaders) are characterised by other academic leadership practices. Our study shows that generation membership and life cycle phase both influence the behaviour of academic leaders. The paper ends with a discussion of the implications for career policy and the organisation of research groups. This is the first study addressing the development of academic leadership over generations and over one's lifetime.

1. Introduction

A well-functioning science system requires both creative and high-performing researchers and an environment in which they can flourish. However, a researcher's natural life cycle affects his performance. Age and experience have non-linear relationships with performance, resulting in a performance decline for the oldest and most experienced researchers (Costas, Van Leeuwen & Bordons, 2010; Goodwin & Sauer, 1995; Simonton 1988; Simonton, 2004; Sturman, 2003; Gingras, Lariviere, Macaluso & Robitaille, 2008). Generation cohort membership also influences activities and performance of researchers (Bayer & Dutton, 1977; Kyvik & Olson, 2008; Levin & Stephan, 1991; Rauber & Ursprung, 2008).

The role of the academic group leader is crucial for stimulating the creativity and productivity of researchers (e.g. Babu & Sing, 1998; Bland & Ruffin, 1992; Harvey, Pettigrew & Ferlie, 2002; Knorr, Mittermeir, Aichholzer & Waller, 1979b; Mumford, Scott, Gaddis & Strange, 2002; Smith, 1971; Spangenberg et al., 1990; Stankiewicz, 1976; Van der Weijden, 2007; Van der Weijden, De Gilder, Groenewegen & Klasen, 2008). Special skills are required for leaders of creative professionals, such as researchers. Academic leaders orchestrate people, their relationships and their expertise in such a way that new ideas are generated (Mumford et al., 2002). For example, leaders provide incentives or rewards for researchers at different professional stages, which can avoid a decline in performance (Gonzalez-Bambrila & Veloso, 2007; Kyvik, 1990; Turner & Mairesse, 2002). Older researchers are more likely to remain productive when they receive professional recognition for their work (Kyvik, 1990).

Knowledge production takes place in increasingly large groups rather than by individual researchers or in small teams, which intensifies the role of the academic group leader. The driving factor behind this increase in scale is the growing complexity of research problems that have to be addressed in multi-, inter- and transdisciplinary research. This development requires larger teams whose members possess a variety of specialties and skills (Börner et al., 2010; Stokols, Hall, Taylor & Moser, 2008; Stokols, Misra, Moser, Hall & Taylor, 2008).

Furthermore, a number of changes in the science system have direct consequences for the role of academic group leaders. The traditional tasks of group leaders are extended with entrepreneurial activities (Hansson & Monsted, 2008). Within this paper we highlight four environmental developments of group leaders. Firstly, research is currently shaped by the pressure to achieve excellence. The emphasis on excellence by science policy is reflected in, for example, specific funding programmes for individual top researchers, and in the concentration of the best researchers in ‘centres of excellence’ (i.e. Hornbostel, Böhmer, Klingsporn, Neufeld & Von Ins, 2009; Van Leeuwen, Visser, Moed, Nederhof & Van Raan, 2003). Secondly, the societal benefits of scientific research are increasingly important. Knowledge transfer and research activities that extend beyond the academic world are a growing focus of attention in science policy (i.e. Gibbons et al., 1994; Etzkowitz & Leydesdorff, 1995; Göransson, Maharajh & Schmock, 2009; Göktepe-Hultén, 2008; De Jong et al., 2011). For example, research funding agencies require an explicit indication of societal relevance of the research project within proposals. Thirdly, there is a growing competition between researchers and research organisations for funding. The share of project funding is increasing worldwide (for a variety of countries: Lepori et al., 2007; recent period in the Netherlands: Van Steen, 2011). Finally, there is a growing emphasis on accountability for investments in science, leading to the implementation of research evaluation procedures and systems.

These developments heavily influence prevailing academic values, norms, and the rules of the science system, which in turn influence, for example, the propensity to collaborate, the quality criteria for output and the strategies of group leaders. The socialisation of new generations of researchers occurs in the doctoral phase, when academic values, norms, and rules are learned (Austin, 2002; Bland & Schmitz, 1986; Morrison, Rudd, Picciano & Nerad, 2011). The period in which researchers are educated, therefore determines their cohort membership.

This also holds for research leaders. As is true for researchers, life cycle (age) affects leadership; leadership knowledge and skills increase when leaders gain more experience throughout their career (Lord & Hall, 2005; Mumford, Zaccaro, Harding, Jacobs & Fleishman, 2000). Additionally, cohort membership also influences performance norms and the leadership activities of research leaders (Bayer & Dutton, 1977; Kyvik & Olson, 2008; Levin & Stephan, 1991; Rauber & Ursprung, 2008). For research leaders, the boundaries between generation cohorts should be based on changes in the research environment. We examine generation effects on leadership by identifying the relevant environmental changes in the science system, and by establishing relationships between these changes and the behaviour of academic group leaders.

To summarise, academic leadership is becoming increasingly complex and demanding, and it requires a broad range of skills and adaptation to changes in the organisation of research and of the science system. The influence of academic leadership on research performance is becoming even more crucial. However, life cycle and generation differences affect academic leadership. This brings us to our research question: How do life cycle and generation differences influence academic leadership? This study is the first to address the development of academic leadership over time and discuss generation differences across our specific sample of academic leaders. Generation effects were examined by a natural experiment. We compared two groups of academic leaders who were socialised in periods either before or after large contextual changes took place. We conducted a cross-sectional analysis where we compared academic group leaders at varying points in their life cycle to investigate differences in leadership behaviour. In the following sections we briefly review the literature on generation differences (Section 1.1) and life cycles (Section 1.2) and present hypotheses about their relationship with academic leadership.

1.1 Generation effects

Within the framework of the generational cohort theory, several generations were distinguished based on the specific time periods people were born in and the time periods they grew up in; for example, the Baby Boomers (1943-1960) and Generation X (1961-1980).This cohort membership influences the behaviour and attitudes of leaders (D'Amato & Herzfeldt, 2008; Gursoy, Maier & Chi, 2008; Sessa, Kabacoff, Deal & Brown, 2008). In academia, however, 'date of birth as a researcher' is far more important than 'date of birth as a human being', and age is a bad predictor of performance (Bayer & Dutton, 1977; Kyvik & Olson, 2008; Simonton, 2004).

'Date of birth as a researcher' typically begins when one pursues a doctoral degree. During the doctoral phase one is socialised as a researcher, learning academic values, norms, and rules (Austin, 2002; Bland & Schmitz, 1986; Morrison et al., 2011). When researchers are educated over varied periods of time, naturally their socialisation may differ. As a result, they will develop varying behaviour and attitudes, which will also be reflected in their academic leadership practices. As shown by various scholars, differences in performance are also co-determined by generation (Bayer & Dutton, 1977; Levin & Stephan, 1991; Rauber & Ursprung, 2008; Kyvik& Olson, 2008). In addition, cohort effects are discipline specific (Gonzalez-Brambila & Veloso, 2007).

Cohorts should reflect changes in the science system that affect the knowledge base or research practices of the researchers in a given era (Gonzalez-Brambila and Veloso, 2007). To identify such changes and establish the appropriate cohorts, we describe some crucial changes in the Dutch science system as illustrated in Figure 1. We also present two hypotheses that specify how cohort membership results in specific academic leadership behaviour.

Science policy in the Netherlands (and most Western countries) during the 1980s was about implementing policy changes that aimed at higher quality, more efficient, relevant and accountable scholarly research. At the same time, there was a growing desire from the general public for transparency in government expenditure and effectiveness in all areas of policy (Westerheijden, 1997). Furthermore, at the end of the 1980s, after a period of university budget restrictions and as a result of direct government interventions, the government and the universities agreed to change their policy relationship to one of 'autonomy and quality': as long as universities were able to show that education and research were of good quality, the government would respect their autonomy. As part of this new implicit contract, the Association of Universities assumed responsibility for the evaluation of research programmes, and were therefore able to strengthen its position (Van der Meulen, 2009). Such expectations led to changes in criteria for the allocation of research funding, and to the introduction of externally organised research evaluations.

In terms of research evaluations, government, intermediary organisations[1] and social groups in the Netherlands, there has been a strong emphasis on the evaluation of research since the end of the 1980s (Rip and Van der Meulen, 1995; Spaapen, 1995; Van der Weijden, 2007). Consequently, the evaluation

1 Intermediary organisation represents a dual alliance with both the government and the scientific community.

of research has become a crucial process throughout the scientific careers of researchers with respect to decisions about appointments, promotion, tenure positions and the allocation of funding. Research evaluations are also an important factor affecting research groups, departments, faculties and institutes. As a result, large numbers of research evaluations were conducted at many different levels. In 1988, the Council of Medical Sciences of the Royal Netherlands Academy of Arts and Sciences organised the first national evaluation of medical and health research in cooperation with the Disciplinary Board of the Medical Sciences of the Association of Universities[2] (KNAW, 1988). The output of research conducted at all faculties of Medical and Health Sciences and at most non-university research institutes in the Netherlands was evaluated by peer review.

Another important change in the Netherlands took place in 1983 (Versleijen et al., 2007). Ex ante evaluations were implemented and linked to university research funding through a new funding scheme, denoted as conditional funding. This funding scheme distinguished between education and research. About half of the block grant was based on teaching components, and the other half on research, although universities retained autonomy in deciding how to distribute the money (Van Arensbergen, 2010). As a condition for funding, each university was required to have a sufficient amount of research incorporated in programmes. The assessments were conducted by specially established disciplinary committees. A positive assessment implied a budget protection of the programme for 5 years (Versleijen et al., 2007). The purpose of the evaluation was to identify high-quality research within disciplines and to provide such research initiatives with a degree of budgetary security. In 1987, a second round of evaluations to allocate funding was initiated in which the previously established research programmes were assessed ex post. This second round of evaluations has evolved over the years into the relatively extensive and formalised system of ex-post evaluation of academic research, which is currently used in the Netherlands[3]. As a result of the rise in research evaluation, focus on research became very strong in universities. This understanding then guides the argument for our first hypothesis:

> *Hypothesis 1: Academic leaders who obtained their PhD after changes in research evaluation had taken effect (cohort young; PhD post-1987) have a higher research focus compared to academic leaders who obtained their PhD before changes in research evaluation had taken effect (cohort old; PhD pre-1988).*

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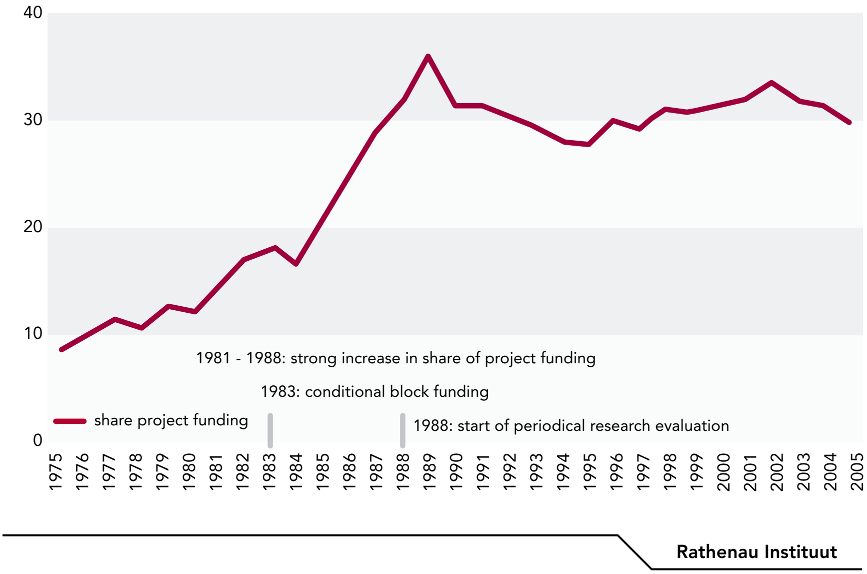
2 In Dutch 'Disciplineoverleg Medische Wetenschappen', the consultation body of the medical schools in the Netherlands. It has transformed into the NFU since 2004, the Dutch Association University Hospitals.

3 VSNU, KNAW and NWO (2009). Standard Evaluation Protocol 2009-2015. This protocol for research assessment of public funded research in the Netherlands is available on www.knaw.nl/sep.

Secondly, another main change that took place in the 1980s was the growth of competitive funding. Block funding traditionally took up around 90% of all university funding, whereas this started to change around 1980. The share of project funding started to rise from 10% to about 30% of total public research funding, as shown in Figure 1. This development increased competition and forced researchers to write proposals to secure funding for PhD projects and postdoctoral research from the various 'new' sources. Such changes occurred during the 1980s and were fully in place around 1987. Therefore, we use 1988 as the year that distinguishes between the two different generations. This leads to the second hypothesis:

> *Hypothesis 2: Academic leaders who obtained their PhD after changes in research funding had taken effect (cohort young; PhD post-1987) focus in their resource strategy more on external funding compared to academic leaders who obtained their PhD before changes in research funding had taken effect (cohort old; PhD pre-1988).*

Figure 1 Structural changes in the Dutch research environment (based on Versleijen et al., 2007)



1.2 Life cycle effects

The life cycle of research leaders refers to years of experience. According to Lord and Hall (2005) and Mumford et al. (2000), leadership also changes over one's life cycle. We assume the same holds true for academic leadership. When academic leaders gain experience, their responsibilities change and this may affect their leadership practices. Furthermore, we expect that changing goals, responsibilities and interests over their life cycle are related to academic leadership practices. As not much is known about changes in research leadership behaviour and the effectiveness over a life cycle, we will use the literature on researchers' life cycles to derive our hypotheses.

A considerable number of studies show how *research performance* changes over time (Costas et al., 2010; Gingras et al., 2008; Goodwin & Sauer, 1995; Long, Allison & McGinnis, 1993; Pezzoni, Sterzi & Lissoni, 2009; Simonton, 2004; Sturman, 2003). Simonton (2004), for example, developed a model for the productive output of scientists which allows for variation in age at career onset. He proposed a typology of scientific careers: low-creative early bloomers, low-creative late bloomers, high-creative early bloomers and low-creative early bloomers.

Literature also shows how the *behaviour* of researchers is not stable over time. At the start of a research career, the main goal is to obtain a scientific reputation. Each scientist begins with a repository of phenomena, facts, concepts, variables, constants, techniques, theories, laws, questions, goals and criteria that define his or her domain sample. This initial creative potential is then transformed into published output through a two-step process of ideation and elaboration (Simonton, 2004). Younger researchers spend more time on research and professional development (Baldwin et al., 2005). However, more research time does not always directly result in more publications. In the beginning of a researcher's career (under 30 years) the productivity rate is relatively low (Dennis, 1956). The probability of producing prize-winning work is also much lower for young (under 30 years) researchers, because their work might not be immediately recognised as praiseworthy (Stephan & Levin, 1993). On the other hand, high performance in the beginning of one's career is a good predictor of high performance at later stages. Receiving a university and PhD degree at a young age, a postdoctoral position early on in one's career, early publications (before the doctorate), research experience (during university), received citations of early work, rapid publications in top journals (especially in cooperation with co-authors), and getting a higher scientific rank at a young age are all good predictors of research performance later in one's career, and lead to greater integration into the scholarly community (Aggarwal, Schirm & Zhao, 2007; Blackburn, Behymer & Hall, 1978; Brancati, Mead, Graves, Levine & Klag, 1992; Cole & Cole, 1967; Dietz & Bozeman, 2005; Horta, 2009; Prpic, 1996).

When researchers acquire responsibility as group leaders, they again have to work on their reputation, which is based on results obtained earlier as young researchers. So just like up and coming researchers, new academic group leaders need to establish their scientific reputation. This leads to the third hypothesis:

> *Hypothesis 3: Academic leaders in the starting phase perform academic leadership practices aimed at acquiring and sustaining reputation as a creative and productive research leader, such as accomplishing an innovative research agenda.*

The role of researchers changes over time, which affects performance (Baldwin, Lunceford & Vanderlinden, 2005; Bayer & Dutton, 1977; Costas et al., 2010; Goodwin & Sauer, 1995; Gingras et al., 2008). During their career, researchers acquire many non-research duties and responsibilities such as teaching, administration, project management, funding, and supervision. As researchers gain experience, their research focus on goal-executing is substituted by goal-setting. A focus on goal-setting means that older researchers are responsible for increasing the group's access to scientific manpower and financing for projects. As a result, older and more established researchers are involved in an increasing number of research projects, and therefore invest less time in each individual research project. This change in focus generally results in strong individual publication growth, through co-authoring papers on a variety of research projects (Knorr & Mittermeir, 1980; Knorr, Mittermeir, Aichholzer & Waller, 1979a). This is most likely the role of the academic group leader (Gingras et al., 2008).

This role change might have positive spillover effects on group performance. More experienced group members (i.e. senior researchers and group leaders) who provide supervision, or act as mentors, positively influence predoctoral or early-career research productivity, self-efficacy, grants and the collaboration between and professional networks of PhD students and other less experienced researchers (Cameron & Blackburn, 1981; Cronan-Hillix, Gensheimer, Cronan-Hillix & Davidson, 1986; Green, 1991; Long & McGinnis, 1985; Paglis, Green & Bauer, 2006; Reskin, 1979; Van Balen, 2010). Experienced researchers, such as full tenured professors and leading scholars, may increase the number of successful PhD candidates in the group and may increase access to material resources, such as research funds that allow for the recruitment of competent researchers (Carayol & Matt, 2004; Dundar & Lewis, 1998). The accumulated professional experience of research leaders also enables them to influence the knowledge and values of the group members, to exploit professional contacts and networks, and to help colleagues (Dill, 1982). In short, the role change from researcher to group leader refers to a more collective perspective, with less supervision from experienced researchers and the securing of research funding as a main task. This leads to the fourth hypothesis:

> *Hypothesis 4: Academic leaders more mature in experience perform academic leadership practices aimed at preserving and extending group vitality.*

Researchers at the end of their careers are the lowest performers (Costas et al. 2010; Goodwin & Sauer, 1995; Sturman, 2003; Gingras et al., 2008). Simonton (2004) shows that supply of new ideas is slowly depleted, resulting in a post-peak decline in individual productivity at the later established career trajectories. He suggests that individual creative potential is consumed faster than it can be replenished because of growing professional and personal responsibilities, a narrower scope of expertise acquisition and a loss of receptiveness to new ideas (Planck's Principle).

Kyvik and Olson (2008) argue that the drop in performance might be a result of obsolete skills, which hinder older academic leaders in shifting their research focus, leading to less important publications. Indeed, very few researchers above the age of 55 get their work awarded with a Nobel Prize (Stephan & Levin, 1993). The diminished impact of their research can also be caused by less visibility in the scientific community. For example, Van Rijnsoever et al. (2008) showed that the level of network activities of experienced researchers starts to decline after 20 years of a scientific career. Promoting your research helps to attract citations (Aizenman & Kletzer, 2008). However, the proportion of time spent on research activities declines for late-career researchers, while time spent on teaching increases (Baldwin et al., 2005). Altogether, this suggests that on average, researchers who are near to retirement show a declining productivity and impact with a shift of focus to educational tasks. This leads to the fifth hypothesis:

> *Hypothesis 5: Academic leaders in the end phase perform academic leadership practices aimed at relinquishing their role as group leader and shifting their focus from research to education.*

2. Data and methods

2.1 Data

The data for this study was collected in a survey in 2002 among academic leaders of biomedical and health research groups in the Netherlands. These group leaders were working in University Medical Centres (UMCs) or in biomedical/medical public research institutes in the Netherlands (Van der Weijden, 2007; Van der Weijden et al., 2008; Van der Weijden, Verbree, Braam & Van den Besselaar, 2009). The participating group leaders (N = 137) returned the completed questionnaires with an overall response rate of 38 per cent. To maximise the response rate, we used the tailored design method (Dillman, 2000). Non-response analysis shows that the respondents can be regarded as a representative sample of the Dutch biomedical and health research groups. The mean difference in publication output is very small and non-significant (resp. 24.35 vs. 24.83 publications) (Van der Weijden, 2007; Van der Weijden et al., 2008). Furthermore, we checked whether the respondents were evenly distributed among the various research institutions and the disciplines, and this proved to be the case (Van der Weijden, 2007).

2.2 Independent variables

To measure generation and life cycle effects, we distributed the respondents over various groups representing either a specific generation or a specific phase in the life cycle career of a group leader. Generation membership is defined as the year the PhD was obtained and determines which period socialisation in academia has taken place. In Section 1.1, we noted that the Dutch science system underwent structural changes in funding and research evaluation before 1988. Consequently, we consider 1988 to be the breakpoint in time between the two generations. The older generation had obtained their PhDs before changes in the science system had taken effect (PhD pre 1988), while the younger generation had obtained their PhDs when changes in the science system had already taken effect (PhD post 1987). Thus, group leaders from cohort old are educated as researchers in a different time period than group leaders from cohort young.

Three life cycle phases can be distinguished. The starting phase includes academic leaders who have 5 or fewer years experience as leaders of their current groups. The departing phase includes academic leaders who are 57 years or older[4], anticipating retirement. Experienced group leaders who have been leading their group for a long period (more than 5 years) and are not anticipating their retirement yet (younger than 57 years) are considered to be in the intermediary phase. Table 1 shows the distribution of the respondents among generations and life cycle phases[5].

Table 1 Distribution of respondents among generations and life cycle phases

Generation	Mean	Starting group leaders	Experienced group leaders	Departing group leaders	Total
Cohort old PhD pre-1988	N	10	51	44	**105**
	Age	52.2	52.7	60.2	**55.8**
	Experience	2.9	12.8	17.4	**13.8**
Cohort young PhD post-1987	N	12	18		**30**
	Age	44.3	45.1		**44.8**
	Experience	4.0	8.7		**6.8**
Total	**N**	**22**	**69**	**44**	**135**
	Age	**48.0**	**50.7**	**60.2**	**53.4**
	Experience	**3.5**	**11.8**	**17.4**	**12.3**

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4 We choose 57 years as breakpoint because group leaders indicated in interviews that 62 is the age at which retirement can start and often starts. Legal retirement age is at 65. Similar to a maximum of 5 years starting phase, we also took a maximum of 5 years for phasing out.

5 Due to missing data about year of PhD obtainment, age, or years of experience as group leader, not all 137 respondents are included in the analyses.

To test for *generation effects* on leadership, we compared academic leaders from cohort old (PhD pre-1988) with academic leaders from cohort young (PhD post-1987). Given the skewed distribution of our data (indicated by a Shapiro-Wilk test), we conducted Mann-Whitney and Chi-Square tests to analyse differences in academic leadership. There are three possible . We identified a 'starting effect' when new group leaders differ from the experienced and the departing peer group leaders in their academic leadership. A 'maturation effect' is detected when experienced group leaders differ from starting and departing group leaders in their academic leadership. Finally, a 'retirement effect' can be identified when departing group leaders differ from starting and from experienced research leaders. To analyse the differences in academic leadership for the three life cycle phases, we also conducted Mann-Whitney and Chi-Square tests. As some subsamples are very small (i.e. 10 starting group leaders in cohort old), we firstly tested generation and life cycle effects on the total sample independently. However, in section 3.3 we will control generation effects for life cycle effects and vice versa.

Our survey addressed items on the various components of academic leadership, viz. resource strategy, leadership, group management, and network management. The survey contained 49 questions in total (Van der Weijden, 2007). In Table 2, we describe the items that were used for this study and the descriptive statistics for each item.

Table 2 Description and descriptive statistics of dependent variables

		Descriptive statistics				
Variables	**Description**	**Mean**	**Median**	**Std dev**	**Minimum**	**Maximum**
Resource strategy						
Funding sources	Percentage of total funding from:					
	– Institutional funding	41.7	40.0	24.5	0	100
	– External funding	58.3	60.0	24.5	0	100
	– Competitive funding	17.0	15.0	15.9	0	70
	– Contract funding	11.2	0	16.9	0	90
	– Charity funding	21.0	15.0	22.2	0	80
	– European funding	3.4	0	7.4	0	40
	– Other funding sources	5.8	0	11.4	0	66.7
Number of funding sources	Measure the total number of funding sources	3.5	3.0	1.1	1	6
Submitted research proposals	Dummy variable measuring whether or not group leaders had submitted research proposals in the period 1999-2001				Yes: 42.3%	No: 57.7%
Group size	Number of scientific and support staff (FTE)	14.8	14.0	7.0	3.0	38.0
Staff constellation	Percentage of total scientific staff:					
	– Professors	11.2	9.5	7.7	0	33.0
	– Senior staff	35.0	33.3	17.3	0	80.0
	– PhDs	47.2	50.0	17.4	0	91.0
	– Other scientific staff	6.7	0	11.3	0	67.0
	– Support staff (analysts and technicians)	24.0	24.1	15.4	0	57.0
	– Permanent staff	54.9	50.0	29.4	0	100

		Descriptive statistics				
Variables	**Description**	**Mean**	**Median**	**Std dev**	**Minimum**	**Maximum**
Leadership						
Time allocation	Percentages of time spent on: – research – group management – education – patient care – percentage of groups – external management tasks (network management)	 45.6 17.3 13.2 14.7 9.2	 43.4 16.7 12.1 10.5 6.6	 16.1 8.4 9.7 16.6 8.2	 11.0 4.6 0 0 Yes: 57.4% 0	 83.5 52.0 46.7 78.0 No: 42.6% 52.0
Group management						
Intangible rewards	Dummy variable measuring whether or not leaders provide intangible rewards (i.e. special honours)				Yes: 53.3%	No: 46.7%
Quality control of research proposals	Measure importance of quality control for research proposals where 1 is 'totally disagree' and 5 is 'totally agree': "Researchers are free to decide whether or not to implement comments of internal pre-evaluations in research proposals"	2.5	2.0	1.0	1	4
Research agenda	Dummy variables measuring whether or not group leaders value considerations to set the research agenda as important: 1) Research themes of international interest 2) Theoretically challenged and innovative research themes 3) Possibility for new research lines 4) PhDs interests and possibilities 5) Opinion of international col leagues 6) Interest of international research programmes 7) Application possibilities in health care 8) Possibility to obtain visibility in top journals Percentage of considerations that are valued as important to set the research agenda: 100 means that a group leader values all 8 considerations as important	 46.0	 42.9	 15.2	 Yes: 51.1% Yes: 68.9% Yes: 30.8% Yes: 34.6% Yes: 32.3% Yes: 25.0% Yes: 46.3% Yes: 40.6% 7.1	 No: 48.9% No: 31.1% No: 69.2% No: 65.4% No: 67.7% No: 75.0% No: 53.7% No: 59.4% 78.6
Job assessments	Dummy variable measuring whether or not leaders evaluate their group members by means of job assess-ments				Yes: 94.9%	No: 5.1%
Network management						
Network activities	Intensity of network activities in days per year where network activities are the sum of days spent on: – lectures – attending conferences – participation in editorial boards – participation in assessment committees	42.7	40.0	21.6	10	130
Characteristics of the leader						
Age	Age of leader in 2002	53.5	55.0	6.5	37	68
Experience	Years of experience as group leader in current research group	12.2	11.0	6.8	1.0	37

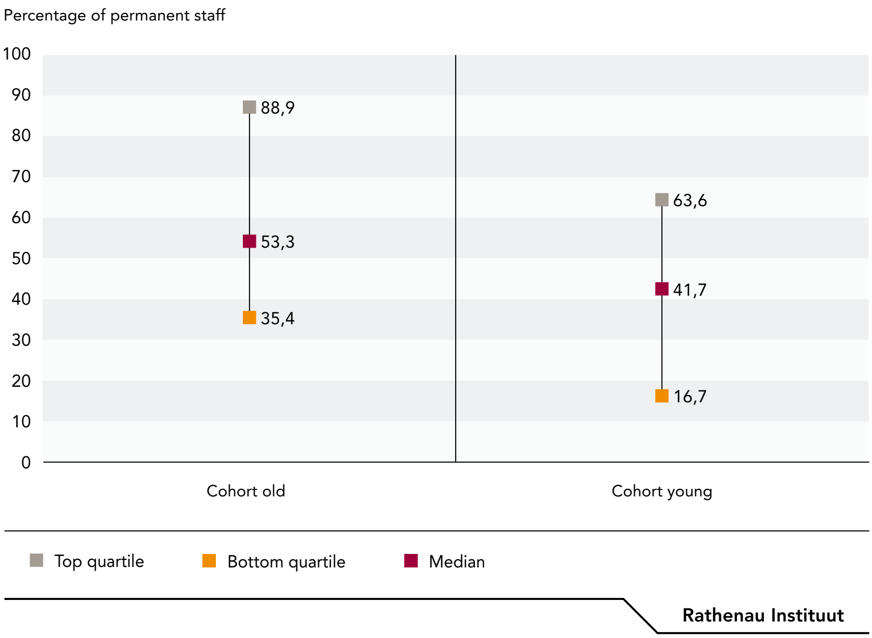
3. Results

In the following sections we report our findings. Results of the test for generation effects are summarised in Table 3, and those for the life cycle effects are summarised in Tables 4-6. In Table 7, we show how the results change when taking both independent variables into account simultaneously.

3.1 Generation effects on academic leadership

Based on major changes in research funding and research evaluation that had taken place in the Netherlands, we defined two cohorts of academic leaders. A generation effect occurs when the two cohorts of academic leaders differ in leadership, group and network management, or in resource strategy. For example, the younger generation of academic leaders has significantly fewer permanent staff compared to the older generation (Figure 2).

Figure 2 Generation effect of proportion of permanent staff



Considering Hypothesis 1, we found evidence that the younger generation of academic leaders places a higher emphasis on research than the older generation (Figure 3). The younger generation spends approximately half as much time on education than the older generation. In contrast, the younger generation spends more time on research and group management activities (Table 3).

Given the high importance placed on obtaining external funding, we expected a higher time investment in network activities. Unexpectedly, we found that the younger generation spent less time participating in networking activities such as by holding memberships in committees and editorial boards (Table 3). However, one is invited for these types of activities based on reputation and network position, which the younger generation of academic leaders is still building up. They do have less experience (Table 1), and therefore we may measure here a starting effect and not a generation effect. We will come back to this in Section 3.2 and 3.3.

Figure 3 Generation effect of proportion of time spent on research and research management of the group

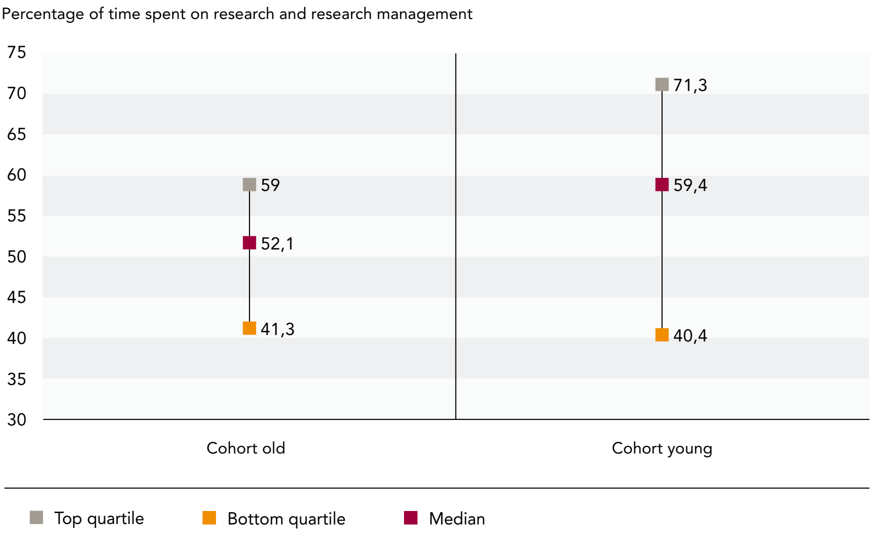


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Table 3 Generation effects on academic leadership

Academic leadership variables	Cohort old Median (n)	Cohort young Median (n)	Old versus young	
Teaching	12.8 (104)	6.2 (30)		r = -0.23***
Research & research management	52.1 (104)	59.4 (30)		r = -0.15*
Networking	40.0 (104)	35.0 (30)		r = -0.20**
External funding	50.0 (99)	77.5 (28)		r = -0.26***
Number of funding sources	3.0 (99)	4.0 (28)		r = -0.15*
Permanent staff (%)	53.3 (99)	41.7 (27)		r = -0.24***
Professors (%)	10.0 (99)	7.7 (27)		r = -0.18**
PhDs interests and possibilities (% yes)	38.6 (101)	20.0 (30)	Odds ratio[a] = 2.52*	

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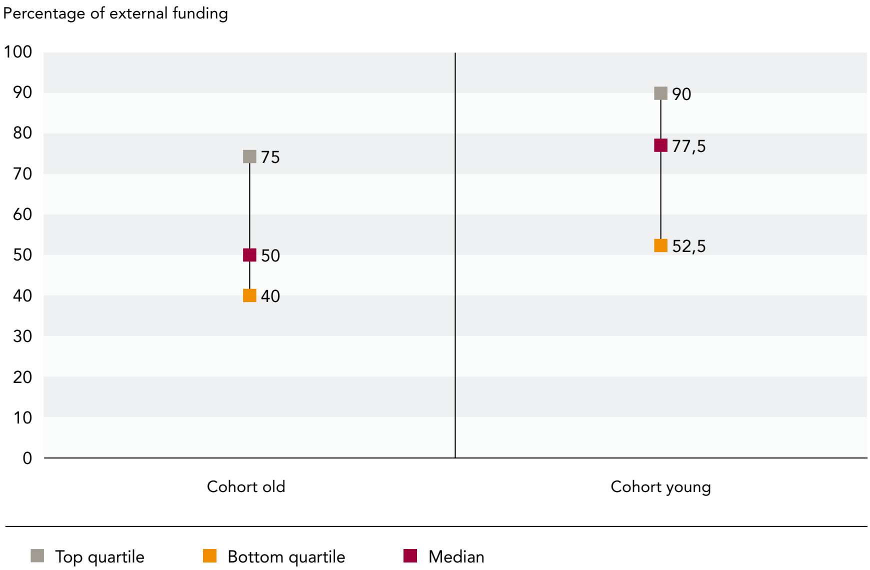
Cohort old = PhD before 1988; Cohort young = PhD after 1987; a) Reference category is cohort old. * p < 0.10; ** p < 0.05; *** p < 0.01.

With respect to Hypothesis 2, our results show that the resource strategy of the younger generation of academic leaders has a considerable higher focus on external funding (Table 3). The younger generation has a higher proportion of external funding (Figure 4) and they obtain funding from more sources. Furthermore, their group composition is different from the older generation. More specifically, the younger generation has substantially fewer permanent staff (Table 3). This is most probably an effect of the changing working conditions, where group leaders are increasingly expected to fund their group through external funding, resulting in mainly temporary positions. In short, when there is no guarantee of stable institutional funding, you cannot guarantee your staff permanent positions. The younger generation also has a lower proportion of professors (Table 3). But in section 3.2 and 3.3 we will see that it concerns only the starting group leaders who have a lower percentage of professors in the group. This, therefore, seems to be a starting rather than a generation effect.

In addition, we found that the younger generation less often feels that PhD students should set their own research agenda (Table 3). This may be due to the fact that PhD students are generally paid through external funding, and therefore the research project is generally predefined by the group leaders' proposal.

In conclusion, Hypotheses 1 and 2 are supported by our test results: The younger generation of academic leaders focuses more on research, and obtains their resources more from external sources.

Figure 4 Generation effect of proportion of external funding



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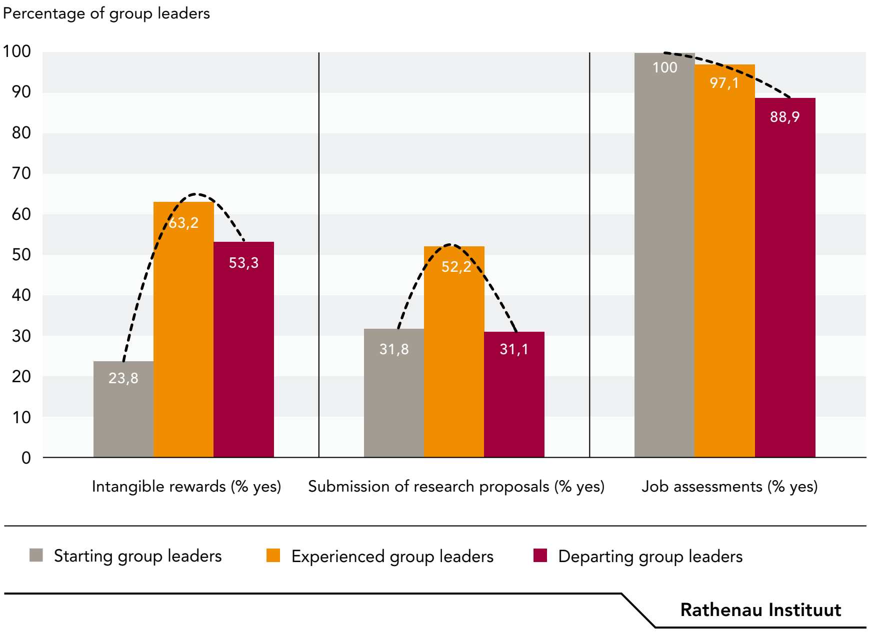
3.2 Life cycle effects

In the life cycle of an academic group leader, we distinguish between three phases. In the starting phase, an academic leader has to gain reputation for the work of his or her research group. In the maturity phase, an academic leader has a stable group and is not yet anticipating departing, and so focuses on strengthening the group vitality. In the departing stage, an academic leader is in the last phase of his or her career and anticipates retirement. We hypothesised that academic leadership differs between these phases. We now report the starting, maturity, and departing effects on academic leadership.

Figure 5 Starting effect of intangible rewards, maturity effect of submission of research proposal, and departing effect of job assessments



A starting effect occurs when starting group leaders behave differently from experienced and departing group leaders. For example, starting group leaders less often provide intangible rewards such as special honours or non-financial prizes; a steep, increasing trend from starting group leaders to experienced group leaders is seen in Figure 5. A maturity effect occurs when experienced group leaders behave differently from starting and departing group leaders. For example, experienced group leaders often submit more research proposals to the medical research council; an inverse u-curve is seen in Figure 5 that represents less activity from starting and departing group leaders. A departing effect occurs when departing group leaders behave differently from starting and experienced group leaders. For example, departing group leaders often have fewer job assessments when evaluating their researchers; a declining trend is seen in Figure 5 from starting to departing group leaders.

3.2.1 Starting effects

The starting effects are summarised in Table 4. As already noted in Section 3.1, starting group leaders spend significantly fewer hours on networking activities, such as participating in editorial boards, and participating in assessments committees. This may be due to the fact that starting group leaders are still building up their networks, and many of these activities are based on a positive reputation and the positions they hold within relevant networks.

Another interesting starting effect is motivational. Starting research leaders emphasise their own research agenda; almost all starting academic leaders in our sample attach high value to challenging, theoretical and innovative research themes. Apparently, starting group leaders consider creativity as highly important and necessary for establishing their reputation (Figure 6).

Table 4 Starting effects on academic leadership

Academic leadership Variables	**Starting leaders**	**Experi-enced leaders**	**Departing leaders**	**Starting vs Experienced**		**Experienced vs Departing**		**Starting vs Departing**	
	Median (n)	Median (n)	Median (n)	Odds ratio	r	Odds ratio	R	Odds ratio	r
Networking	30.0 (22)	40.0 (69)	40.0 (43)		-0.30***		ns		-0.23*
Theoretically challenging	90.5 (21)	61.2 (67)	69.0 (42)	6.02** [a]		ns		4.26* [a]	
Intangible rewards (% yes)	23.8 (21)	63.2 (68)	52.3 (44)	5.50*** [b]		ns		3.50** [b]	
Professors (%)	7.4 (18)	10.0 (67)	11.1 (41)		ns		ns		-0.32**

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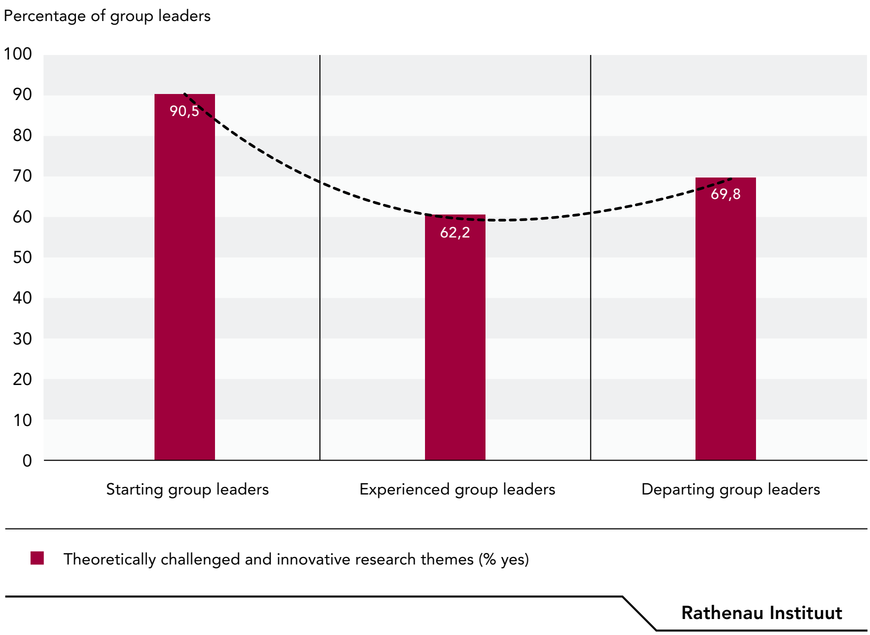
Reference category: [a]: starting group leaders [b]: experienced group leaders.
* p < 0.10; ** p < 0.05; *** p < 0.01; ns = not significant.

Concerning group management, starting leaders provide far fewer intangible rewards (Figure 5) than experienced and departing group leaders. Perhaps less experienced group leaders place less emphasis on motivating their group members, because they need to promote their research line externally to build a reputation. Finally, starting group leaders have a smaller proportion of professors in their group, probably because some of these groups are not directed by full professors but by associate professors.

Figure 6 Starting effect of creativity



We found evidence for Hypothesis 3. Leadership practices of starting academic leaders focus more on developing a research agenda and building a reputation by finding an individual creative research niche, and they place less emphasis on internal management.

3.2.2 Maturity effect

The maturity effects are summarised in Table 5. When an academic leader acquires reputation for his or her own new research line, the next phase is to guarantee survival of the group. Following reputation, the next obvious main goal is to obtain enough funding. Indeed, the results show that experienced group leaders acquire a significantly higher proportion of external funding compared to starting and departing group leaders (Figure 7). Also, the odds ratios show that experienced and departing group leaders are almost 2.5 times more likely to submit research proposals to the medical research council than starting group leaders (Table 5). Furthermore, they put considerably more emphasis on the quality control of research proposals. To conclude, Hypothesis 4 is confirmed, as leadership practice of academic leaders in their maturity phase aim to strengthen group vitality by obtaining new research funds.

Table 5 Maturity effects on academic leadership

Academic leadership	Starting leaders	Experi-enced leaders	Departing leaders	Starting vs. Experienced		Experienced vs. departing		Starting vs. departing	
	Median (n)	Median (n)	Median (n)	Odds ratio	R	Odds ratio	R	Odds ratio	r
External funding	45.0 (22)	70.0 (64)	50.0 (42)		-0.22**		-0.20**		ns
Submitted research proposals (% yes)	31.8 (22)	52.2 (69)	31.1 (45)	2.34* a)		2.34** a)		ns	
Quality control of research proposals	3.0 (19)	2.0 (65)	3.0 (35)		-0.23**		-0.23**		ns

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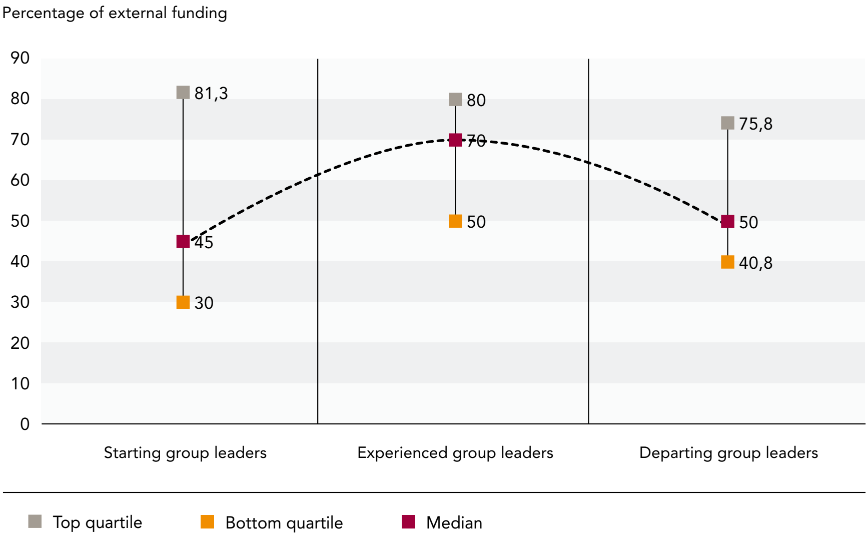
a Reference category is experienced group leaders.
* p < 0.10; ** p < 0.05.

Figure 7 Maturity effect of the proportion of external funding



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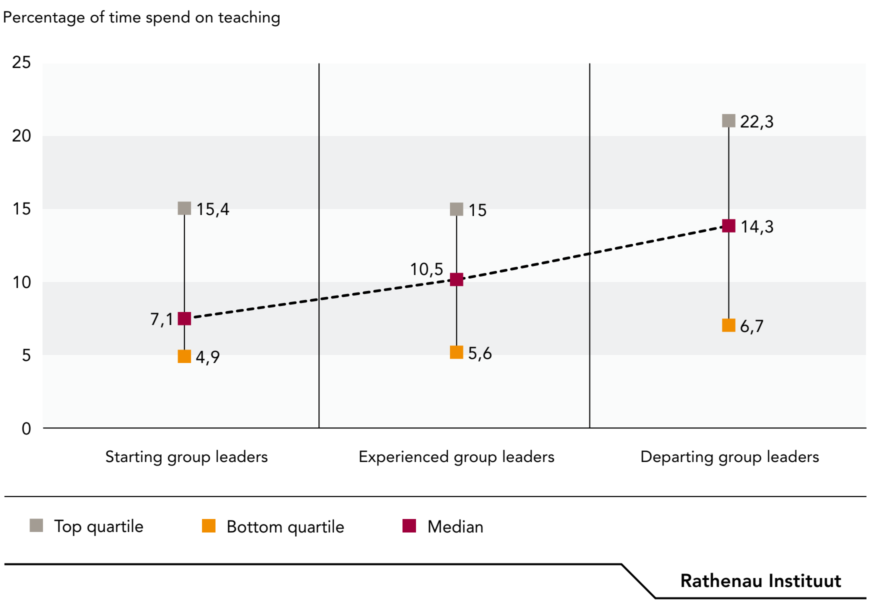
3.2.3 Departing effects

Several indicators demonstrate the departing effect (Table 6), referring to the activities of departing group leaders that are different from starting and experienced group leaders. They spent more time on teaching – i.e. they spent twice as much time on teaching activities compared to the starting group leaders (Figure 8), while less time was spent on research activities and group management. It is plausible that departing group leaders develop a role that is more focused on education and less on research. That does not mean that departing group leaders are not devoted to research anymore; they still spend a considerable amount of their total work time on research and research management of the group (47.1 %, see table 6).

This shift from research to education impacts the motivation to set the research agenda. Departing group leaders often find it more important that PhD students follow their own interests. At the end of their career, group leaders may put more emphasis on supervision, and – not to be hampered by group interests – they give young researchers more freedom to explore their individual interests. Producing high impact research is of less importance, and only a quarter of the departing group leaders attach value to obtaining visibility in top journals. In general, departing group leaders have a smaller focus on research. Finally, departing group leaders organise fewer job assessments; this task is possibly taken over by their successors (Figure 5).

Figure 8 Departing effect of proportion of time spend on teaching



Hypothesis 5 is also confirmed; the results show that academic leaders who are in their departing phase are relinquishing their roles as group leaders by shifting their focus from research to education and supervision.

Table 6 Departing effects on academic leadership

Academic leadership	Starting leaders	Experi-enced leaders	Departing leaders	Starting vs. Experienced		Experienced vs. Departing		Starting vs. Departing	
	Median (n)	Median (n)	Median (n)	Odds ratio	r	Odds ratio	R	Odds ratio	r
Teaching	7.1 (22)	10.5 (68)	14.3 (44)		ns		-0.19**		-0.23*
Research and research management	58.7 (22)	52.9 (68)	47.3 (44)		ns		-0.21**		-0.21*
Research agenda	50.0 (21)	43.8 (64)	37.5 (41)		ns		-0.19*		-0.26**
PhDs interests and possibilities (% yes)	22.7 (22)	29.9 (67)	47.6 (42)	ns		2.14* a)		3.09* a)	
Visibility in top jour-nals (% yes)	42.9 (21)	48.5 (68)	26.2 (42)	ns		2.66** b)		ns	
Job assessments (% yes)	100 (22)	97.1 (69)	88.6 (44)	c)		4.29* b)		c)	

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Reference category: a: departing group leaders; b: experienced group leaders; c: cannot be computed.

* $p < 0.10$; ** $p < 0.05$.

3.3 Combined effects of life cycle and generation on academic leadership

In the previous sections (3.1 and 3.2), we investigated the effects of generation and life cycle stage on the total sample separately. However, some of the differences found in academic leadership practices may be the (additive) result of both generation and life cycle processes. But other differences in academic leadership could be the result of either generation or life cycle processes. To test this, we will control generation effects for life cycle and vice versa in this section.

In section 3.1, we showed that the two generations differ in several variables of academic leadership. Some of the academic leadership variables were also influenced by life cycle processes. Table 7 shows the generation effects controlled for life cycle stage.

Table 7 Generation effects controlling for life cycle effects

Academic leader-ship variables	Generation	Starting leaders	Starting vs. Experi-enced	Experi-enced leaders	Experi-enced vs. Departing	Departing Leaders (old generation)	Starting vs. Departing
		Median (n)		Median (n)		Median (n)	
Number of funding sources	Cohort old	3.0 (10)		3.0 (48)		3.0 (41)	
	Cohort young	4.0 (12)		4.0 (16)			
	Total	3.5 (22)	ns	3.0 (64)	ns	3.0 (41)	ns
Permanent staff	Cohort old	42.7 (8)		53.1 (50)		58.3 (41)	
	Cohort young	47.5 (10)		35.7 (17)			
	Total	45.2 (18)	ns	50.0 (67)	ns	58.3 (41)	ns
External funding	Cohort old	30.5 (10)		60.0 (48)		50.0 (41)	
	Cohort young	55.0 (12)		80.0 (16)			
	Total	45.0 (22)	-0.22**	70.0 (64)	-0.20**	50.0 (41)	ns
Teaching	Cohort old	9.1 (10)		12.1 (50)		14.3 (44)	
	Cohort young	6.1 (12)		6.7 (18)			
	Total	7.1 (22)	ns	10.5 (68)	-0.19**	14.3 (44)	-0.23*
Research & research management	Cohort old	55.5 (10)		52.7 (50)		47.3 (44)	
	Cohort young	61.3 (12)		58.6 (18)			
	Total	58.7 (22)	ns	52.9 (68)	-0.21**	47.3 (44)	-0.21*
PhDs interests and possibilities (% yes)#	Cohort old	20.0 (10)		34.7 (49)		47.6 (42)	
	Cohort young	25.0 (12)		16.7 (18)			
	Total	22.7 (22)	ns	29.9 (67)	2.13*	47.6 (42)	2.09*
Networking	Cohort old	32.5 (10)		50.0 (51)		40.0 (43)	
	Cohort young	30.0 (12)		35.0 (18)			
	Total	30.0 (22)	-0.30***	40.0 (69)	ns	40.0 (43)	-0.23*
Professors	Cohort old	9.4 (8)		9.1 (50)		11.1 (41)	
	Cohort young	6.7 (10)		11.1 (17)			
	Total	7.4 (18)	ns	10.0 (67)	ns	11.1 (41)	-0.32**

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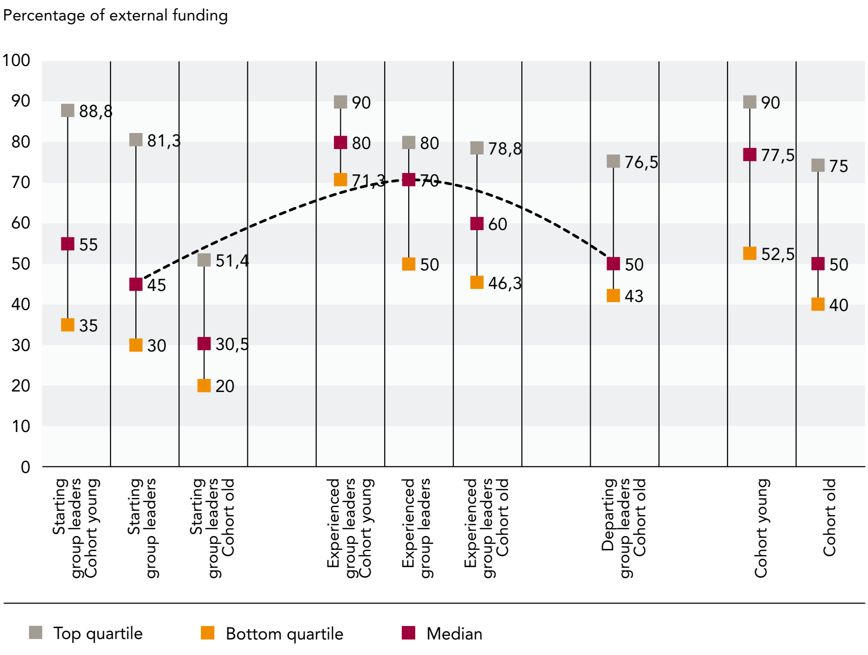
ns = not significant; * p < 0.10; ** p < 0.05; *** p < 0.01; # odds ratio with reference category departing group leaders.

The *number of funding sources* and the *share of permanent staff* do not significantly differ between the three life cycle phases, and are indeed solely generation effects. With respect to the *amount of external funding*, we found a generation effect as well as a life cycle effect. The amount of external funding that is acquired clearly represents a combined effect of generation and life cycle. Figure 9 illustrates that the proportion of external funding is the highest for experienced group leaders, who have as a main goal to secure vitality of the group. Figure 9 also shows that the newer generation of group leaders, in both the starting and the maturity life cycle phases, obtain much more external funding compared to the older generation. This generation comparison cannot be done for the departing leaders, as they all belong to the older generation.

Figure 9 Maturity and generation effect of external funding



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Another variable that differs between generations (Table 7) is the shift from research to education. As Table 7 shows, here the departing age group differs from the two other groups. Given that the departing group is a subset of the older generation, the generation effect may be overestimated in section 3.1. As in both generations, the starting group leaders and the experienced group leaders differ from each other in the same direction; research and teaching are additively influenced by generation and life cycle. Both the older generation and the soon retiring group leaders shift their time allocation from research towards education. Also, departing leaders and leaders from the older generation seem to value more the own interests of PhD students.

In section 3.1 and 3.2, we already mentioned that the time spent on networking activities and the percentage of professors in the research group are both starting effects rather than a generation effect. This is seen in Table 7; the starting group leaders spend fewer days per year on networking activities and have a lower share of professors in their group. Table 7 shows no support for generation effects.

Finally, we checked whether the (previously not yet discussed) variables that showed differences between the life cycle groups differ between the generations. This is not the case (Table 8).

Table 8: Life cycle effects controlling for generation effects

Academic leadership Variables	Cohort Old	Cohort Young	Cohort Old vs, Cohort Young	
Starting effects	Median (n)	Median (n)	Odds ratio	r
Theoretically challenging (% yes)	69.0 (100)	66.7 (30)	ns	
Intangible rewards (% yes)	52.9 (104)	55.2 (29)	ns	
Maturity effects				
Submitted research proposals (% yes)	39.0 (105)	53.3 (30)	ns	
Quality control of research proposals	2.0 (89)	2.0 (29)		ns
Departing effects				
Research agenda	37.5 (97)	50.0 (29)		ns
Job assessments (% yes)	94.3 (105)	96.7 (30)	ns	

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ns = not significant.

4. Conclusion and discussion

4.1 The study

In order to study the changes in academic leadership behaviour, we distinguished between changes related to life cycle and changes related to generation differences. In the mid-1980s (until 1988), science policy implemented a national research evaluation procedure that assessed all Medical and Health Science faculties and departments of non-university research institutes in the Netherlands. In the same period, a new funding system was introduced for universities. Finally, in this period, the share of competitive project funding grew fast. Based on these changes in research evaluation and funding, we defined two cohorts of academic leaders in our survey sample of biomedical and health group leaders. There is a new generation of group leaders who were socialised into the academic world after the implementation of these changes took effect, and there is an old generation of group leaders who were socialised before these changes had taken effect. As a result, we expected the younger generation to be more adapted to the new environment, which is reflected in their larger orientation on research and on external funding.

Considering life cycle effects on academic leadership, we distinguished three phases based on experience as a group leader and on age. The starting phase includes academic leaders with five or fewer years of experience. The maturity phase includes experienced academic leaders who are not anticipating retirement yet (younger than 57). The departing phase includes the oldest academic leaders (57 years or older) who are near retirement. We compared activities and attitudes between these three life cycle phases and expected differences in goals, interests and responsibilities.

Before summarising our conclusions and presenting implications, we mention some limitations of our study. Firstly, our sample is limited to the biomedical and healthcare sciences, while cohort as well as life cycle effects can vary between disciplines (Gonzalez-Brambila & Veloso, 2007; Simonton, 1988). However, the biomedical and healthcare sciences cover about 40% of all public research in the Netherlands. In addition, the biomedical and healthcare sciences consist of rather heterogeneous types of research, including fundamental pre-clinical research, application-oriented clinical research, and healthcare research with a social sciences oriented nature. Nevertheless, we do not disregard that the situation might be different in, for instance, technical sciences or humanities. The same holds for scientific disciplines where research is traditionally less organised in groups, and so academic leadership probably represents a slightly minor role. As a second limitation, the study is conducted in the Netherlands which has some consequences for international generalisation. Academic leadership practices may of course differ between countries, so comparative studies are certainly recommended. However, the Netherlands is not a small country in terms of research output and the country's academic culture is comparable with that of other Western countries. Finally, the sample was not large enough to conduct a more advanced statistical multivariate analysis.

4.2 Conclusions

In this study, we show differences in academic leadership practices influenced by generation and life cycle phase. The institutionalisation of research evaluations and the implementation of project funding in the Dutch science system in the middle of the 1980s have had consequences for the behaviour of academic leaders. The young generation of academic leaders – socialised in a period wherein these changes had already taken effect – is more adapted to this new, research oriented, competitive environment later in their careers as group leaders. In comparison with the older generation of academic leaders, the younger generation spends more time on research activities and group management and they spend less time on education. Also, they acquire a higher proportion of external funding from more various sources. This higher dependence on external funds may have led to a lower proportion of permanent staff and it may determine the research topics of PhDs, giving young researchers less freedom to explore their own individual research interests.

As explained in section 1.2, we expected that academic leaders who are in different stages of their careers have different goals, interests and responsibilities. As a consequence they will show different academic leadership practices. Academic leaders who just started to lead their own research groups need to build up a reputation. This is confirmed by the finding that starting leaders emphasise a need for new and creative research themes. Their lower network activity mirrors their lower reputation; starting group leaders need more time to gain visibility in the scientific community before they get invited for, e.g., assessment committees. The need to promote their research externally might result in less emphasis on internal group management, such as motivating their researchers with intangible rewards.

When reputation is obtained, the next step is obviously to retain it. Then, the main focus of experienced academic leaders is to preserve and extend group vitality. Our findings support this, as acquiring new research funds is the highest priority, and academic leaders in their maturity phase obtain more external funding than academic leaders in other life cycles. Furthermore, on average, experienced academic leaders are more active in submitting research proposals than starting and departing group leaders. Finally, they are more active in checking the quality of research proposals from their group members.

Academic leaders who are near retirement age were also expected to behave differently. In preparation of their leave, they are likely to reduce research activities and place more emphasis on education. More specifically, although departing academic leaders in our sample spend about half of their time on research and research management of their group, they spend a lower proportion of time on research activities and group management than starting and experienced academic leaders. Also, they spend a higher proportion of their time on education. On average, departing group leaders consider visibility in top journals as less important than starting and experienced academic leaders. Finally, departing leaders (more than starting and experienced academic leaders) attach value to the autonomy of PhD students, which indicates a shift from a group leader's role to a supervisory role.

4.3 Implications

This study shows that if science policy changes incentives in the science system, researchers adapt their behaviour. The period in which researchers get socialised determines their attitudes and activities in their further career. What does this imply for any mentioned current developments, such as stress for academic excellence, an increasing emphasis on the societal benefits of research, and the growing competition between researchers and research organisations for funding? With respect to the 1980s changes, academic leaders were forced into a more entrepreneurial attitude, indicated by a greater dependence on external funding and a stronger focus on research. More recent developments reinforce this tendency, and this entrepreneurial attitude is becoming important even earlier in research careers. For instance, the implementation of new grant schemes for young talented researchers[6] gives researchers in an early phase (immediately after defending their dissertation) the autonomy to elaborate their own research agenda. These grants provide great opportunities for young talented researchers to explore their own creative research niches. However, it also intensifies competition between researchers at an early stage in their career. At the same moment, it may create an 'obligatory point of passage' for entering an academic career. This is a potential risk, since the proportion of applicants that get funded is relatively low, and a lot of rejected applicants are good performers as well (Bornmann et al., 2010; Van den Besselaar & Leydesdorff, 2009). To summarise, the new developments, which force researchers to independence, will lead to a radicalisation of competition. How this will affect scientific careers and research leadership in the future remains an open question.

The differences in goals, responsibilities and interests in the different life cycle phases lead to differences in behaviour. What can we learn from the observed role change over the life cycles of academic leaders? First, it should be noted that the roles of academic leaders who approach retirement age should not be underestimated. In fact, their roles move more from knowledge production to knowledge transfer (viz. educational and supervisory tasks). However, they remain spending a considerable amount of time on research, and they are still productive and thus do not lose touch with research practices. That is, they fulfil an important role in the education of the new generation of researchers. In particular, our results show that they are more sensitive for the autonomy, possibilities and interests of PhD students, and may therefore stimulate more strongly the creativity of young researchers. Given that researchers still fulfil a meaningful task in knowledge transfer at the end of their career, one could think about extending the scientific careers of researchers beyond the current retirement age of 65 in the Netherlands[7].

Finally, a somewhat more speculative implication involves the size and composition of research groups. Looking at the different roles of starting, experienced and departing academic leaders, one may think of the division of labour between leaders in various life cycle stages. Then, a research group

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6 The Netherlands Organisation for Scientific Research (NWO – Dutch research council) implemented the Innovational Research Incentives Scheme in 2000. These grants are meant for excellent researchers in different phases of their career; Veni (the youngest researchers who just obtained their PhD), Vidi (researchers who want to set up their own research line and appoint one or more researchers), Vici (senior researchers who want to start their own research group). Similar grants for young researchers are implemented, for example, in Germany: the Emmy Noether Programme, which aims to support young researchers in achieving independence at an early stage of their career, and in Sweden: Project Grant Junior Researchers. Also, the European Research Council has funds that offer opportunities for young investigators to develop independent careers: ERC Starting Independent Research Grant.

7 Retirement age varies between countries due to their specific tax laws and/or pension rules.

would consists of a less experienced group leader who develops his or her own creative research niche with support of a more experienced group leader that secures funding for the research group, and an older (highly experienced) leader who takes care of the supervision of young researchers. This would of course lead to larger teams, which may increase coordination costs. On the other hand, a bigger group size enables more variety of specialties and skills, and that is essential for addressing complex research problems (Borner et al., 2010; Stokols et.al. 2008a; 2008b). The development of larger research groups may also affect the vertical relations between the large research team and the research organisation. Probably, larger research teams are more powerful players in the research organisation, resulting in an expanded autonomy from the institute's management. This is also an interesting topic for future research.

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4 Addressing Leadership and Management of Research Groups: a Multivariate Study

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Abstract
Combining two theoretical approaches, we develop a model in which four dimensions of management and leadership, together with environmental variables and the personal characteristics of group leaders, affect performance of research groups. We show that various effects that were found in bivariate studies disappear when taking the full set of variables into account. A multivariate analysis shows which of the independent variables do play a role in the various performance dimensions. The study shows that the different performance dimensions (output, visibility, productivity, quality) ask for different leadership strategies. Implications are discussed.

Keywords
Resource dependence, task group effectiveness, research performance, research leadership, research management, networks

1. Introduction
Great expectations of science and technology have been raised due to highly complex societal and scientific problems such as climate change, infectious diseases and the economic crisis. To solve these highly complex societal and scientific issues, we cannot just wait for the answers that come from smart, intelligent scientists working in their own ivory towers. These challenges ask for a change in the organisation of how science is conducted.

The growing complexity and interdisciplinarity of research problems asks for more and different expertise combined in one research group. Research is increasingly conducted in larger research groups over the last few decades, even in disciplines were researchers traditionally conduct research on their own. This change was already observed in the 1970s (Stankiewicz, 1976). Thus, the academic excellence of individual, creative, innovative and enthusiastic researchers should be managed; the need for academic leadership has become more widespread.

It is the responsibility of the academic group leader to create adequate conditions that help the meeting of the collective and individual research goals such as high research performance (e.g. Amabile, Schatzel, Moneta, & Kramer, 2004; Bland & Ruffin, 1992; Goodall, 2009; Van der Weijden, 2007; Van der Weijden et al., 2008). Pelz and Andrews (1966; 1979) were the first who thoroughly investigated determinants for a stimulating research environment. They highlighted, for example, communication, motivation, and group size as important variables that influence research performance. Several studies that followed showed a positive relationship between leadership practices and performance (e.g. Babu & Sing, 1998; Bland & Ruffin, 1992; Harvey, Pettigrew, & Ferlie, 2002; Knorr & Mittermeir, 1980; Mumford, Scott, Gaddis, & Strange, 2002; Stankiewicz, 1976). However, these studies focused on the importance of leadership in general rather than which specific leadership tasks and practices positively related to performance.

In the earlier work of some of the authors, it was concluded that group leaders need to put different strategies into practice to achieve different research goals (van der Weijden, 2007; van der Weijden et al., 2008). This conclusion shows the complexity of the management of research groups, viz. group leaders have many choices in steering their research group and each choice effects research performance in a different way. What makes the task of a group leader even more difficult is that research output has a multidimensional nature (Jansen et al., 2007). Examples are publications, reports, presentations, technical contributions, contributions to public debates, education, patents and innovations. Not only is output a multidimensional concept, the same holds for the quality of the output. Quality might be measured in terms of productivity, impact, innovativeness, creativity, societal relevance and recognition. In a recent study, we defined high-performing research groups based on the multidimensional nature of performance and found that leaders of high-performing groups are all-rounders. This means that they are able to combine diverse activities, such as being involved in research and simultaneously stimulating and supervising their group members (Verbree et al., forthcoming-a). Furthermore, performance can be evaluated in relation to the mission of a research group, and in relation to external expectations on what a research group in a specific field should deliver to its discipline and to society (De Jong et al., 2011). Thus, effective leadership and achieving high performance depends on environmental contingencies.

An important element in the contingencies of the research organisation is that, increasingly, research is embedded in a heterogeneous institutional field. Industrial and societal connections through funding and problem orientation have been increasing (Hessels, 2010), resulting in the development of entrepreneurial research environments (Etkowitz, 1998; Etkowitz & Leydesdorff, 2000). University researchers are consequently embedded in an environment with heterogeneous demands (Gulbrandsen & Smedy, 2005). Studies on the effects of changes in the research funding landscape suggest that such changes lead to an increased striving for autonomy by researchers and research groups (Sanz-Menendez & Cruz-Castro, 2003). This striving for autonomy has been attributed to the organisation of semi-independent research groups that try to avoid dependency on a single external resource. Encouraging researchers to search for external funding reduces the influence institutional-level policies can have on their research choices. The manner in which increased diversity in the environment of research groups affects management, leadership and research performance of groups remains an open question (Auranen & Nieminen, 2010).

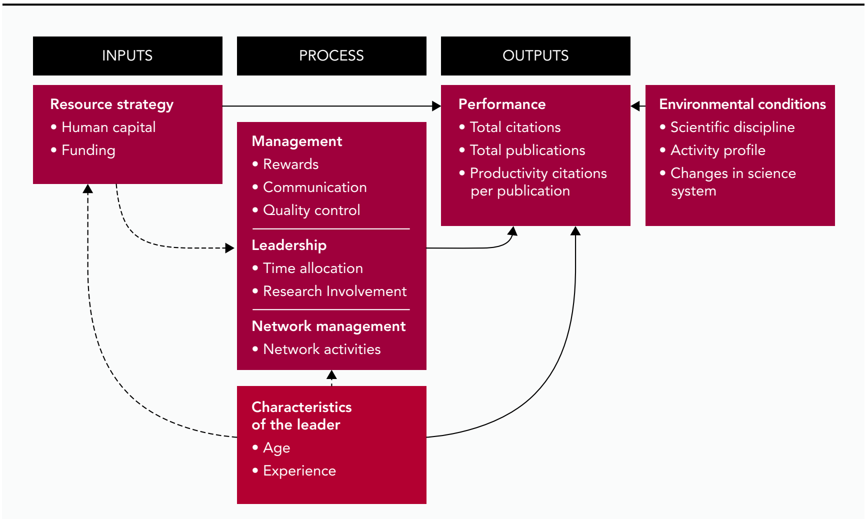
In this paper, we explore the mechanisms behind academic leadership and research performance in relation to the environment of research groups. In other words, while earlier bivariate studies show that many leadership and management variables influence different indicators of performance, the next step is to combine these various variables of academic leadership in one model. This approach enables us to answer our research question of how various academic leadership practices are interrelated and simultaneously influence research performance. In the next section, we introduce the components of our model and its theoretical background.

2. Conceptual model

Academic leadership is defined as the way in which academic group leaders use their abilities, preferences and experience to manage and lead their researchers and their research group (Verbree et al., forthcoming-a). Van der Weijden (2007; 2008) identified a broad set of individual indicators of leadership that relate to research performance. In a follow-up study we classified these variables into four comprehensive components of academic leadership (Verbree et al., forthcoming-a). The first component captures the inputs for research; *resource strategy* is the task of acquiring and combining resources. The second and third components of academic leadership refer to the process of conducting research. It is the task of a group leader to manage the research process and to lead researchers. Following Zaleznik (1977), we distinguish between the *management* tasks and the *leadership* tasks of a group leader. Management refers to process management, i.e. group leaders have a responsibility to complete research projects and improve the functioning of the group. The group leader has a different role in the leadership task. Here, the leader needs to stimulate and inspire researchers, also by formulating a challenging research agenda. In addition to the internal tasks of management and leadership, a group leader performs external tasks that are meant to position the group in scientific and societal environments. This is how the group obtains legitimacy, reputation and visibility. We call this final component *network management*.

We use Gladstein's (1984) inputs-process-output model of group effectiveness to understand how the four components of academic leadership interrelate and simultaneously determine performance. However, group effectiveness is not determined only by the leader but also by the environment in which he or she operates, as is suggested by the need for network management and the acquirement of resources. This is why we augment our model with the insights of Resource Dependence Theory (Pfeffer & Salancik 1978). Figure 1 presents our model.

Figure 1 Conceptual model of the relationship between academic leadership and performance of research groups



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2.1 Resource strategy

Funding and human capital are two key resources that group leaders must acquire to conduct research and realise research output (Johnes, 1988). A lack of (institutional) funding is obviously detrimental to research (e.g. Babu & Sing, 1998; Pruthi, Jain, Wahid, & Nabi, 1993; Heinze et al., 2009). To overcome the constraints of eternally scarce institutional funds, research groups increasingly try to acquire funding from a variety of external (and increasingly also international) sources (Geuna, 2001; van der Weijden et al., 2009). Yet, funding sources have different expectations from the work they fund and elicit different strategies from their applicants. And the outcomes are not necessarily related to research performance (Carayol & Matt, 2006; Cherchye & Abeele, 2005; Groot & García-Valderrama, 2006). Competitive research council funding might stimulate researchers in their early academic careers (Bornmann et al, 2010; Hornbostel et al., 2009; Van den Besselaar & Leydesdorff, 2009). On the other hand, industry or contract funding seems to be more appropriate for applied research (Groot & García-Valderrama, 2006, Gulbrandsen & Smeby, 2005; Carayol, 2003; Louis et al, 2007).

Available resources constrain group size. Should a research group be large or small? Large groups can realise a large amount of output across a broad range of (interdisciplinary) research topics (Louis et al., 2007; Pineau & Levy-Leboyer, 1983; Spangenberg et al., 1990). Then again, the benefits of group size may dissipate owing to diminishing marginal returns to labour (Dundar & Lewis, 1998; Jordan, Meador, & Walters, 1988, 1989; Omta, 1995). Although smaller groups may produce less output and address a narrower range of research topics, they are easier to manage – especially for less-experienced group leaders – and the coordination costs of organising scholarly communication and collaboration among group members are much lower (Urwick, 1956; Carayol & Matt, 2004, 2006; Heinze et al., 2009). Given the advantages of both big and small, it is suggested that research groups need critical mass in order to produce a large amount of output with a broad scope, but there seems to be a threshold level in size beyond which productivity declines (Blackburn et al., 1978, Stankiewicz, 1979; Von Tunzelmann et al., 2003). This threshold can vary among research fields (Baird, 1986; Kyvik, 1995; Cherchye & Abeele, 2005). Moreover, the threshold can vary due to changes in the internal structure of the group. Distributed leadership, experienced group leaders and a high level of group cohesiveness enables an increased group size (Omta, 1995; van der Weijden et al., 2009; Mehra et al., 2006; Stankiewicz, 1979). In summary, the relationship between size and research performance seems to be influenced by the internal structure of groups and how groups adapt to changes in their internal structure.

The effects described may be influenced by the manner in which groups are dependent on their environment. In larger groups it is easier to organise a variety of different activities related to research, such as teaching or patient care. Large and diverse groups may therefore have an advantage over smaller groups when their size and diversity reduce their dependence on critical resources (Pfeffer & Salancik, 1978). However, research shows that leaders of smaller research groups are more productive in generating societal output, such as giving presentations for non-scientific public, developing clinical guidelines, and writing policy reports (Van der Weijden et al., 2011 – forthcoming). The degree of environmental dependency influences group performance. The outcome depends on the way in which group leaders deal with this influence by using management, leadership and network activities to integrate group action in the organisational context (Gladstein, 1984:513).

2.2 Group management

Academic group leaders have several tools to manage the research process. First, they can enhance performance by offering rewards (Omta & de Leeuw, 1997; Spangenberg et al., 1990). The literature suggests that intangible rewards are generally more effective than material rewards. Material rewards are only useful under limited conditions, for example when researchers feel that their salaries are not growing sufficiently fast or when they believe their salaries to be lower than those of their peers (Gustad, 1960; McKeachie, 1979). Praise and prizes or a pat-on-the-back positively correlate with a group's amount of publications, acquired funding and number of research proposals submitted and granted (Van der Weijden et al., 2008).

The second tool is to provide facilities that enable interactions between researchers. Examples are internal research meetings, retreats and project meetings (e.g. Frederiksen et al., 2004; Mets & Galford, 2009; Van der Weijden, 2007). Communication provides an intellectual stimulus (Pelz and Andrews, 1966) and the consensus is that more communication results in better performance (Allen & Sloan, 1970; Harris & Kaine, 1994; Kretschmer, 1985; Ramsden, 1994; Visart, 1979). Research groups typically perform project-based work of a non-routine and complex nature. Such work requires effective coordination and the integration of ideas. This makes the integrative communication structure of the group highly relevant (Cummings & Cross, 2003; Katz & Tushman, 1979; Tushman & Katz, 1980). An additional finding in the literature is that it is easier to create interactions within longer established research groups (e.g. Martin-Sempere, Garzon-Garcia, & Rey-Rocha, 2008). Moreover, external communication with the organisation may help to foster group performance by organising support from other units and top management in the institute (Gladstein, 1984).

Quality control is the third tool of the group leader. Leaders must find a balance between autonomy and coordination. Autonomy stimulates creativity while coordination is needed to organise interactions and achieve a collective goal (Pelz, 1956; Pelz and Andrews, 1966; Hackett, 2005; Pinau & Levy-Leboyer, 1983; Andrews & Farris, 1967). Coordination and autonomy are interrelated. The overall degree of individual autonomy is bound by a collective research agenda (Leisyte et al., 2008). Among less experienced researchers – juniors as well as newcomers – supervision is more important than autonomy in stimulating performance (Van der Weijden, 2008; Katz 1978a; 1978b). As they gain experience, there is less need for supervision. Some suggest that, in general, researchers need to be free to define and pursue their individual scientific interests to express their creativity (Heinze et al., 2009; Haraszthy & Szanto, 1979).

2.3 Leadership

Leadership can be described as steering researchers with the inspiration and vision of the leader. “Skill on the part of the principal scientist in the care and feeding of all members of the group is critical to its success and productivity” (Sinderman, 1985, p. 22). Goodall (2009) found that research group leaders should not only be good leaders and have good management skills. They should also be top scholars in order to achieve high performance of research universities. Leadership also leads to creativity in scientific research. Leaders provide facilities for addressing new problems or ideas; they provide a protected area for conducting research and complement skills and attributes by selecting new group members (Heinze et al., 2009).

Motivation characterises individual researchers but it can also be considered a characteristic of the research group. Andrews (1979a) found that researchers’ levels of motivation can vary between research groups. Research groups with highly motivated group members have higher performance: their members – group leaders, senior researchers, technical staff – judge their groups to be more productive and innovative.

If motivation is both an individual and a group characteristic, it can be shaped and stimulated by academic leadership, for example by offering group rewards. The academic group leader plays a key role. He or she must show strong commitment to the research of group members, for example by contributing technical competence, showing an interest in projects, keeping informed and participating in the research (Andrews & Farris, 1967). All in all, a strong orientation towards research is said to be beneficial for performance (Blackburn et al., 1978; Fox, 1992; Gottlieb & Keith, 1997; Harris & Kaine, 1994; Porter & Umbach, 2001; Prpic, 1996b; Ramsden, 1994; Shin & Cummings, 2010).

2.4 Network management

Group leaders need to manage both their internal and external relationships. Internal relationships are relevant for coordination, knowledge sharing and collective action. Moreover, a research group is dependent on its environment for gaining access to resources (such as knowledge, information, reputation or experience) and therefore needs to build external relationships (Reagans et al., 2001; 2004; Oh et al., 2004; 2006).

Building internal and external relationships are complementary processes in which group leaders play a crucial role. Having strong internal ties as well as many weak external ties increases team productivity. Mehra et al. (2006) found that a leader's external and internal social network centrality scores were independently related to group performance and to his or her leadership reputation as perceived by their subordinates, peers and supervisors. In other words, a leader plays a crucial role in building the group's social capital[1]:
It is particularly important for smaller groups to invest in their integration into national and international networks. As argued by Von Tunzelmann et al. (2003, p. 15), "it is generally not 'smallness' which is the main problem but 'loneliness'."

Networks can extend to research groups located in the same research institute, in other domestic research institutes or research institutes abroad[2]. Interactions can also take place outside the scientific community with stakeholders in industry, government and other segments of society (e.g. De Jong et al., 2011; Laredo & Mustar, 2000; Omta & De Leeuw, 1997; Spaapen, Dijstelbloem, & Wamelink, 2007). Interactions within or outside academia have different effects. For instance,

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1 "the set of resources made available to a group through members' social relationships within the social structure of the group and in the broader formal and informal structure of the organisation." (Oh et al., 2004; 2006).

2 See Katz & Martin, 1997, for a conceptualisation of research collaboration and their different forms.

science-science relations can stimulate academic careers, while science-industry relations do not (van Rijnsoever et al., 2008). All these kinds of relationships contribute to research output and quality (e.g. Adams et al., 2005; Fox & Mohapatra, 2007; He, Geng, & Campbell-Hunt, 2009; Omta & De Leeuw, 1997).

One particular form of external relationships concerns the international communications with research groups abroad, which are positively related to research performance (e.g. Spangenberg et al., 1990). Interactions with peers, for example by attending conferences and engaging in international collaborations, provide the intellectual exchange that is essential for knowledge creation and the development of new ideas (Melin, 2000; Wagner, 2005). International collaborations have a stronger positive impact on research output compared to domestic and departmental collaborations (Shin & Cummings, 2010; Smeby & Try, 2005). What is the *causal relationship* between collaboration and performance? Collaboration can be required to obtain ideas, skills, expertise and equipment that add to performance (e.g. Bozeman & Corley, 2004). On the other hand, the best performing researchers might attract other researchers who are willing to collaborate (Fox & Mohapatra, 2007). Recently, He et al. (2009) did a causal analysis that suggested that international collaboration predicts future research output rather than the other way around. In general, external connections can be regarded as boundary-spanning; they increase the diversity of external resources and inputs, which is understood to enhance performance (Cardinal, 2001).

2.5 Characteristics of the group leader

Output changes when researchers become older. The relation between age and output most likely has the shape of an inverted U-curve with a peak in performance when the researcher is between his early forties and mid-fifties (Gonzalez-Brambila & Veloso, 2007; Levin & Stephan, 1991; Pelz & Andrews, 1966). This is not to say that the observed drop in individual performance above a certain age hinders group performance. Responsibilities change when researchers become older and more experienced. The intensity of non-research activities increases (Knorr & Mittermeir, 1980). An experienced researcher – like a full professor or chief scientist – can increase the number of successful PhD candidates in the group and is responsible for acquiring material and human resources, for example by attracting competent researchers (Carayol & Matt, 2004; Dundar & Lewis, 1998).

The long professional experience of leaders allows them to shape the knowledge and values of group members, to make good use of professional contacts and networks, and to help colleagues (Dill, 1982). Becoming older and gaining experience also changes a person's style of leading and managing (Oshagbemi, 2004). In earlier studies we have shown that weak-performing group leaders are in fact younger and less experienced. They need time to develop their research group as well as their leadership skills (Verbree et al., forthcoming-a). Conversely, when group leaders get older and enter their final career phase, they start to cut back on several leadership tasks, including their network activity (Verbree et al., forthcoming-b; van Rijnsoever, 2008).

2.6 Environmental conditions

The environment in which a research group is embedded can heavily influence performance (e.g. Cherchye & Abeele, 2005). Numerous studies have shown that movement to a more prestigious research department positively impacts individual research performance (Allison & Long, 1990; Crane, 1965; Keith & Babchuk, 1998; Long, 1978; Long, Allison, & McGinnis, 1979; Long & McGinnis, 1981; Ramsden, 1994; Reskin, 1979). Additionally, within three to six years of moving, researchers conform to the context of their new university, industry or government sector, independent of initial productivity (Long & McGinnis, 1981). Likewise, Dietz and Bozeman (2005) found evidence for their hypothesis that researchers who exhibit a career pattern of relatively uninterrupted job sequences in academia have higher publication productivity than those who had positions in the industry or government.

Performance also varies among research groups because they can have different core goals. Laredo and Mustar (2000) concluded that a group can have one or two main activities, while other activities are complementary. They identified five different types of activities in which groups can be involved: the production of (scientific) certified knowledge; the involvement in education, training activities and embodied knowledge; the contribution to a competitive advantage (innovation processes, e.g. proprietary knowledge); the production of new public goods or services, and the participation in public debate.

The focus on a particular main activity has strong implications for research performance (Prins, 1990). On a group level, studies have shown that departments with a strong emphasis on research have higher publication productivity, while departments that emphasise practitioner training or health care duties generally have lower research productivity (Baird, 1986; Perkoff, 1985). In an analysis of individual research performance, Van der Weijden et al. (2008) found that in research groups with a focus on applied research (i.e. delivering useful improvements for practice), PhD students receive fewer awards and prizes. In contrast, in research groups with a focus on innovative research (i.e. being original) or quality control (i.e. having a clear and detailed work plan), PhD students have a stronger international orientation, and tend to do part of their research abroad.

Performance standards are not only set by research institutes, but also by the scientific community. Scientific disciplines have highly different publication and citation patterns, which means that differences in the number of publications and citations do not reflect quality differences among disciplines (e.g. Baird, 1986; Crane, 1972; Martin & Irvine, 1983; Neuhaus & Daniel, 2009; Schubert & Braun, 1996; Van Raan, 2004; Whitley, 2000). As a result, performance can only be evaluated in an appropriate context (Bornmann, Mutz, Neuhaus, & Daniel, 2008; Van der Meulen, 1995).

Finally, research groups are embedded in a national science system. The organisation and performance of national science systems differs (Bonaccorsi, 2005; Dawson, Van Steen, & Van der Meulen, 2009). These differences relate to agenda setting, funding conditions, evaluation procedures, academic career policy, governance and regulations, and so on. For instance, science policy aims to stimulate collaboration among research groups by means of thematic funding programmes, e.g., in the field of genomics (Archambault et al., 2003; Braam, 2008). There are few studies about the influence of specific conditions in the science system on research practices and performance. A recent study of Verbree et al. (forthcoming-b) does show that changes in the science system influence leadership practices.

3. Data and methods

The data were collected in two surveys among biomedical and health research group leaders in the Netherlands. Questionnaires were sent out in 2002 and 2007 to group leaders employed at University Medical Centres (UMCs) or (bio) medical public research institutes (van der Weijden et al., 2008; van der Weijden et al., 2009). Names and addresses of group leaders (mainly chaired professors) were obtained from administrative records. In 2002, 137 Dutch academic group leaders returned completed questionnaires by post with an overall response rate of 38%. In 2007, 188 group leaders returned a completed questionnaire with an overall response rate of 27%[3]. We used the tailored design method to maximise the response rate (Dillman 2000). We have combined both data sets to increase our sample size to a total of 325 respondents.

Five years may seem a short period, but it is long enough for the science system to change. For example, the implementation of so-called 'excellence programmes' can raise expectations about performance levels; assessment criteria for funding are extended with societal relevance and policies encourage the setting up of inter-institutional collaborations. Such changes can influence academic leadership practices. We know that there is a difference in behaviour between the older and younger generations of group leaders that can be traced back to changes in the science system (Verbree et al., forthcoming-b)[4]. However,

3 Non-response analysis shows that the respondents can be regarded as a representative sample of the Dutch biomedical and health research groups. The respondents were evenly distributed among the various research institutions and the sub-disciplines. Performance levels between respondents and non-respondents did not significantly differ.

4 Generation was defined by the year of PhD; the older generation obtained their PhD before 1988 and the younger generation after 1987. The year 1988 was chosen, since this was the end of a time period with many changes in the Dutch science system (for more detail see Verbree et al. 2010)

we do not know whether changes in the science system also influence the relationship between academic leadership and performance. Therefore, we use the year in which group leaders filled in their questionnaire (2002 or 2007) as a proxy for changes in the science system (table 1)[5].

Group leaders were asked to classify the research of their groups. They could select one or more specialisations from a list of 28 (sub)disciplines in health research (e.g., public health, immunology, oncology; for an overview see Van der Weijden, 2007, p. 202). Using this information, we classified the research groups in three categories, distinguished by relation to patients:

- Pre-clinical research is basic (life science) research and is usually laboratory-based (for example, immunology, micro-biology and neurosciences).
- Clinical research is application-oriented and involves direct patient contact (for example, dermatology, nephrology and psychiatry).
- Para-clinical research often has a social sciences perspective and researchers have an advisory relationship with patients (for example, social medicine, public health and medical psychology).

The survey was used to collect information on a wide range of characteristics and activities of academic leadership, namely resource strategy, internal leadership and management, and network management. Survey questions also covered the characteristics of the leader and environmental conditions.

Some of the survey items produced very low variance among the answer categories; a high proportion of group leaders indicated that they perform a specific activity or that they consider an activity highly important. Where variance was low, we have either constructed a dichotomous dummy variable or we have excluded the item from the analysis. The measurement and descriptive statistics of all variables included in our models are presented in table 1.

5 Due to missing data in 2007, we cannot use generation as a proxy for changes in the science system.

Table 1 Description and descriptive statistics of the independent variables

		Descriptive statistics				
Variables	**Description**	**Mean**	**Median**	**Standard deviation**	**Minimum**	**Maximum**
Resource strategy						
Scientific staff	Number of scientific staff (FTE)	12.40	11.0	6.36	2.00	36.00
Staff composition	Percentage of total scientific staff: – Professors – Senior staff – PhDs – Other scientific staff	 11.10 32.58 49.62 6.70	 10.00 31.25 50.00 0	 7.09 15.33 16.19 10.91	 0 0 0 0	 33.00 80.00 91.00 67.00
Funding sources	Percentage of total funding from: – Institutional funding – Competitive funding – Contract funding – Charity funding – European funding – -Other funding sources	 36.18 19.15 14.60 19.04 5.95 5.08	 30.00 20.00 10.00 11.80 0 0	 23.77 17.56 18.94 20.86 12.11 11.14	 0 0 0 0 0 0	 100 80 90 100 85 90
Concentration of funding	Measure for the dependence on different funding sources equal to the coefficient of variation (σ/μ) where maximum dependence on one source gives a score of 2.45 (high concentration) and a perfectly equal distribution among the six sources gives a score of 0 (low concentration)	1.30	1.24	0.41	0.24	2.45
Management						
Intangible reward	Dummy variable measuring whether or not leaders provide intangible rewards (i.e. special honours)				yes: 55.4%	no: 43.7%
Communication	Measure for the intensity of interactions where 1 is never or occasionally; 2 is at least once a year; 3 is at least once in six months; 4 is at least once a month; 5 is at least once a week: – Feedback meetings (to discuss research projects, concept papers, or research proposals) – Literature meetings – Project meetings: dummy variable where 1 indicates project meetings at least once a week and 0 indicates project meetings less than once a week	 3.35 3.63	 3.33 4.00	 0.60 1.28	 1.67 1.00 1: 49.2%	 5.00 5.00 0: 50.2%
Quality control	Measure for the degree of control versus autonomy: – "Researchers are free whether or not to implement comments of internal pre-evaluations in research proposals", 1 is totally disagree; 5 is totally agree. – Percentage of considerations[6] that are valued as important in setting the research agenda: 100 means that a group leader values all 14 considerations as important, which indicates that researchers have more freedom to fit their individual goals within the research agenda.	 2.62 49.51	 2.00 50.0	 1.07 17.22	 1.00 0	 5.00 100

		Descriptive statistics				
Variables	**Description**	**Mean**	**Median**	**Standard deviation**	**Minimum**	**Maximum**
Leadership						
Research involvement	Measure for the degree of research involvement of the leader where 1 is totally disagree and 5 is totally agree:					
	– Role as co-worker versus manager: "I feel more like a researcher than like a manager"	3.43	4.00	1.01	1.00	5.00
	– High-skilled leader: "My staff think of me as a highly skilled scientist"	3.64	4.00	0.85	1.00	5.00
	– First author: "I regularly publish as first author in international journals"	2.88	3.00	1.22	1.00	5.00
Quality attitude	Measure for the importance of quality control for acquiring funding where 1 is totally disagree and 5 is totally agree: "Internal pre-assessments of research proposals generally results in a higher chance of receiving external funding"	3.94	4.00	0.896	1.00	5.00
Time allocation	Percentages of time spent on[7]:					
	– research	44.98	42.95	16.13	11.00	87.40
	– education	13.44	11.00	10.22	0	55.50
	– group management	16.85	16.70	8.40	0	52.00
	– network management	8.86	6.20	8.15	0	52.00
Network management						
Network activities	Intensity of network activities in days per year where network activities are the sum of days spent on: – lectures – attending conferences – participation in editorial boards – participation in assessment committees	41.23	40.00	20.14	10	130
Characteristics of the leader						
Age	Age of leader at the time of the survey (in 2002 and 2007 respectively)	53.07	54.00	6.73	36.00	68.00
Experience	Years of experience as group leader in the current research group	11.99	10.50	7.05	0.50	37.00
Environmental conditions						
Activity profile	Dummy variable that measures whether research groups have a patient care duty or focus only on research activities				patient: 56.6%	research: 43.1%
Scientific discipline	Dummy variables representing:					
	– Para-clinical groups				11.7%	
	– Pre-clinical groups				45.5%	
	– Clinical groups				42.8%	
Changes in the science system	Dummy variable that measures whether leaders filled in the questionnaire in 2002 or 2007, which refers to the specific time period in which leaders managed their group				2002: 42.2%	2007: 57.8%

6 Examples of considerations to set the research agenda are: a possibility to explore new research lines; application-oriented research, and to create visibility in top journals.

7 Total sum of percentages of work time is not 100%, because some group leaders also spent time on patient care.

We use four different aspects of academic performance as dependent variables in our models (table 2). The total publication count of the group leader represents the amount of knowledge produced by the group. The total citation count of the group leader's publications reflects the visibility of the leader's group. The third indicator is the number of publications per group member, which is a measure for productivity and controls the output for group size. The final indicator is the number of citations per publication, which is generally considered a proxy for quality or creativity, and reflects the relative visibility of an average group publication. When a group attracts a lot of citations for each publication, they work at the research front and publish innovative ideas that their colleagues consider interesting (Wouters, 1999).

Correlation among the four indicators is moderately strong (table 3). This indicates that each indicator has a different meaning (e.g. King, 1987, Martin, 1996, Schubert & Braun, 1996, Tijssen, 2003). The moderately strong relationship also shows that a research group can score very high on one or a few indicators but low on the others. Differences in publication strategies can result in different performance profiles (Moed, 2000). In other words, research groups can aim for different goals, use different strategies to reach them and perform according to different performance indicators. We want to understand how academic leadership contributes to the achievement of different research goals as represented by the four performance indicators. This is why we use multiple indicators for performance.

Table 2 Descriptive statistics of the dependent variables

Dependent variables	Mean	Median	S.D.
Publications	27.28	22.00	23.01
Citations	262.88	171.00	289.73
Productivity	2.52	1.95	2.23
Citations per publication	8.18	6.18	1.95

Table 3 Spearman's rho for performance indicators

		Citations	Productivity	Quality
Publications	Spearman's rho Sig. (2-tailed) N	0.795*** 0.000 320	0.769*** 0.000 312	0.239*** 0.000 320
Citations	Spearman's rho Sig. (2-tailed) N		0.643*** 0.000 310	0.719*** 0.000 320
Productivity	Spearman's rho Sig. (2-tailed) N			0.231*** 0.000 310

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Data about the academic performance of the 325 research groups were collected from three databases: PubMed, the Web of Knowledge and the Dutch Research Database. PubMed (the US National Library of Medicine's search service) was used to obtain the publication counts of research groups over a three-year period, respectively 1999-2001 and 2004-2006. Thomson Reuters Web of Knowledge was used to obtain publication counts for the same period. We collected publication counts from both databases by searching for the group leaders' surname and first two initials. In addition, we collected citation counts and the number of citations per publication from the Web of Knowledge for the publications published in the specific three-year period with a citation span of respectively 1999-May 2003 and 2004-May 2008. Productivity was calculated by normalising the number of publications by group size. The two databases sometimes gave dissimilar publication counts for the same research group, caused either by errors in the database or by a difference in content. We used the lower publication count of the two databases to minimise errors. The 'Nederlandse Onderzoeks Databank' (Dutch Research Database) was used to check whether research group leaders were affiliated to more than one organisation.
When they were, we included their publications from both affiliations.

The four indicators of performance that represent our dependent variables can all be described as count data. They refer to the number of times publications and citations occur, the number of discrete papers each individual group member produces (productivity) and the number of times each individual publication is cited, or citations per publication (Cameron & Trivedi, 1998). Our data are characterised by overdispersion: the sample variances exceed the sample means (table 2). We therefore used negative binomial regressions to test our models (Cameron & Trivedi, 1998; Gardner et al., 1995; Allison, 1980).

4. Results

The main results of the regression models are presented in tables 4-7. For each indicator of performance, we first test individual components of our conceptual model. Model 1 includes only resource strategy variables; the inputs of a research group. Model 2 includes only management and leadership variables, which capture the process. We then combine inputs and processes in model 3. Model 4 measures the complete conceptual model by incorporating the influence of environmental conditions and the characteristics of the leader. At each stage, we have tested all possible variables in our dataset (e.g. all resource strategy variables in model 1). Variables that were not significantly associated to the dependent variable were excluded from subsequent models.

4.1 Publications

Four variables emerge from the regression models for the total number of publications. First, it seems that 'bigger is better': the more scientific staff groups have, the more output they produce. The effect of group size is, however, modest (1.034 publications for each additional researcher). Another aspect of resource strategy is far more important. Groups with a higher percentage of PhDs produce significantly more output (2.641 for each additional percentage share in group members). Only two management and leadership variables make it into the final model. There is a modest but significant positive relation between the intensity of network activities (in days per year) and the total number of publications. Group leaders with a stronger perception of themselves as high-skilled scientists also produce more publications. Disciplinary differences are obvious: total output of para-clinical research groups is 48% lower than that of other groups.

4.2 Citations

The total number of citations serves as a proxy for the visibility of the group. Six variables have a significant association with total citations. Bigger is once again better. Every additional member of staff makes the group more visible. The effect of size is remarkably similar to that for total publications (1.028 citations for each additional researcher). Visibility is enhanced particularly by the presence of relatively larger numbers of PhDs (6.212) and senior researchers (4.166). The results for the concentration of funding show a significant negative relation with total citations. This suggests that stronger dependence on fewer funding sources lowers a group's visibility. The effects of resource strategy coincide with the effects of two variables that measure leadership and management. A leader who considers himself a researcher rather than a manager adds to the group's visibility. Similarly, network activities appear to raise visibility.

A surprising result is that quality control variables do not show up among the significant coefficients, even though citations are often equated with quality.

It is only in the total number of citations that the age of the group leader makes a difference. There is a modest but significant negative relation between age and total citations. Here, as in the other performance indicators, para-clinical research groups behave significantly different. The total number of citations received by para-clinical research groups is 65% lower than that of other groups.

4.3 Productivity

Productivity is the total number of publications normalised for group size. The results mirror those of our first performance indicator, the total number of publications. There is clear evidence of diminishing marginal returns to labour: each additional member of staff lowers the output per researcher. The effect is significant but modest. A higher percentage of PhDs has a positive impact on group productivity, which explains the effect of this variable on total group output. Among the management and leadership variables, only network activities make a difference. There is a significant positive association between time spent on network activities and group productivity. Time spent on education has a negative effect in models 2 and 3. The same can be seen in the results for the total number of citations. This appears to suggest that group leaders who spend more time on education have less time to be involved in research or to support external visibility. However, the effect disappears when we observe the difference between para-clinical and other groups. Para-clinical groups have significantly lower productivity than other groups.

4.4 Citations per publication

The number of citations per publication is often considered as a proxy for scientific quality. The size and composition of groups is not associated with the number of citations per publication. We do, however, see a strong negative effect on the concentration of funding. Groups that depend on fewer sources of funding receive fewer citations per publication. An additional indication that quality matters is that the percentage of funding acquired from charities has a modest positive effect. The selection criteria of charities are known to lean heavily towards the quality of proposals rather than towards social relevance (Van der Weijden et al., forthcoming). The direction of causality is, however, not given. As a quality indicator, citations per publication also provide access to specific funding sources, such as charities. Again, there is no significant association between citations per publication and variables that measure specific quality control activities. However, citations per publication are higher for research group leaders who emphasise the importance of quality. Also, the more time research group leaders spend on research, the more citations per publication their group output gets. Para-clinical research groups receive 56% fewer citations per publication than other groups. Clinical research groups also structurally receive fewer citations per publication (-32%).

Table 4 Output (publications)

Variables	**Model 1**			**Model 2**			**Model 3**			**Model 4**		
	Unstandardised coefficients			Unstandardised coefficients			Unstandardised coefficients			Unstandardised coefficients		
	B	S.E.	Exp(*ß*)	*B*	S.E.	Exp(*ß*)	*B*	S.E.	Exp(*ß*)	*B*	S.E.	Exp(*ß*)
Resource strategy												
Scientific staff	0.036***	0.010	1.037				0.031***	0.010	1.031	0.033***	0.010	1.034
PhDs	1.167***	0.374	3.213				1.198***	0.377	3.315	0.971**	0.379	2.641
Senior staff												
Other scientific staff												
Concentration of funding												
Institutional funding												
Contract funding												
Charity funding												
Leadership & mgt												
Intangible reward				0.213*	0.119	0.808						
Project meetings												
Literature meetings												
High-skilled leader				0.164**	0.065	1.178	0.123*	0.067	1.131	0.129*	0.067	1.138
Co-worker												
Quality attitude												
Time on education												
Time on research												
Time on network mgt												
Network activities				0.010***	0.003	1.011	0.010***	0.003	1.010	0.009***	0.003	1.009
Characteristics leader												
Age												
Environmental conditions												
Para-clinical										-0.662***	0.190	0.516
Clinical												
Constant	**2.239**			**2.311**			**1.383**			**1.554**		
Chi-square	**28.669**			**27.859**			**46.332**			**56.934**		
Valid cases	**312**			**311**			**303**			**303**		

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Note: Unstandardised coefficients – *ß* – refer to the dependent variable (natural log of citations per publication), but Exp(*ß*) refers directly to citations per publication.

* p < 0.10; ** p < 0.05; *** p < 0.01.

Table 5 Visibility (citations)

Variables	Model 1			Model 2			Model 3			Model 4		
	Unstandardised coefficients			Unstandardised coefficients			Unstandardised coefficients			Unstandardised coefficients		
	B	S.E.	Exp(*ß*)	*B*	S.E.	Exp(*ß*)	*B*	S.E.	Exp(*ß*)	*B*	S.E.	Exp(*ß*)
Resource strategy												
Scientific staff	0.025**	0.010	1.026				0.021**	0.011	1.021	0.028***	0.010	1.028
PhDs	2.322***	0.552	10.199				2.402***	0.540	11.048	1.827***	0.555	6.212
Senior staff	1.943***	0.592	6.982				1.667***	0.577	5.298	1.427**	0.587	4.166
Other scientific staff												
Concentration of funding	-0.333*	0.181	0.717				-0.373**	0.159	0.689	-0.425***	0.161	0.653
Institutional funding	-0.006**	0.003	0.994									
Contract funding	-0.006*	0.003	0.994									
Charity funding												
Leadership & mgt												
Intangible reward				0.350***	0.119	1.419	0.214*	0.126	1.239			
Project meetings												
Literature meetings												
High-skilled leader				0.218***	0.069	1.243						
Co-worker				0.106*	0.059	1.112	0.171***	0.060	1.186	0.178***	0.060	1.195
Quality attitude												
Time on education				-0.021***	0.006	0.979	-0.017***	0.006	0.983			
Time on research												
Time on network mgt												
Network activities				0.011***	0.003	1.011	0.010***	0.003	1.010	0.010***	0.003	1.010
Characteristics leader												
Age										-0.21**	0.010	0.980
Environmental conditions												
Para-clinical										-1.052***	0.196	0.349
Clinical												
Constant	**4.140**			**3.275**			**2.976**			**4.389**		
Chi-square	**52.928**			**68.146**			**89.246**			**107.421**		
Valid cases	**295**			**309**			**289**			**292**		

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Note: Unstandardised coefficients – *ß* – refer to the dependent variable (natural log of citations per publication), but Exp(*ß*) refers directly to citations per publication.

* p < 0.10; ** p < 0.05; *** p < 0.01.

Table 6 Productivity (publications per person)

Variables	**Model 1**			**Model 2**			**Model 3**			**Model 4**		
	Unstandardised coefficients			Unstandardised coefficients			Unstandardised coefficients			Unstandardised coefficients		
	B	S.E.	Exp(*ß*)	*B*	S.E.	Exp(*ß*)	*B*	S.E.	Exp(*ß*)	*B*	S.E.	Exp(*ß*)
Resource strategy												
Scientific staff	-0.042***	0.009	0.959				-0.045***	0.009	0.956	-0.044***	0.009	0.957
PhDs	1.134***	0.362	3.107				1.339***	0.361	3.817	0.943***	0.359	2.567
Senior staff												
Other scientific staff												
Concentration of funding												
Institutional funding												
Contract funding												
Charity funding												
Leadership & mgt												
Intangible reward												
Project meetings												
Literature meetings												
High-skilled leader												
Co-worker				0.150***	0.057	1.162						
Quality attitude												
Time on education				-0.009*	0.006	0.991	-0.011**	0.006	0.989			
Time on research												
Time on network mgt												
Network activities				0.005**	0.003	1.005	0.008***	0.003	1.008	0.008***	0.003	1.008
Characteristics leader												
Age												
Environmental conditions												
Para-clinical										-0.662***	0.182	0.516
Clinical												
Constant	**5.444**			**4.871**			**5.146**			**5.289**		
Chi-square	**28.312**			**15.391**			**43.046**			**49.642**		
Valid cases	**312**			**309**			**310**			**311**		

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Note: Unstandardised coefficients – *ß* – refer to the dependent variable (natural log of citations per publication), but Exp(*ß*) refers directly to citations per publication.

* p < 0.10; ** p < 0.05; *** p < 0.01.

Table 7 Quality (citations per publication)

Variables	Model 1			Model 2			Model 3			Model 4		
	Unstandardised coefficients			Unstandardised coefficients			Unstandardised coefficients			Unstandardised coefficients		
	B	S.E.	Exp(*ß*)	*B*	S.E.	Exp(*ß*)	*B*	S.E.	Exp(*ß*)	*B*	S.E.	Exp(*ß*)
Resource strategy												
Scientific staff												
PhDs												
Senior staff												
Other scientific staff	-1.657***	0.583	0.191				-1.335**	0.619	0.263			
Concentration of funding	-0.434***	0.140	0.648				-0.320**	0.147	0.726	-0.300**	0.145	0.741
Institutional funding												
Contract funding												
Charity funding	0.009***	0.003	1.009				0.005*	0.003	1.005	0.006**	0.003	1.006
Leadership & mgt												
Intangible reward												
Project meetings				0.251**	0.119	1.285						
Literature meetings				0.102**	0.046	1.108	0.089*	0.050	1.093			
High-skilled leader												
Co-worker												
Quality attitude				0.123**	0.061	1.131	0.103*	0.062	1.108	0.107*	0.062	1.113
Time on education												
Time on research				0.011***	0.004	1.011	0.007*	0.004	1.007	0.008**	0.004	1.008
Time on network mgt				0.013*	0.007	1.013						
Network activities												
Characteristics leader												
Age												
Environmental conditions												
Para-clinical										-0.827***	0.198	0.437
Clinical										-0.387***	0.130	0.679
Constant	**7.182**			**5.044**			**5.995**			**6.380**		
Chi-square	**30.254**			**40.153**			**41.419**			**55.245**		
Valid cases	**295**			**303**			**282**			**290**		

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Note: Unstandardised coefficients – *ß* – refer to the dependent variable (natural log of citations per publication), but Exp(*ß*) refers directly to citations per publication.

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

5. Analysis

In this section we follow the structure of our conceptual model and look across the four performance indicators to extract higher-level conclusions.

5.1 Inputs

Increasing group size is sufficient for increasing gross performance (the total number of publications or citations). Bigger is not better for productivity or for quality. There is no association between group size and citations per publication. Productivity declines for every additional group member. This decline suggests the existence of diminishing marginal returns to labour in medical research.

Group composition has considerable impact. A higher percentage of PhDs translates into higher output, more citations and higher productivity. It has no effect on quality. A higher percentage share of senior researchers also produces more citations. A possible explanation is that seniors have higher reputations and international connections, and therefore their work attracts more citations. More seniors equals higher visibility.

Performance is closely associated with the diversity of sources from which groups collect funding for their research. Lower variation in funding sources decreases visibility (the total number of citations) and lowers quality (citations per publication). Apparently, it is best not to be dependent on a single source. Yet, the fact that there is a relation says nothing about the direction of causality. The effects on visibility and quality can work both ways.

A higher number of citations per publication is a proxy for quality and high-perceived quality may help group leaders acquire new funds from different sources. This assumes that citations are used in the assessment of funding proposals. If they are, an established reputation (or past performance) raises the likelihood of acquiring funding for the following project, an effect otherwise known as the Matthew effect.

The inverse argument is that group leaders who are active in different funding instruments make their work visible in different (scientific) communities and attract citations from a wider audience. A group that depends on a single source is bound by the specific requirements of that source and is less able to adapt its agenda to emerging hot issues, which thus lowers the probability of citation. Groups that are active in several funding instruments are more flexible.

5.2 Process

The most surprising result is that actual management activities – such as quality control, group meetings and rewards – show no strong association in the full regression models. A research group leader affects his group's performance in a more indirect manner, namely through his attitude towards research and the quality of the output, and through his external networking activities.

External networking activities significantly increase performance. They contribute to total output, total citations and productivity. A possible explanation is that networking in committees, editorial boards, conferences and so on, increases the likelihood that submitted papers will be accepted (possibly because it provides a better understanding of procedures and priorities), that publications will find their way to the right communities of interested peers, and that papers will be cited. Through external networking – at conferences, in editorial boards and in committees – research group leaders increase the likelihood that papers produced by their researchers will be accepted for publication. If a larger proportion of publications is accepted for publication, productivity goes up. Networking may be how the leader 'sells' the work of his group to the outside world.

It appears to be more important what a leader thinks or believes – his or her attitude, including self-evaluation – than what he or she does. Actual management activities make no difference. For example, literature suggests that intangible rewards are more effective than tangible rewards (Van der Weijden et al., 2008). However, in a multivariate analysis, when all elements of management, leadership and resources are taken into account, the effect of rewards disappears. An analysis of high-performing groups (Verbree et al., 2012 forthcoming-a), based on the same survey data, revealed that management and leadership are closely interrelated: being a good leader involves managerial tasks. However, management activities as such – e.g. giving rewards or organising regular meetings – have no additional effect on performance.

While management activities have no additional effect, the attitude of the leader makes a big difference. A self-evaluation of being a high-skilled scientist raises output. A leader who sees himself as a researcher rather than a manager raises the total number of citations, thus adding to the group's visibility, presumably by raising the quality of the work. A strong positive attitude towards quality (quality-mindedness) raises citations per publication. Through their impact on achieved quality, research group leaders increase the visibility and reputation of their groups and may increase the probability and speed of the acceptance of submitted publications.

5.3 Environmental conditions and characteristics of the leader

Some determinants of performance are beyond the control of research groups leaders. They are locked into a particular discipline with its own publication and citation culture; they have a fixed activity profile, e.g., a combination of clinical research and patient care, and they have certain given characteristics, such as age and experience. The characteristics of the research group leader only matter for total citations that decline at an older age. This might be a life cycle effect. As leaders approach the end of their careers, they cut back on some network activities (Verbree et al., 2012 forthcoming-b), which lowers the number of citations. Yet, the most prominent environmental condition is scientific discipline, which reflects disciplinary differences in the publication and citation culture.

Pre-clinical groups receive significantly more citations per publication. Even more prominent, however, is the difference between para-clinical and other research groups.

Para-clinical research groups differ significantly from clinical and pre-clinical research groups. They have lower performance on every indicator. Their leaders also behave differently. Some of the effects found for management activities – such as literature discussion meetings, intangible rewards and time spent on education – disappeared when the regression models were controlled for the difference between para-clinical and other groups. These effects only appeared to show up because this is precisely where leaders of para-clinical groups differ. They are less prone to giving intangible rewards, spend more time on education, have a higher percentage of other scientific staff and organise fewer literature meetings than leaders of pre-clinical and clinical groups (table 8). In other words, the management variables correlate with the difference between para-clinical and other groups (as measured in a dummy variable) rather than with performance. The environment in which research groups are located affects both the activities of group leaders and the performance of the group.

Table 8 Academic leadership by scientific discipline

	Para-clinical	Clinical and Pre-clinical	Asymptotic significance (2-tailed)
Variable	Median, Mean (n)		
Other scientific staff [a]	14.29 13.41 (37)	0.00 5.80 (284)	0.001***
Intangible reward: yes [b]	36.8% (38)	58.5% (284)	0.012**
Literature meetings [a]	3.00 2.79 (38)	4.00 3.74 (284)	0.000***
Time on education [a]	17.50 20.39 (38)	10.00 12.52 (286)	0.000***

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a Note: Mann-Whitney tests, *p < 0.10, ** p < 0.05, ***p < 0.01
b Note: Chi-Square test, *p < 0.10, ** p < 0.05, ***p < 0.01

Finally, we found no effect of changes in the science system. The time (i.e. 2002 or 2007) a position as group leader was occupied was used as a proxy for changes in the science system. The behaviour of group leaders may have changed between 2002 and 2007 in response to changes such as the increased demand for societal quality (Hessels, 2010; van der Weijden et al., 2011 – forthcoming). However, the time group leaders were socialised in the science system – i.e.

their education as researcher to obtain their PhD – is a far better proxy for measuring changes in the science system (Verbree et al., 2012 forthcoming-b). Unfortunately, we were not able to use PhD cohorts due to missing data in our 2007 sample but we will certainly use this in a follow-up study.

6. Conclusions and discussion

Although the literature endorses the positive contributions of academic leadership to research performance, the specific effects of various leadership practices on performance have not been disentangled yet. Based on the literature and existing theories about group effectiveness (Gladstein, 1984) and environmental conditions (Pfeffer & Salancik, 1978), we have developed a model which aims to explain how various components of academic leadership influence performance, controlling for conditional factors. Our approach enables us to show which specific academic leadership practices influence the four performance goals of achieving high output, securing high visibility, reaching high productivity and attaining high quality.

Each performance indicator calls for a specific strategy. The strongest instruments are the proportion of PhDs and time spent on network activities. The higher the proportion of PhDs and the more time a leader spends on network activities, the more publications and citations a group accumulates and the higher productivity will be. These instruments do not work for quality. The best way to raise the number of citations per publications is to have a quality-minded leader who spends a relatively large amount of time on research. High visibility requires leaders who perceive themselves to be more like researchers than like managers, as well as a higher percentage of senior researchers. High output calls for leaders who consider themselves high-skilled scientists. The same holds for inputs. Increasing group size raises output and visibility but lowers the average productivity as a result of diminishing marginal returns to labour. In short, different performance goals call for different strategies. Finally, diversity in funding sources is beneficial to visibility (total citations) and quality (citations per publication). Through diversity of funding, the research portfolio of a group may become more varied, implying larger audiences and the probability of more citations.

As a consequence, the research goals that a group aims to achieve suggest the strategy it needs to follow. This confirms what we found in our earlier studies: leaders apply different strategies depending on their research goals, and outstanding performance on multiple performance indicators requires an all-round academic leadership approach (van der Weijden et al., 2008; Verbree et al., 2012 forthcoming-a).

Increasing emphasis on quantitative performance indicators is raising the pressure to ‘publish or perish’ (Hessels, 2010). A stronger emphasis on rewarding publication volume will have serious consequences for the scores on other performance indicators. Research groups that adjust to higher publication norms will change their strategy, possibly to the detriment of their visibility, productivity and quality, as the Australian case showed (Butler 2003). Only a small selection of excellent research groups have such unique qualities that they perform well on any sort of indicator (Verbree et al., 2012 forthcoming-a).

Surprisingly, we found that performance is not affected by management practices. Rewards, communication and quality control do not seem to matter. That does not mean that management is pointless. All research group leaders carry out management activities; they cannot do without them. But they have no additional effect on performance. Management and leadership are strongly correlated. Leaders of high-performing research groups are highly dedicated to management and leadership tasks (Verbree et al., 2012-forthcoming-a).

Far more prominent in achieving high performance is the self-evaluation of the leader. The leader sets an example to which group members respond by aspiring specific research goals (Goodall, 2009; Heinze et al., 2009). The leader is dominant in deciding how the group responds to environmental demands (Gornitzka, 1999; Pfeffer & Salancik, 1978; Reale & Seeber, 2011). A resource-based strategy strengthens the autonomy of group leaders. Our results show that research groups that are less dependent on one or a few funding sources are more visible and produce higher-quality output. Diversity in funding sources decreases the decision authority of the research institute (Sanz-Menéndez & Crus-Castro, 2003). When groups become less dependent on institutional funding, research institutes lose their ability to influence research groups top-down. The most the institute can probably do is select group leaders (Strandholm, Kumar & Subramanian, 2004). As a result, leaders of research groups become entrepreneurs, autonomous within their organisational environment, by acquiring their funds from a diverse set of sources (Etkowitz, 1998; Etkowitz & Leydesdorff, 2000; Gulbrandsen & Smeby, 2005; Hessels, 2010). How does this change the relationship between group leaders and higher-level management? Is synergy between the goals of the research group and the institute still possible? We will capture this topic in further research[8].

The characteristics of the leader do not seem to make a difference. We only found a minor effect of the leader's age on visibility. This may be, however, because we did not include the dashed arrows of our model (figure 1) in the analysis. The characteristics of the leader are more likely to influence performance indirectly – via academic leadership – than directly. Less experienced group leaders have fewer network activities and smaller groups which subsequently has a downward effect on performance (Verbree et al., 2012-forthcoming-a). The same is probably true for resource strategy: the set of resources determines a leader's practices. For instance, a bigger research group most likely requires more coordinating management activities. This issue, too, will be addressed in future research.

8 Recently, we sent out a third questionnaire that covers this topic.

Of the environmental conditions, only *discipline* has an effect on performance. Para-clinical groups have significantly lower performance and their leaders appear to behave differently. However, this may not so much be an effect as simply the fact that publication and citation behaviour as well as group missions systematically differ between disciplines. This suggests that different disciplinary environments require other leadership strategies and other research goals (Reale & Seeber, 2011). Sample size did not enable us to do the analysis on the level of the three disciplines individually. However, we aim to do so using a next survey. We recommended extending this study to other scientific disciplines to investigate how non-medical disciplines and activity profiles relate to performance.

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5 From Bench to Bedside: the Societal Orientation of Research Leaders

The case of biomedical and health research in the Netherlands

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Abstract

The societal impact of research is increasingly important in science policy. However, not much is empirically known about how societal impact is generated. This paper aims at contributing to a better empirical understanding of generating societal impact.

We examine the opinions of research leaders about the increased emphasis on societal impact, i.e. does it influence their research agenda, communication with stakeholders, and knowledge dissemination to stakeholders? Furthermore, we investigate the diversity and quantity of their societal output. We also study whether societal and scholarly productivity are positively or negatively related. Finally, we investigate which managerial and organisational factors (e.g. experience of the principal investigator, group size and funding) influence societal output.

The study is based on a survey among principal investigators in biomedical and health science in the Netherlands. Within this domain we distinguish between different types of research: i) para-clinical groups with an advisory relationship with patients and mostly a social sciences research perspective; ii) pre-clinical groups with little or no patient contact and laboratory-based fundamental research, and iii) clinical groups with direct patient contact and an application-oriented type of research. In this way the study covers a wide variety of research types.

Our study shows that research leaders have, on average, a rather positive opinion about the societal orientation of their research. The study also indicates a wide variety of societal oriented output. Furthermore, societal output and scientific output are unrelated, suggesting that stimulating social relevance

requires specific organisational and contextual interventions, separate from interventions that stimulate scientific quality. We end the paper with a discussion on which incentives may be needed to stimulate societal impact.

Keywords
Societal output, research groups, research funding, communication, incentive structures, science system

1. Introduction
Academic science is currently shaped by pressure towards academic excellence and by aspirations towards knowledge transfer and research activities beyond academia. Over the years, discussions about the societal value of academic science have become more extensive – and research funding agencies increasingly ask for the explicit societal relevance of proposed research. Within science policy studies, a series of concepts has been introduced to theorise these changes in the science-society relationship: 'mode 2 knowledge production' (Gibbons et al., 1994), 'triple helix of university-government-industry relations' (Etzkowitz & Leydesdorff, 1995), 'knowledge society' (Stehr, 1994), 'Pasteur's quadrant' (Stokes, 1997), 'third mission activities' (e.g. Pålsson, Göransson, & Brundenius, 2009; Göransson, Maharajh, & Smock, 2009; Krücken, Meijer, & Müller, 2009; Gregersen, Linde, & Rasmussen, 2009; Ca, 2009) and 'academic entrepreneurial cultures' (e.g. Göktepe-Húlten, 2008). Society can potentially benefit from academic research in various ways, ranging from contributions to culture and education to specific insights or products with economic or socio-political value.

Despite the stronger emphasis on societal impact in science policy and the numerous theoretical contributions, empirical studies on the generation of societal impact are scarce. In this paper, our aim is to contribute empirical evidence on how the quest for societal relevance is taken up by principal investigators[1]. We investigate five research questions: i) what is the attitude of principal investigators towards societal relevance; ii) what type of societal (meaning non-scholarly) output do they produce, and iii) is societal relevance reflected in scientific output? Next, we address two highly debated issues that might explain research leaders' opinions about societal relevance and their societal performance. First, it is often argued that academic excellence automatically produces societal relevance: the latter does not need to be encouraged. Other argue that a focus on societal relevance endangers academic research. Such a focus may hinder fundamental research due to a premature search for applications. The question is therefore iv) how societal and scholarly productivity are related. Second, policy makers are looking for ways to encourage socially relevant research. The last question is v) how the

1 PIs are defined as research group leaders in this study. The research group is the smallest unit at the micro level of knowledge production.

management and organisation of research, such as funding arrangements and the characteristics of research groups, influence societal performance.

In this paper, we focus on the biomedical and health disciplines. The primary reason for this is their obvious societal role in improving health and wellbeing. Progress made in biomedical and health research over the years has resulted in an increased quality of life and a reduced mortality and morbidity (Garcia-Romero, 2006). Biomedical and health research has a dual mission; it is concerned with both the production of scientific knowledge and with the utility and implementation of scientific achievements in the healthcare system (Council for Medical Sciences, 2002). The dual mission refers to translational research. Translational research not only aims at obtaining fundamental knowledge, but also at translating this knowledge into applicable treatments: research that seeks to move from bench to bedside; from laboratory experiments to actual point-of-care patient applications (Woolf, 2008). Therefore, research evaluations should not only focus on the scientific performance of biomedical and health research, but also take into account its societal quality.

Secondly, biomedical and health disciplines make up about 40% of all research in the Netherlands, as in many other developed countries, and it covers a wide variety of research types. We distinguish between three research types based on their relationship with patients: i) para-clinical groups with an advisory relationship with patients and mostly a 'social sciences' research perspective (e.g. social medicine), ii) pre-clinical groups with little or no patient contact and laboratory-based fundamental research (e.g. immunology), and iii) clinical groups with direct patient contact and an application-oriented type of research (e.g. dermatology). Therefore, the results can be generalised to a broad range of research fields.

Thirdly, biomedical and health research is heavily dependent on external research funding (Ellenbroek, Van Ark, & Klasen, 2002; Van der Weijden, 2007). Scientists, research groups and organisations are accountable for their use of funds to a range of public, not-for-profit (charities) and commercial sources. Consequently an evaluation of how and why biomedical and health research delivers social benefits is crucial to stakeholders, which include government, a variety of funders, industry, regulatory bodies, patients and the general public (UK Evaluation Forum, 2006). In other words, societal relevance (Hessels, Van Lente, & Smits, 2009) is currently at the core of the relationship between academic biomedical & health science and society. This underlines the importance of further improving the close relationship between academic research and clinical practice, and the dialogue with stakeholders[2]. Hemlin and Rasmussen (2006) argue that discussions about the societal value of academic

2 A study of NIGZ and TNO showed that Dutch policy makers view scientific information as not directly applicable and relevant to making contributions in the policy-making process (Keijsers, Paulussen, Peters, Fleuren, & Lammers, 2005).

science have consequences for research evaluations, which should now be viewed as an open monitoring system in which scientific, industrial and public actors connect in a dynamic dialogue. However, project selection and research evaluation procedures do not generally cover the societal value of academic research in an explicit manner, and explicit criteria developed for this purpose are still in their infancy. Indicators to measure societal relevance are not available (Atkinson- Grosjen & Douglas, 2010; De Jong, Van Arensbergen, Daemen, Van der Meulen, & Van den Besselaar, 2011). Within the Dutch context, ZonMw[3], the Dutch research council for biomedical and health research, is one of the first councils that takes societal relevance explicitly into account in its selection procedures.

1.1 Methods for evaluating societal impact

In the meantime, several attempts have been undertaken to develop methods for evaluating the societal relevance of research. i) One example is the project 'Evaluating Research in Context' (and the related EU funded SIAMPI project)[4] which recently carried out pilot studies within Dutch universities, in various disciplines, such as architecture, electrical engineering, mechanical engineering, nanoscience, computer science and law (De Jong et al., 2011, for a brief overview). ii) Another example is the study of Meagher, Lyall and Nutley (2008) who developed a method to assess the impact of social science research conducted in the UK on policy and practice. iii) Also worth mentioning here is the study of Laredo and Mustar (2000), which proposed a method for characterising the activity profile of research laboratories as a research compass card. They argue that besides contributing to the production of scientific knowledge and to education and training, laboratories are also involved in the creation of competitive advantages and of public and collective goods, and they participate in the public debate. Indicators to measure these activities are presented. Unfortunately, examples of indicators that measure the participation of laboratories in the public debate were not explicitly described. iv) Finally, Merkx & Van den Besselaar (2008) proposed an approach for evaluating the societal relevance at the research field level, and they applied this to coastal research.

Within biomedical and health research, specific methods have been proposed and applied – the biomedical and health fields seem to be leading in this respect (Lyall, Bruce, Firn, Firn, & Tait, 2004). The three most well-known frameworks are: (a) The *Payback Framework*, developed in the UK by Buxton and colleagues (Buxton & Hanney 1996; Hanney, Gonzalez-Block, Buxton, & Kogan, 2003; Hanney, Grant, Woodings, & Buxton, 2004). It describes the wide range of health-related research and the social and economic benefits that may result from biomedical research – but not so much at the level of

3 The Netherlands Organisation for Health Research and Development.

4 ERiC project: www.eric-project.nl. The related EU-funded SIAMPI project has similar aims: www.siampi.eu.

individual research groups as at the level of research programmes and fields. (b) The *Research Institute Framework*, developed by the KNAW Council for Medical Sciences (2002) in the Netherlands. It measures the societal impact of health care research on the level of research institutes. (c) The *Societal Impact Framework* (van Ark and Klasen, 2007), which focuses on communication between researchers and a variety of stakeholders. Within this framework, the societal outcomes of research are evaluated in terms of the quality of the various communication processes. Recently, some pioneering work on the application of the frameworks has been done to improve our understanding of societal impact, i.e. how research is translated from bench to bedside (e.g. Nason et al., 2007; Oortwijn, 2007; Advisory Council on Health Research, 2007). Elements of these frameworks were used in the construction of our questionnaire.

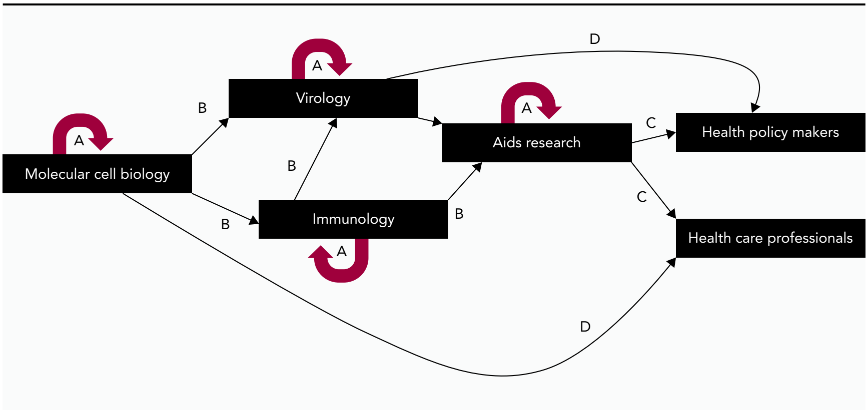
1.2 Creation of societal impact

Impact of research is generated through the communication networks. That holds for scholarly impact on peers in the field, for scholarly impact in other fields and for societal impact. Within this perspective, we distinguish between direct and indirect societal impact (De Jong et al., 2011).

Firstly, societal impact can be produced directly by producing non-scholarly output for stakeholders, based on the *expertise* of the involved researchers. Non-scholarly means that the output is not meant for peers in the field, but for the other audiences such as the general public, policy makers and medical professionals. In figure 1, these interactions are represented by arrows C and D.

With regard to directly generated societal impact, there is a variety of 'non-scholarly' output of research that may contribute to the improvement of health and wellbeing, such as advice on new treatments, policy advice and plans for organising healthcare systems, strategies for healthcare innovation, or informing the general public about health risks. These outputs can – just as scholarly output – be measured at the group level.

Figure 1 The interaction between research and societal audiences



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Secondly, societal impact can be produced indirectly where research output (new knowledge) is taken up by other researchers (arrows B) who, in turn, use it in their own research that leads to results relevant for stakeholders (arrows C), such as medical professionals working in hospitals.

Indirectly generated societal impact refers to biomedical and health research results in academic papers, with new knowledge that may – when taken up in patient care, drugs or instruments – contribute to the improvement of health and to new treatments for diseases. Sometimes the contributions may be the effect of serendipity, but often biomedical and health research is explicitly directed at scholarly problems that have to be solved in order to make progress in curing or preventing diseases. For example, fundamental results of research in molecular cell biology may inform basic research in virology and immunology. The results of the two latter fields may in turn inform aids research which produces useful therapies to be used in patient care. In other words, fundamental research results are taken up in a sequence of steps by other, more applied researchers, and finally by professionals. In biomedical research, a concept has been introduced for this: translational research.

In this paper, we focus on the direct link between researchers and societal audiences. However, we will show for one case (virology) that societal orientation is visible through indirect links.

1.3 Research questions

In this paper, we present the results of a study about societal orientation of Dutch academic biomedical and health research groups and answer the following questions:

1. What are the opinions of research leaders about the increasing emphasis on the societal impact of research?
2. Which different types of *direct* societal output products are realised by biomedical and health research groups?
3. After having answered these questions, we focus on the *indirect* way of realising societal impact: how is societal orientation reflected in scholarly output? We answered this question for virology, one of the core fundamental research fields in the domain under study.
4. What is the relationship between the societal and scientific productivity of biomedical and health groups?
5. Which managerial and organisational characteristics support the societal output of biomedical and health research groups?

2. Data and methods

2.1 A survey among research leaders

The data were collected in 2007 in a survey among biomedical and health research leaders (principal investigators) employed by university medical centres (UMCs) or by biomedical public research institutes in the Netherlands (Van der Weijden, 2007; Van der Weijden, De Gilder, Groenewegen, &Klasen, 2008; Van der Weijden, Verbree, Braam, Van den Besselaar, 2009). Names and addresses were obtained from administrative records. In total, 188 group leaders returned a completed questionnaire by post, resulting in an overall response rate of 27%. To maximise the response rate, we used the tailored design method (Dillman 2000).

We obtained information about the research leaders' opinions on societal impact of research. We used 5-point Likert scales, with answers ranging from totally agree to totally disagree. The research leaders were also asked to indicate which types of societal output were realised (Table 1), including an estimation of the quantity of societal output in the period 2004-2006. Elements of three societal impact frameworks discussed in paragraph 1.1 were used to construct these questions.

Table 1 Ten types of societal output

(1)	Presentations to non-scientific public (professionals, policy makers or patients)
(2)	Contributions to public media (TV, radio or newspaper)
(3)	Education for professionals and policy makers, such as retraining courses
(4)	Contributions to symposia and conferences directed to societal communities
(5)	Membership of committees that are developing guidelines or policy recommendations
(6)	Publications in professional or policy journals
(7)	Clinical guidelines
(8)	Policy reports
(9)	Editorships of professional medical and health journals
(10)	Membership of committees of funding organisations, such as charities

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The scholarly performance[5] was measured by the number of publications in journals indexed in the Web of Science of which the principal investigator was a (co-)author. Finally, the survey contained questions about i) organisational characteristics (i.e. funding sources), ii) managerial characteristics (i.e. leadership experience) and iii) disciplines of the groups' research within biomedical and health research (among others, health care research, immunology and dermatology) (Van der Weijden, 2007; Van der Weijden et al., 2008, for more detail about the survey design).

2.2 Non-response analysis

Non-response analysis shows that the respondents can be regarded as a representative sample of the Dutch biomedical and health research groups. Firstly, we checked whether the respondents were evenly distributed among the various research institutions and the sub-disciplines, and this proved to be the case. Secondly, we compared scholarly performance of respondents and non-respondents. Since publication counts are highly skewed, a Mann-Whitney test was used. Respondents did not significantly differ ($Mdn = 25.0$) from non-respondents ($Mdn = 23.0$), $U = 62315.0$, $p = 0.365$, $r = -0.03$. The mean difference between the two groups was also small (33 publications for respondents versus 31 for non-respondents).

2.3 Some characteristics of the sample

The biomedical and health leaders in the sample supervised research groups with an average size of 17 FTE staff members. The average age of the respondents was 53 years in 2007, and the majority were male (87%). Most of the leaders had

5 Scholarly performance is defined here as the number of publications over a three year period (2004-2006), and Thomson Reuters (formerly ISI) Web of Knowledge and PubMed (US National Library of Medicine's search service) were used as data sources.

been functioning as heads of their research groups for a long time: on average 12 years. In 74% of the cases, the respondents indicated that they had a co-leader. Research leaders spent their time on research, management, supervision, education and patient care. Most groups (87%) were located in a university medical centre (UMC) and the others (13%) were working in public research institutes. Of the 188 respondents, 34 were leaders of para-clinical research groups, 73 were research leaders of pre-clinical research groups and 81 were research leaders of clinical research groups. Writing and publishing scientific articles (90%), developing new knowledge (55%) and training young researchers (36%) were reported as the most important goals of the research groups.

2.4 Analysing indirect societal impact of biomedical research

In order to map the application orientation of basic biomedical research, we selected a core basic research field: virology. By analysing the journal citation network of the main journal in this field (Journal of Virology), we identified the relevant virology journals, as well as research fields that are a knowledge source for virology and fields that are using virology knowledge. This informs us about the relations between virology and applications in clinical and health care oriented research, in other words, about the relationship between societal impact and fundamental research. In the second step, we analysed the titles and keywords of all papers in virology journals in order to identify words that refer to the application context of virology knowledge in medical treatments. The more frequently these title words and keywords appear, the stronger the application orientation of fundamental research. We repeated the analysis for a variety of years, in order to identify changes in application orientation and in the practical contributions of virology research. The details of the methods are explained elsewhere (Van den Besselaar, 2000; Van den Besselaar & Heimeriks, 2006).

3. Findings

3.1 Societal orientation of research leaders

Science policy makers and research managers increasingly emphasise that research should be useful for society. This is not received enthusiastically everywhere. For example, a UK study suggests that researchers who engage in popularisation are seen as 'lesser' researchers by their peers, and that many think that societal output is produced by researchers "who are not good enough for an academic career" (Royal Society 2006). What is the opinion of biomedical and health research leaders about this? Are they working in an ivory tower, or do they also consider societal relevance to be of great importance? In the survey, we asked whether the increasing emphasis on societal impact has implications for research group goals. Do research group leaders take societal relevance into account when formulating the group's research agenda? And in their research, are they focussing on existing medical problems and useful innovations?

As Table 2 indicates, the attitude of research leaders towards societal relevance is, on average, slightly positive. Pre-clinical research leaders had, compared to para-clinical and clinical leaders, more neutral views[6].

Table 2 Opinions of research leaders on societal research goals

		n	Median	Bottom quartile	Top quartile	Mean	Std deviation
Research in my group takes societal needs into account	Para-clinical	25	4.00	4.00	4.00	3.80	0.957
	Pre-clinical	78	4.00	3.00	4.00	3.42	0.933
	Clinical	80	4.00	3.00	4.00	3.76	0.945
Research in my group is adapted to medical problems within society	Para-clinical	25	4.00	3.00	4.00	3.64	1.036
	Pre-clinical	78	4.00	3.00	4.00	3.42	0.974
	Clinical	80	4.00	3.00	5.00	3.83	1.063
Research in my group results in useful practical innovations	Para-clinical	25	4.00	3.00	4.50	3.64	1.114
	Pre-clinical	78	4.00	3.00	4.00	3.40	1.024
	Clinical	80	4.00	3.00	4.00	3.79	0.910

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Note: five-point scale with 1 is 'totally disagree', 3 is 'not disagree, not agree', 5 is 'totally agree'

Does this positive attitude towards societal orientation in research translate into interactions with stakeholders? When asked about the effects of the recent increase in emphasis on societal impact, research leaders reported a slight intensification of interactions with various stakeholders (Table 3). Overall, respondents had neutral views about changes in their interactions with professionals in prevention and care, policy makers, the general public, patient organisations and (pharmaceutical) industry and firms. In general, pre-clinical group leaders had more neutral attitudes towards the improved interactions with stakeholders compared to para-clinical and clinical leaders, similar to their opinion on societal research goals. Interactions with industry show a slightly different pattern: group leaders from all three disciplines do not report intensified interaction[7] with companies (see Table 3).

6 Mann-Whitney tests with a Bonferroni correction show that leaders of pre-clinical groups significantly differ in their attitude towards taking societal needs into account, adapting to medical problems within society, and contributing to useful practical innovations from clinical leaders, and in their attitude towards taking societal needs into account from para-clinical leaders, with a level of significance at 0.10.

7 Mann-Whitney tests with a Bonferroni correction show that leaders of pre-clinical groups significantly differ in their attitude towards interactions with stakeholders from para-clinical leaders (viz. professionals in prevention and care and policy makers) and clinical leaders (viz. policy makers and patient organisations), with a level of significance at 0.10.

Table 3 Intensification of interactions between research leaders and stakeholders

		n	Median	Bottom quartile	Top quartile	Mean	Std deviation
Professionals in prevention and care	Para-clinical	25	4.00	3.00	4.50	3.76	1.012
	Pre-clinical	77	3.00	3.00	4.00	3.36	0.842
	Clinical	80	4.00	3.00	4.00	3.58	0.897
Policy makers	Para-clinical	25	4.00	3.00	4.00	3.64	1.036
	Pre-clinical	77	3.00	3.00	4.00	3.12	0.827
	Clinical	80	4.00	3.00	4.00	3.53	0.900
General public	Para-clinical	24	4.00	2.25	4.00	3.42	1.018
	Pre-clinical	78	3.00	3.00	4.00	3.19	0.913
	Clinical	80	4.00	3.00	4.00	3.45	0.013
Patient organisations	Para-clinical	25	3.00	3.00	4.00	3.44	1.121
	Pre-clinical	78	3.00	2.75	4.00	3.12	0.882
	Clinical	80	4.00	3.00	4.00	3.43	0.911
Industry	Para-clinical	25	3.00	2.00	4.00	2.92	1.152
	Pre-clinical	77	3.00	2.00	4.00	3.10	0.882
	Clinical	80	3.00	2.25	4.00	3.20	1.060

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Note: five-point scale with 1 is 'totally disagree', 3 is 'not disagree, not agree', 5 is 'totally agree'

The next question is whether the increasing emphasis on the societal impact of biomedical and health research results in knowledge dissemination. Does it result in more or better (i) knowledge exchange with, (ii) knowledge products for and (iii) knowledge use by stakeholders? In general, research leaders had neutral views (see Table 4). They perceived only minor improvements in the exchange of scientific knowledge with their stakeholders. Again, pre-clinical group leaders predominantly had a more neutral view about the improved knowledge dissemination with stakeholders, while para-clinical and clinical group leaders were somewhat more positive[8].

8 Mann-Whitney tests with a Bonferroni correction show that leaders of pre-clinical groups significantly differ in their attitude towards knowledge dissemination from leaders of para-clinical and clinical leaders, with a level of significance at 0.10.

Table 4 Intensification of knowledge dissemination to stakeholders

		n	Median	Bottom quartile	Top quartile	Mean	Std deviation
Knowledge exchange	Para-clinical	25	4.00	3.00	4.00	3.76	0.879
	Pre-clinical	75	3.00	3.00	4.00	3.20	0.900
	Clinical	78	4.00	3.00	4.00	3.54	0.863
Knowledge products	Para-clinical	25	4.00	3.00	4.00	3.56	1.003
	Pre-clinical	74	3.00	2.00	4.00	3.00	0.979
	Clinical	78	3.00	3.00	4.00	3.32	0.987
Knowledge use	Para-clinical	25	3.00	3.00	4.00	3.36	0.757
	Pre-clinical	75	3.00	2.00	4.00	2.99	0.951
	Clinical	78	3.00	3.00	4.00	3.37	0.839

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Note: five-point scale with 1 is 'totally disagree', 3 is 'not disagree, not agree', 5 is 'totally agree'

The last question is whether research leaders' views on the importance of societal research goals are related to interactions with and knowledge dissemination to various societal stakeholders. Indeed, the more positive the opinions are about societal orientation of research, the higher the level of perceived interactions with various stakeholders; and the more perceived knowledge exchange with, the more knowledge products for, and the more knowledge use by stakeholders (see Table 5).

Table 5 Societal research goals by degree of interaction with stakeholders and knowledge dissemination

		Interaction with stakeholders					Knowledge dissemination		
Societal research goals		Profession-als in prevention and care	Policy makers	General public	Patient organisa-tions	Industry	Knowledge exchange	Knowledge products	Knowledge use
Research in my group takes societal needs into account	Spearman's rho	0.553*	0.409*	0.390*	0.450*	0.267*	0.520*	0.557*	0.503*
	n	182	182	182	183	182	178	177	178
Research in my group is adapted to medical prob-lems within society	Spearman's rho	0.366*	0.318*	0.287*	0.382*	0.275*	0.520*	0.455*	0.518*
	n	182	182	182	183	182	178	177	178
Research in my group results in useful practical innovations	Spearman's rho	0.474*	0.469*	0.342*	0.380*	0.338*	0.572*	0.562*	0.582*
	n	182	182	182	183	182	178	177	178

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Note: * $p < 0.001$

In summary, biomedical and health research leaders are, on average, slightly positive about the increased societal orientation of their research. Pre-clinical research leaders have more neutral views, which are easy to understand, as pre-clinical research is more 'fundamental' and therefore – in general[9] – more distantly related to care, cure and health policy issues. The more positive research leaders are about taking into account societal impact when formulating the group's research agenda, the more positive they are about interactions with stakeholders, and the more they think it results in knowledge dissemination to stakeholders.

3.2 Societal output of biomedical and health research groups

Whereas the previous section was about the *societal orientation* of research leaders, we turn in this section to the *non-scholarly output of research*. The biomedical and health groups produced different types of societal research output. Products can be 'tangible', such as reports, but we also included productive interactions with stakeholders as output (ERiC, 2010). In Table 6 we list the different products, the percentage of groups producing these types of output and the amount produced.

The most frequently mentioned products are (i) presentations about research results to non-scientific audiences, such as professionals, patients and the general public, (ii) presentations in public media, such as television, radio and newspaper, in order to communicate research findings to the general public, and (iii) educational activities for professionals in the private sector, policy sector or in prevention and care, by 84%, 76% and 69% of the research groups respectively. It is remarkable that research leaders could easily indicate whether a specific type of societal output has been produced, but many were not able to estimate how much. On average, only half of the research leaders reported this.

9 Not always: often ethical issues are involved in pre-clinical research.

Table 6 Societal output of Dutch biomedical and health groups (2004-2006)

		Percentage of groups	Mean of output quantity
1	Presentations to non-scientific public *N*	84 *184*	8.9 *116*
2	Contributions to public media *N*	76 *184*	7.0 *104*
3	Education / courses for professionals *N*	69 *184*	6.9 *86*
4	Membership of committees developing guidelines / policy recommendations *N*	67 *184*	3.0 *89*
5	Contributions to conferences directed to stakeholders *N*	66 *184*	7.0 *88*
6	Professional publications *N*	65 *184*	17.5 *88*
7	Clinical guidelines *N*	54 *184*	2.7 *75*
8	Policy reports *N*	38 *184*	2.8 *49*
9	Editorship of societal-oriented biomedical and health journals *N*	38 *184*	2.5 *41*
10	Membership of committees funding societal-oriented biomedical/health research *N*	34 *184*	2.5 *48*

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In general, we did find relationships between the societal orientation of research leaders and their reported amount of societal research output[10]. In other words, research leaders who have more positive views about societal research goals, interaction with stakeholders and knowledge dissemination to stakeholders are more active in realising societal output.

Differences exist among medical disciplines concerning societal research output. In general, para-clinical groups are most active and productive in realising societal output , while pre-clinical groups are least active and productive in realising societal output (Table 7)[11]. In particular, para-clinical groups are significantly more active in realising policy reports and in participating in committees for funding societal oriented research than pre-clinical and clinical groups. Pre-clinical groups are significantly less active in participating

10 This was calculated with Spearman's rho.

11 Pearson's chi-square statistics show that para-clinical research groups were significantly more active in the mentioned societal output products, and that pre-clinical research groups were significantly less active in the mentioned societal output products, with a level of significance at 0.05. Mann-Whitney tests with a Bonferroni correction show that para-clinical groups significantly differ in productivity of the mentioned societal output products, and that pre-clinical research groups significantly differ in productivity of the mentioned societal output products, with a level of significance at 0.05.

in committees for developing guidelines or policy recommendations and generating professional publications. Moreover, para-clinical groups were also more productive than their pre-clinical and clinical colleagues. They were significantly more productive in giving presentations to non-scientific audiences, contributing to the public media, writing policy reports and participating in funding committees that stimulate societal biomedical and health research. In contrast, pre-clinical groups were less productive in comparison with their para-clinical and clinical colleagues. Specifically, they were significantly less productive in giving presentations and educating or giving courses to policy makers or professionals, and they were less often members of committees that develop guidelines or policy recommendations.

Table 7 Societal output of research groups by discipline (2004-2006)

Societal output	Activity and productivity	Para-clinical groups	Pre-clinical groups	Clinical groups
Presentations	Percentage of groups	92.0	77.2	87.5
	Units per FTE (mean)	1.67*	0.30*	0.45
Public media	Percentage of groups	84.0	65.8	82.5
	Units per FTE (mean)	0.72*	0.34	0.40
Education/courses	Percentage of groups	84.0	59.5	72.5
	Units per FTE (mean)	0.74	0.26*	0.55
Committees developing guidelines/ policy recommendations	Percentage of groups	80.0	51.9*	77.5
	Units per FTE (mean)	0.30	0.13*	0.20
Conferences/symposia	Percentage of groups	80.0	50.6	77.5
	Units per FTE (mean)	0.57	0.28*	0.45
Professional publications	Percentage of groups	92.0	46.8*	75.0
	Units per FTE (mean)	1.08	0.79	1.32
Clinical guidelines	Percentage of groups	52.0	39.2	70.0
	Units per FTE (mean)	0.20	0.13	0.22
Policy reports	Percentage of groups	76.0*	25.3	38.8
	Units per FTE (mean)	0.44*	0.11	0.10
Editorship societal oriented journals	Percentage of groups	48.0	29.1	43.8
	Units per FTE (mean)	0.22	0.18	0.15
Committees funding societal oriented research	Percentage of groups	64.0*	24.1	33.8
	Units per FTE (mean)	0.26*	0.12	0.14

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* Significantly different at $p < 0.05$.

In conclusion, biomedical and health research groups produce a variety of societal research output. Para-clinical researchers are the most active and productive in this respect, while pre-clinical are less active and productive. It seems that research leaders are unacquainted with reporting the amount of societal output.

Finally, we cannot conclude that research groups that are more productive in societal output are also more positive about the increased emphasis on societal impact.

3.3 Health care relevance of biomedical research: the virology case

The former section addressed the *direct* way of creating societal impact by producing non-scholarly output, while this section focuses on the *indirect* way of creating societal impact. In particular, we investigate whether fundamental (pre-clinical) biomedical research is oriented at societal health care issues, and whether that has changed over time. As research *programmes* have to generate expectations of relevance in order to acquire funding, the research programmes do not seem appropriate places to study societal orientation of research.

A better way of finding indicators for societal orientation may be found in research output. One may think of two indicators. Firstly, are fundamental biomedical *journals* cited by the more applied ones that focus on clinical problems? In other words, is basic biomedical research a knowledge input for clinical research that is more directly oriented towards medical practice? Secondly, are fundamental biomedical research *papers* addressing important health-related issues?

We use virology, one of the pre-clinical research fields, as an example. The *Journal of Virology* is the most cited journal in the field. Analysing the citation environment of this journal, we found the citation network of virology research as presented in Table 8. The columns give the distribution of references from the field indicated in the column heading over the research fields represented in the rows. In the core of the network is the virology cluster, consisting of some 20 virology journals. As shown in Table 9, virology draws heavily on molecular cell biology: 23.7% of all citations from the virology cluster refer to this research field. Virology journals also often cite immunology journals (8.3%) and the main multidisciplinary journals *Science* and *Nature* (7.9%). Smaller knowledge sources for virology are AIDS research and research on infectious diseases, vaccine research and immunology.

Taking the perspective from more application-oriented research fields, such as AIDS research and vaccine research (the last two columns), we can identify whether virology is a knowledge source for these fields. Both fields heavily cite virology journals, indicating the relevance of virology for these more applied fields. These citation patterns suggest that the knowledge exchange between pre-clinical fields (virology, but also in this case molecular biology, and immunology) and the clinical fields (AIDS, infectious & tropical diseases, vaccine research) is fairly intensive. We compared this pattern with previous years, and the citation network is stable.

Table 8 Knowledge streams in the virology citation network

	Virology	Molecular Cell Biology	Immunology	Multidisciplinary science*	Aids &Infectious Diseases	Vaccine research
Virology	55.2%	3.4%	4.5%	2.1%	19.7%	25.7%
Molecular cell biology	23.7%	71.7%	26.1%	36.3%	10.0%	10.0%
Immunology	8.3%	6.6%	55.7%	5.0%	16.8%	19.8%
Multidisciplinary science*	7.8%	17.9%	12.1%	56.2%	8.1%	7.1%
Aids & infectious diseases	3.8%	0.3%	1.2%	0.4%	42.5%	9.7%
Vaccine research	1.2%	0.1%	0.5%	0.1%	2.9%	27.7%

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* This set consists of journals such as *Science*, *Nature* and *PNAS*.

Another indicator of societal orientation is based on the titles of papers in virology journals. Do the titles point at diseases and therapies, or at fundamental cellular & biological processes, including laboratory techniques? In Table 9, we listed the most frequently occurring title words and author keywords. Many of these refer to (a) clinically important viruses that cause human infections and (b) therapies and drugs (italics in Table 9). This pattern, too, has been stable over the years.

Table 9 Title words and author keywords of papers in virology journals

Word	freq	Word	freq	Author keyword	freq	Author keyword	freq
Virus	2447	*Cytomegalovirus*	125	*HIV1*	86	*HBV*	25
Human	920	Identification	122	*HIV*	85	*West Nile virus*	25
Protein	767	Genetic	118	Real time pcr	74	Replication	24
Infection	726	Binding	116	*Rotavirus*	48	Molecular epidemiology	24
Cells	433	Genome	115	*Hepatitis C virus*	48	Elisa	24
Hepatitis	401	T-cell	112	Pcr	48	*Epstein-Barr virus*	24
Immunodeficiency	384	Acute	108	Rtpcr	45	*Flavivirus*	24
HIV	375	Envelope	106	Genotype	45	Genotyping	23
Viral	350	Entry	105	Phylogenetic analysis	44	*Baculovirus*	23
RNA	270	Assay	104	*Norovirus*	44	*SIV*	22
Replication	253	Sequence	103	Interferon	38	Detection	21
Influenza	235	Murine	102	*Cytomegalovirus*	36	*HPV*	21
Expression	219	Activity	101	*Adenovirus*	35	*Influenzavirus*	21
Cell	212	*Vaccine*	99	Apoptosis	33	*Enterovirus*	21
Gene	188	Antibody	99	*Vaccine*	31	*Resistance*	20
Characterisation	186	Activation	99	*Gastroenteritis*	30	*Children*	20
DNA	170	Receptor	98	*Epidemiology*	29	*Ribavirin*	19
Disease	169	*Papillomavirus*	97	*Influenza*	29	*Influenza A virus*	19
Herpes	156	Region	96	*Hepatitis B virus*	28	Neutralisation	19
Respiratory	147	Responses	92	Real time rtpcr	28	*SARS-CoV*	18
Simplex	142	Real-time	91	Genotypes	28	*Human cytomegalovirus*	18
Patients	131	Cellular	90	*HCV*	27	*Coinfection*	17
Mice	129	Domain	90	*Diagnosis*	27	Innate immunity	17
Molecular	128	*Herpesvirus*	90	Pathogenesis	25	*Gene therapy*	17

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If we generalise the findings on virology, we may conclude that pre-clinical ('fundamental') fields are strongly oriented to clinical issues. Moreover, citation relations show that they inform the clinical fields to a considerable extent. In other words, the increased attention for the societal benefits of research does not appear to be related to a lack of such relevance. Rather, it may more strongly reflect the quest for a clearer engagement with societal relevance through the direct communication with a variety of societal stakeholders.

3.4 Societal and scientific productivity

It is often argued that societal orientation negatively influences the scholarly quality of research (e.g., Royal Society 2006). However, studies *measuring* societal output and scholarly performance show different results. A study of Norwegian university professors (Gulbrandsen and Smeby, 2005) measured entrepreneurial output of researchers in terms of whether R&D activities had resulted in commercial results such as patents, commercial products, establishment of firms and consulting contracts[12]. This study found that entrepreneurial output is not significantly related to academic output. A recent study of societal quality in a University Medical Centre in the Netherlands (Mostert, Ellenbroek, Meijer, Van Ark & Klasen, 2010) showed no relationship between societal and scientific quality. Finally, a French study (Jensen, Rouquier, Kreimer & Croissant, 2008) examined the relationship between popularisation activities (e.g. public or school conferences, interviews in newspapers, collaboration with associations) and academic activities (number of papers and citations). This study found that the various disciplines differ in this respect. No relation was found between engineering and chemistry, but a modest positive relation was found between the life sciences.

We answer this question for Dutch biomedical and health research. Research quality is high in this domain, measured in publication volume and citation impact (NOWT 2010). In the 2004-2006 period, the biomedical and health groups in our sample published an average of 1.9 papers per FTE (29 papers per group) in journals indexed in the Web of Science. As Table 10 indicates, no significant correlations exist between the scientific and societal productivity of the research groups. This holds for all types of societal output considered in this study.
This implies that societal relevance does not follow automatically from high quality research, but it also does not hinder high quality research. This leads to the next, and last question: under which conditions can research simultaneously be of high scholarly and societal quality?

Table 10 Societal productivity per category by scientific productivity#

	Scientific productivity	
	Spearman's rho	N
Presentations to non-scientific public	-0.007	114
Contributions to public media	-0.071	101
Education / courses for professionals	-0.102	84
Membership of committees developing guidelines / policy recommendations	0.000	88
Contributions to conferences directed to stakeholders	-0.046	86
Professional publications	0.012	86
Clinical guidelines	-0.065	74
Policy reports	-0.052	48
Editorship of societal-oriented journals	-0.241	47
Membership of committees funding societal-oriented research	-0.006	40

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The mentioned type of societal output (units per FTE) by scientific output (papers per FTE)

12 Dichotomously: yes or no. These kinds of societal output were not included in our study.

3.5 Management, organisation and societal output of research groups

The fifth question we address is to what degree the management and organisational characteristics of biomedical and health research groups might influence societal output. In other words, we investigate whether managerial and organisational conditions, such as the influence of funding profiles, leadership experience, group size, work environment and translational research, are related to societal orientation and the output of research groups.

3.5.1 Funding

Biomedical and health research increasingly depend on external funding. Consequently, research councils and other funding organisations put an emphasis on societal relevance, which may influence the research strategies and, as a consequence, the level of the societal output of groups. How do the various modes of research funding influence the production of societal output? In order to answer that question we distinguish between four different funding arrangements, each with different conditions: i) (basic) institutional funding, ii) funding by research councils, iii) commissioned research funded by industry or government and iv) funding by charities. Research groups differ in their strategies, possibilities and capabilities for attracting funding from these sources, which results in different funding profiles. Do these profiles relate to the quantity of societal output of research groups? Table 11 represents correlations between the percentage of funding coming from the different sources and the quantity of societal output.

Institutional funding correlates positively with the quantity of societal output. Groups with a relatively high percentage of institutional funding produced, for instance, more clinical guidelines and participated more intensively in societal committees and editorial boards.

Table 11 Societal productivity by funding source#

	Institutional Funding	Industry & ministries	Charities	all councils	
	Spearman's rho				N
Presentations to non-scientific public			-.287***		109
Contributions to public media			-.420***		99
Education / courses for professionals			-.267**		82
Membership of committees developing guidelines / policy recommendations	.183*		-.193*		84
Contributions to conferences directed to stakeholders			-.379***		86
Professional publications					
Clinical guidelines	.288**				69
Policy reports	.280*		-.307**		46
Editorship of societal-oriented journals	.355**				46
Membership of committees funding societal-oriented research		-.453***			46

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Percentage of funding from the mentioned source; note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

We did not find any positive relations between the proportion of funds coming from *(pharmaceutical) industries, companies or government ministries* and the societal output of biomedical and health research groups. In fact, biomedical and health groups that receive a high percentage of funding from these sources conduct mostly contract research for these societal stakeholders with a societal or economic goal[13]. In other words, we assume that the societal output is anchored in the research commissioned.

Groups that obtained more funding from *charities* scored significantly lower on several types of societal output products than others. This observation can be explained by the funding conditions of charities. Although charities focus on specific diseases (cancer, or heart diseases, for example) in their project selection process, they mainly concentrate on the scientific quality of the proposal. Dutch charities do not explicitly take societal relevance and societal output into account when selecting research proposals[14]. Most probably, research funded by charities is

13 In our study, the entrepreneurial activities and commercial performance of research groups, such as the identification and measurement of scientist-invented patents were not taken into account. This will be included in future research.

14 We verified grant selection procedures on the websites of three big charity funds in the Netherlands, i.e., de Nederlandse Hartstichting: www.hartstichting.nl/research (Dutch Heart Foundation); de Maag Lever Darm Stichting: www.mlds.nl/index.html (Dutch Digestive Foundation), and KWF Kankerbestrijding: www.kwfkankerbestrijding.nl (Dutch Cancer Society). Also, we verified grant selection procedures at research councils in the Netherlands.

intrinsically of social relevance since it targets a disease: societal impact is expected to emerge from the contribution to new knowledge about a specific disease.

Finally, the proportion of funding from all research councils together[15] is not related to societal output. However, when we only consider the activity of research groups at the Medical and Health Research Council (ZonMw) in the Netherlands, a moderate positive correlation exists between the number of grants obtained and societal productivity. The more frequently research groups apply for funding and receive grants from ZonMw, the more societal output is produced. Interestingly, this council strongly emphasises the need for socially relevant research and uses societal orientation in their proposal assessment criteria. Our analysis suggests that this seems to be effective (Table 12). The opposite is the case for the other research councils[16] in our study: they do not assess the societal quality of proposals in an explicit way, with the expected result. In conclusion, assessment procedures of research funding agencies are potentially powerful incentives and have serious implications for the behaviour of biomedical and health scientists.

Table 12 Societal productivity by ZonMW-activity#

	Spearman's rho	N
Presentations to non-scientific public	.352***	114
Contributions to public media	.240**	101
Education / courses for professionals	.225*	84
Membership of committees developing guidelines / policy recommendations	.205*	88
Contributions to conferences directed to stakeholders	.272**	84
Professional publications		
Clinical guidelines		
Policy reports	.373***	48
Editorship of societal-oriented journals		
Membership of committees funding societal-oriented research	.428***	40

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ZonMw (Medical and Health Research Council) activity is the number of proposal submissions and received grants normalised for group size.

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

3.5.2 Leadership experience

Research management and leadership activities such as internal communication and rewarding structure are positively correlated with scholarly performance

15 Research councils in the Netherlands: NWO is the Dutch Research Council; ZonMw is the Dutch Research Council for medical science; KNAW is the Royal Netherlands Academy of Arts and Sciences.

16 The other research councils refer to NWO and KNAW (see also note 15).

(Van der Weijden, 2007; Van der Weijden et al., 2008). However, the way research leaders manage their groups did not seem to relate to the societal output of research groups. Nevertheless, the amount of leadership experience in management is related to the societal output of research leaders. Groups that have more experienced research leaders produce less societal research output, such as contributions to public media, presentations for a non-scientific public, policy reports, professional publications, contributions to non-scholarly conferences, education of professionals and memberships of committees developing clinical guidelines and policy recommendations (Table 13). This suggests that the younger generation of principal investigators is more aware of the increased societal demand for relevance.

3.5.3 Group size

Group size also correlates negatively with societal productivity as shown in Table 13. For example, smaller groups developed more clinical guidelines, produced more policy reports and gave more presentations to non-scientific audiences per group member. Furthermore, research leaders of smaller groups were more often editors of professional journals as well as members of committees for developing guidelines, policy recommendations and funding societal-oriented research. Why this is the case needs further exploration. Are research leaders who focus on societal output less interested in acquiring research money for building up a large group? Or are research leaders inclined to reduce their societal activities, when the research group grows and an increasing amount of time is needed to manage the group?

Table 13 Societal output by leadership experience and group size#

		Leadership experience	Group size
Presentations to non-scientific public	Spearman's rho *N*	-.203** 113	-.408*** 116
Contributions to public media	Spearman's rho *N*	-.252** 101	-.203** 104
Education / courses for professionals	Spearman's rho *N*	-.394*** 84	-.307*** 86
Membership of committees developing guidelines / policy recommendations	Spearman's rho *N*	-.421*** 86	-.396*** 89
Contributions to conferences directed to stakeholders	Spearman's rho *N*	-.217** 87	-.375*** 88
Professional publications	Spearman's rho *N*	-.273** 85	
Clinical guidelines	Spearman's rho *N*		-.522*** 75
Policy reports	Spearman's rho *N*	-.379*** 48	-.527*** 49
Editorship of societal-oriented journals	Spearman's rho *N*		-.482*** 48
Membership of committees funding societal-oriented research	Spearman's rho *N*		-.357** 41

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The mentioned type of societal output (units per FTE) by leadership experience (in years) and group size (FTE)

Note: * p < 0.10, ** p < 0.05, *** p < 0.01

3.5.4 Work environment

University-based groups are more active in realising various types of societal output within the period of 2004-2006 than non-university groups. In comparison with non-university groups, a significantly higher percentage of the university-based groups gave presentations to a non-scientific public, contributed to the public media, participated in committees for developing guidelines or policy recommendations, contributed to stakeholder conferences, realised professional publications and developed clinical guidelines[17]. Principal investigators working in universities also had more positive opinions about i) societal goals (i.e. adaptation to medical problems in society and useful practical innovations); ii) interactions with societal stakeholders (i.e. patient organisations

17 Pearson's chi-square statistics show that university-based groups were significantly more active in generating various societal output products than non-university groups. No significant differences were found for policy reports, education or courses for professionals, editorship of societal-oriented biomedical and health journals, and committee membership for funding societal-oriented biomedical and health research.

and policy makers), and iii) knowledge dissemination (i.e. knowledge exchange, products and use), than their colleagues at public research institutes[18].

3.5.5 Translational research
Finally, one of the manifestations of the increased focus on societal impact is the emergence of *translational medical science*: research that aims to translate fundamental knowledge into applicable treatments. That is, research that moves from bench to bedside. Increasingly, biomedical research is organised in this way. Using pre-clinical research groups (bench) that spend time on patient care (bedside) as indicators of translational medical science, we found that pre-clinical 'translational research' groups[19] are more active in generating societal output than those that do not spend time on patient care.

This exploratory study provides answers to our five research questions, as it gives a first impression of the views and activities of Dutch biomedical researchers with respect to societal output. Two limitations should be mentioned here: i) the results were collected in a one-shot study, and so our results cannot be compared over time, and ii) the sample size creates restrictions for a more in-depth analysis.

4. Conclusions and discussion

We have demonstrated that, on average, principal investigators have a slightly positive attitude towards the increased emphasis that policy makers and research managers put on the societal impact of research. Their societal orientation is expressed in societal goals, communication with stakeholders and knowledge dissemination to stakeholders. The positive view towards societal orientation leads to more activity in realising societal output. Biomedical and health research groups do produce a broad range of societal outputs. Principal investigators are not used to reporting the amount of societal output, which is not surprising, since the measurement of societal output is not implemented in the research evaluation system in the same way that scientific output is.

18 Mann-Whitney tests show significant differences between university-based groups and non-university groups in societal orientation, with a level of significance at 0.05.

19 Pearson's chi-square statistics show that a higher percentage of pre-clinical research groups that spent time on patient care generated societal output compared to pre-clinical research groups that did not spend time on patient care. Specifically, there was a significant association between patient care and realising presentations to non-scientific public (89.2% vs. 66.7%, $p < 0.05$), contributions to media (81.1% vs. 52.4%, $p < 0.01$), education/courses for professionals (70.3% vs. 50.0%, $p < 0.10$), guidelines/policy recommendations (81.1% vs. 26.2%, $p < 0.001$), contributions to conferences for stakeholders (62.2% vs. 40.5%, $p < 0.10$), professional publications (59.5% vs. 35.7%, $p < 0.05$), clinical guidelines (75.7% vs. 7.1%, $p < 0.001$) and policy reports (43.2% vs. 9.5%, $p < 0.01$).

The three distinguished disciplines differ in their societal orientation and societal output. Para-clinical groups are most active and productive in generating societal output, followed by clinical groups. Pre-clinical groups are least active and productive and they also have somewhat more neutral views towards societal orientation. Yet, pre-clinical research – as shown for the virology case – is oriented at and relevant for clinical studies, and consequently, for clinical practice. In other words, pre-clinical seem to disseminate new knowledge to stakeholders via scholarly output. It seems that pre-clinical groups express their societal orientation indirectly on a research field level instead of directly via measurable societal output on a group level. Only when pre-clinical groups spend time on patient care, i.e. do translational research, are they more active in generating societal output. Apparently, translational research stimulates a broader societal orientation.

We found in our case that scientific and societal productivity are independent. There are groups that have both high scientific and societal productivity, groups that have both low scientific and societal productivity, and groups that have high (or low) scientific productivity and low (or high) societal productivity. An orientation towards the wider socioeconomic benefits of research is thus certainly not a residual task for researchers "who are not good enough for an academic career" (Royal Society, 2006). This suggests that specific efforts are required to stimulate societal research output, and that societal impact is not simply the consequence of policies stimulating high scientific quality.

What could these specific policies look like? Our study found several managerial and organisational characteristics that relate to societal output and this leads to some policy implications. The relation between type of funding and societal output is mixed, which might be a result of the assessment procedures of research funding agencies. Institutional funding correlates positively with societal productivity. Contrarily, charity funding correlates negatively with societal productivity. This could be a result of their project selection criteria, since charities mainly focus on the scientific quality of proposals. Perhaps charities perceive the creation of new knowledge about a specific disease as socially relevant, and they might disseminate this new knowledge to a wider society themselves rather than leave this as a task for the research group. Concerning funding from industry and ministries, no relationship was found. Actually, it is conceivable that the research commissioned by these stakeholders already has a societal or economic goal. Therefore, funding received from industry and ministries can be considered as a type of societal output. Finally, funding from research councils – received in competitions – does not correlate with societal output. Not surprisingly, because they do not assess the societal quality of proposals. However, this seems different for the Medical and Health Research Council that explicitly stimulates societal relevance in its selection procedures. Here we found that research groups that apply more often for grants and receive more grants from this council, are also more productive in generating societal output. In conclusion, a vigorous incentive to stimulate societal relevance might be a condition for funding allocations as this seems to influence the behaviour of research leaders.

Principal investigators with less leadership experience lead groups that are more productive in realising societal output. This could be a generation effect. The increasing need to demonstrate socioeconomic benefits from investments in research affects the strategies of research groups. The younger generation research leaders may adapt to this with more ease than the older generation (Verbree, Van der Weijden, Van den Besselaar, forthcoming – 2012). However, we are aware that a longitudinal (panel) study over a longer period of time is needed to verify statements about generational differences and the effects of experience. We plan to do this in the future. We also found a negative relation between group size and societal output, suggesting that there is a trade-off between societal orientation and trying to create a large research group. This merits further investigation. Finally, the effect of a work environment on societal orientation calls for further research. Do university-based research groups have a stronger societal orientation than other research groups, because universities stimulate this?

Overall, our study shows a relatively strong orientation to societal relevance within the Dutch biomedical and health research fields, and this reflects the changing contract between science and society. As Dutch biomedical and health research is internationally at the top of the discipline (NOWT, 2010), we consider these results to be more generally relevant. Whereas in the past, society funded research with the expectation that societal payoff would come at a certain point, nowadays society increasingly expects the inclusion of social benefits in research programming and in research from the outset. The younger generation of researchers takes up this challenge more explicitly than the older generation. This indicates a change in the science system in this respect: the new generation of principal investigators adapts its attitude in response to the changing science-society relationship (Verbree et al., forthcoming-2012). This adaptation of research leaders to the changing science-society relationship can potentially be reinforced by the implementation of incentives in funding allocation processes.

However, the incentives for focusing on societal impact are still weak within the science system, as research evaluation systems have only recently started to include societal impact as one of the criteria. The process of knowledge transfer to society may be improved considerably by supporting the societal orientation of research leaders in a more explicit manner (De Jong et al., 2011). The current incentive structure in the science system, including research careers, still seems largely based on scientific performance in a narrow sense. It has been pointed out that ties to society and political bodies do not lead to payoffs that can be mapped by the conventional indicators of successful scientific performance, including contract funding (Atkinson-Grosjean & Douglas, 2010; Krücken et al., 2009; Göransson, et al., 2009, Hessels, 2010). Universities, for example, like to exhibit their societal engagement, but, in practice, these activities remain largely unrewarded. Financial rewards may be an instrument for stimulating the broader impact of university research (Hessels & van Lente 2010). A study by a German university (Krücken, Meijer, & Müller, 2009) showed that societal output activities were all dependent on the personal motivation, voluntary commitment and informal, pre-existing personal ties of academic scientists. In addition, Jensen et al. (2008) showed that dissemination activities of French scientists have almost no (positive or negative) impact on their scientific careers. We expect a reduction in tensions between organisational goals and individual goals once societal activities are no longer valued as 'leisure time activities', and instead play a role in evaluating performance. This may help solving the problem that junior scientists are rarely active in generating societal output (Göransson, Maharajh, & Smock, 2009). Scientists should engage in a two-way dialogue with stakeholders at an early stage in their careers (Winston 2009), and this idea is strongly supported in the medical field[20]. Incentives aiming to intensify collaborations between academia and societal practitioners are a main factor for accomplishing socially relevant knowledge (De Jong et al., 2011; Knights & Scarbrough, 2010). In conclusion, universities and research institutes now have a duty to evaluate both scientific and socially relevant output (Jensen et al., 2008). As a consequence, scientists should also be rewarded when they are active in producing socially relevant output.

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20 This paper has been presented to 72 biomedical and health research leaders in the Netherlands who are working in three different university medical centres. 71% share the opinion that scientists should be stimulated to think about the possible societal impact of their research projects at a very early phase in their academic careers.

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6 Dynamics of Academic Leadership

In this study, we have investigated the dynamics of academic leadership and how this influences performance of research groups. Academic leadership is defined as the management and leadership of researchers and the research group; it refers to a variety of opinions, tasks and practices of academic group leaders. Four components of academic leadership were distinguished in the literature. (i) Leadership in a strict sense is the way researchers are directed and stimulated by the vision and inspiration of the leader. (ii) Group management concerns the tools that are used to manage the research process. (iii) Network management covers the activities undertaken to position the research group in the academic and societal environment to obtain legitimacy, reputation and visibility. (iv) Finally, resource strategy is the task to acquire and combine resources for the group.

In this final chapter I will summarise the conclusions of the four studies. Subsequently, I will discuss the theoretical implications that follow from the main conclusions, and examine their contribution to a theoretical framework. The model as presented in chapter three – explaining how academic leadership influences research performance – will be adjusted as well as extended. The new model brings forth a hypothesis on how research performance is also affected by internal group dynamics and by higher level management. Finally, science policy implications concerning the organisation of research groups and research evaluation will be discussed.

1. Conclusions

1.1 Characteristics of leaders of high-performing and weak-performing groups

In the second chapter, the differences in academic leadership between leaders of high-performing and other research groups was investigated. It appeared that leaders of high-performing groups can be characterised as all-rounders. They set the example by showing strong research commitment. In comparison with the other group leaders, they behave more like co-researchers than managers, they consider themselves as highly-skilled scientists, set high level quality standards, are less distracted by non-research tasks and have a higher proportion of PhD students. Leaders of high-performing groups are also more devoted to group management compared to the other group leaders. They organise internal communication more frequently and provide more opportunities for researchers who are free to bring up individual research interests. In addition to internal management tasks, they put more effort into network management than the other group leaders. They pay relatively much attention to gaining visibility and reputation (i.e. by visiting conferences and participating in assessment committees) and to obtaining resources from various sources – especially from competitive funding agencies.

Finally, the issue of weak-performing groups was addressed. The findings suggest that weak performance is a characteristic of less experienced group leaders. That is why the third chapter focuses on the characteristics of academic leaders and the changes over time.

1.2 Characteristics of academic leaders

More specifically, the third chapter examined how generation and life cycle influence academic leadership. Generation is defined by the year a PhD is obtained (PhD cohort membership). Life cycle phase refers to the years of experience as group leader (less experienced, experienced or departing group leaders). Both generation and life cycle phase influence the behaviour of academic group leaders. Two generations of academic group leaders were defined on the basis of environmental changes in the Dutch science system; these changes are the institutionalisation of research evaluation and the growth of project funding, both during the mid-1980s. The two generations have been socialised into the academic world in two different time periods. It was hypothesised that this would be reflected in their academic leadership practices. The study supported this. The younger generation of group leaders spent more time on research activities and group management but less on education. The younger generation had a higher proportion of external funding from more various sources and had a lower proportion of permanent staff. And, when it came to setting the agenda, they considered the prospects and interests of PhDs less important than the older generation did.

With regard to life cycle, it was hypothesised that academic leaders at different stages of their careers have different goals, interests and responsibilities that are reflected in their leadership behaviour. The starting group leaders (with 5 years or less of experience) still need to build up a reputation and this results in lower network activity; they need more time to get visibility. They less often motivate researchers with intangible rewards. Finally, they give high priority to raising creative research themes; this might be their main strategy for setting a reputation. Experienced group leaders (with more than 5 years of experience) need to retain their reputation through the preservation and improvement of group vitality; consequently, their highest priority is to acquire new research funds. They have a higher proportion of external funds, but they are also more active in submitting research proposals to the medical research council, and they attach more value to the quality control of research proposals submitted by their group members. The nearly departing group leaders (57 or older, near retirement) tend to reduce their research activities in preparation for their departure as group leaders. They spend less time on research activities and group management and consider visibility in top journals less important. However, their coaching and educational role increases as they spend more time on education. The older research leaders more often emphasise that PhD students should have the chance to follow their own interests and define their own research themes.

Academic leadership strategies and research goals
The fourth chapter introduced a conceptual model of the relationship between academic leadership and research performance. This model is based on the two preceding chapters, on Gladstein's (1984) inputs-process-outputs model of group effectiveness, and on the resource dependence theory (Pfeffer & Salancik, 1978). The model was tested to answer the question how various academic leadership practices simultaneously influence research performance. In general, it was concluded that the research goals that a group aims to achieve (achieving high output, securing high visibility, achieving high productivity and attaining high quality) determine the strategy that the group should follow.

Different goals call for different leadership strategies. To be precise, the higher the proportion of PhD students and the more time spent on network activities, the higher the output, visibility and productivity will be. To raise quality (indicated by a high number of citations per publication), however, one needs other instruments: a quality-minded leader who spends a relatively large amount of time on research. High visibility requires leaders who regard themselves more as co-researchers than as managers, and a higher proportion of senior researchers. On the other hand, high output calls for leaders who consider themselves high-skilled scientists. In comparisons with the leadership role, management is a side issue for achieving high research performance. Performance is not affected by management practices; rewards and the degree of communication and quality control do not seem to matter.

Different goals also call for different resources. Increasing group size raises output and visibility, but lowers average productivity as a result of diminishing marginal returns on labour. Diversity in funding sources is beneficial for gaining visibility and quality.

1.3 Towards broader research goals
Chapter five explored the societal orientation of academic leaders and investigated how societal and scientific productivity are related. It appeared that, on average, academic leaders look favourably on the societal orientation of their research agenda, their communication with stakeholders, the degree of knowledge dissemination to stakeholders and the generation of a wide diversity of societal output. Nevertheless, a positive view towards societal orientation does not automatically generate more societal output. Moreover, leaders are not used to reporting the amount of societal output. This is not surprising, since measurement of societal output is not implemented in the research evaluation system to the same extent as scientific output is.

The three medical disciplines (i.e. para-clinical, pre-clinical and clinical) differ in societal orientation and output; para-clinical groups are most active and productive in generating societal output. They are followed by clinical groups. Pre-clinical groups are the least societally oriented and productive ones and they have slightly more neutral views towards societal orientation, too. Yet, pre-clinical research groups – as shown in the virology case – seem to disseminate new knowledge to stakeholders via scholarly output. It seems that pre-clinical groups express their societal orientation indirectly through contributing to the stock of knowledge, instead of directly via measurable societal output on a group level. However, some of the pre-clinical groups contribute in a more direct way to knowledge transfer, by spending time on patient care – through translational research – and they are also more active in generating societal output. Apparently, translational research stimulates a societal orientation.

Scientific and societal productivity are not correlated. This suggests that specific incentives are required to stimulate societal research output, and that societal relevance is not simply the result of policies that stimulate high scientific quality.

1.4 Taking it altogether

The four empirical studies together are an attempt to answer the research question: how does academic leadership influence performance of research groups? Two key factors can be indicated that influence the performance of research groups positively. Leadership turns out to be crucial for achieving high performance. Academic leaders set the example by showing strong research commitment and determining the quality standard. As explained by one of the experts interviewees:

"If you are confronted with excellence, [as when you are at] a good conference, then you improve yourself, as well [as when you have] a good work discussion with sharp people, where people can think laterally, which makes the group think laterally. It's really like skating behind someone. If you're riding a lap and you scratch and scrape, and then you ride behind someone and it goes so much smoother, what has changed for you? Yes, nothing, but you have a good example and you're obviously doing what is right. When you are making music together with someone who plays very well, you start playing better yourself, but when he is gone then... That incubation of talent and the incubation of the above-average [is what] makes people perform better without you even adding something."

The other key factor is network management. It concerns the way in which academic leaders position their group in the scientific and societal environment and how they respond to environmental opportunities and constraints. On the one hand, network management refers to obtaining resources from a wide variety of external sources (especially competitive funds)-that increase autonomy and human capital (especially PhD students). On the other hand, network management refers to gaining visibility and a reputation through i.e. conference attendance and committee membership.

Furthermore, the production of societal output also seems to depend on network management. In fact, neither leaders' attitudes towards societal orientation nor their scientific productivity are related to the generation of societal output. It is the way they respond to the requirements and incentives from funding agencies that determines their activities and productivity in societal output. One of the expert interviewees explains why scientific and societal collaboration is necessary and what it creates.

"The days are gone when you could stand in your lab as a loner and do a few experiments. It has all become so multidisciplinary that you are always dependent on other people; you can hardly do anything by yourself. In technological or clinical research you must always collaborate. People who want to do everything completely on their own do not fit in this society anymore, because it has become far too complex. [...] You can see it growing in the Netherlands, that it can have much added value when you bundle research, when you ensure you do not compete with each other but stimulate cutting-edge research. [...] I regularly give talks for patients, through the patients association, because they want to know what we are doing and if there is anything we can do for them, that´s a nice spin-off. [...] In a consortium your work becomes more visible, but it also works the other way around, because the moment your patients' association commits itself to us, it becomes easier to get access to patients. If you want to do a study and you say that it is being done within the consortium, patients know what you´re talking about. And that means you can reach people and ask them if they want to cooperate with research. That works really well and it works both ways."

Thus, the main factors that influence performance of research groups are leadership and network management. However, research performance is indirectly influenced by characteristics of academic leaders, such as experience, age and (generational) cohort membership.

2. Theoretical implications and further research questions

Previous studies have shown the importance of academic leadership in order to create the right conditions for achieving individual and collective research goals, such as high research performance (Amabile et al., 2004; Andrews, 1979b; Babu & Sing, 1998; Bland & Ruffin, 1992; Goodall, 2009; Harvey et al., 2002; Knorr & Mittermeir, 1980; Omta, 1995; Omta & De Leeuw, 1997; Pelz & Andrews, 1966; Stankiewicz, 1976; Van der Weijden, 2007; Van der Weijden et al., 2008). These and other empirical studies identified various determinants for a productive research environment, including human and financial resources, intangible rewards, research communication, quality control, motivation, international communication and collaboration, and experience of the group leader. These determinants refer to different tasks, practices and opinions of academic leaders that create the optimal research environment for research groups.

In most of the empirical studies, only one or a few of these factors were included. This study, however, elaborates on earlier work of Van der Weijden

(2007; 2008), who conducted one of the few studies that does examine a wider set of academic leadership determinants of research performance[1]. The study concluded that group leaders have different (combinations of) research goals and each research goal calls for a different strategy. Van der Weijden's study shows the complexity of steering a research group. Other bivariate studies show similar effects. My study, however, takes a next step and tries to disentangle how different academic leadership practices are interrelated and how they simultaneously influence research performance.

Previous studies on the relationship between academic leadership and research performance are empirically rather than theoretically driven. My study is a first effort to explain, within a theoretical framework, the mechanisms behind the connection between academic leadership and research performance. As a first contribution, based on a literature review, academic leadership was defined as the management and leadership of researchers and research groups (presented in chapter two). The various determinants of academic leadership were classified into four comprehensive components:

– Resource strategy: acquiring and combining (financial and human) resources;
– Leadership: steering researchers through inspiration and vision;
– Group management: managing and coordinating the research process, and
– Network management: obtaining legitimacy, a reputation, and visibility in the academic and societal environments.

Subsequently, a conceptual model was presented in chapter four. This model was based on previous empirical results (including chapters two and three of this study); on Gladstein's inputs-process-outputs model of group effectiveness (1984); and on Resource Dependence Theory (Pfeffer & Salancik, 1978).

Testing the model led to the conclusion that the main factors that influence the performance of research groups are leadership (i.e. how the leader evaluates his commitment towards research and his attitude to quality) and network management (i.e. activities of the leader in the scientific community as well as the ways of acquiring external funding and recruiting human resources). Management is strongly correlated to leadership and therefore has no additional effect on research performance (see also chapter two). Characteristics of the leader (age and experience) seem to influence research performance indirectly via academic leadership (chapter three): less experience leads to less network activity and a lower percentage of PhD students, and this in turn leads to lower performance (see also chapter two and four). Finally, the scientific discipline is the main environmental condition that influences the performance of a research group.

1 One of the first studies on this topic was conducted by Pelz & Andrews (1966).

What is the next step in understanding the relationship between academic leadership and performance of research groups? Firstly, the empirical findings of chapter five call for extending the model with societal activities (societal research goals, interaction with stakeholders and knowledge transfer to stakeholders) and societal output. It turns out that societal and scientific productivity are unrelated. Societal output is an additional dimension of research performance.

Secondly, the model should be extended with bottom-up and top-down processes. In the current model, the behaviour of the group leader is the primary determinant of the group's research performance. As suggested in the introduction, achieving high performance may not only be the result of the behaviour of academic group leaders, but it may also be influenced by bottom-up and top-down processes. Bottom-up processes concern the group dynamics; that is, how individual researchers with different competencies and activities interact with each other. Top-down processes concern conditions and constraints created at a higher organisational level, such as the management and policy practices of heads of departments, deans and boards of research organisations.

How should the model be adjusted in order to account for the effects of bottom-up and top-down processes on the performance of research groups? With regard to bottom-up processes, the question is: how we can understand the relation between group dynamics, academic leadership and research performance? This study shows that the attitude of the group leader is an important factor in achieving high performance. But is the leader's attitude converted into a group norm? According to Van Knippenberg & Hogg (2003), leaders influence their group members in an effective way because they are group member themselves. A leader can influence group members more effectively if he or she is a representative of the group's identity (prototypical leader), and if his or her behaviour is perceived by the group members to benefit the group. Hence, the conversion of the leader's research and quality commitment into a group norm depends on how the group members evaluate their leader. Yet, little is known about the communication processes between leaders and group members that can lead to the development of group norms (Hogg & Reid, 2006). As Monge and Contractor (2003) argue, various social theories are needed to understand communication processes and the emergence of communication and organisational networks. For example, communication between leaders and followers can lead to the development of group norms by physical proximity (influencing attitudes through an increase in communication because of physical closeness), by cognitive consistency (a drive towards shared attitudes) and by social learning (contagion of attitudes because of mimetic processes).

With regard to top-down processes, the question is how higher-level management, academic leadership and research performance are related. This study and previous studies have shown that higher involvement in research yields higher research performance (i.e. Pelz, 1956; Jauch, Glueck, & Osborn, 1978; Babu & Singh, 1998). This so-called professional commitment[2] is reinforced when researchers receive recognition from their scientific community (Cornwall & Grimes, 1987). Professional commitment is also influenced by organisational expectations, goals, values and norms (Cornwall & Grimes, 1987; Tuma & Grimes, 1981; Schein, 1968). The influence of the organisational context can be classified under the concept of organisational commitment, which refers to an affective connection[3] with the organisation (Mowday, Porter, & Steers, 1979). It means that one wants to stay in the organisation because it is the most convenient environment to achieve one's personal goals (Ashforth & Mael, 1989). Numerous studies have shown that individual research performance depends to a large extent on the organisational context. Organisations provide facilities for high performance such as contacts and equipment (Allison & Long, 1990; Crane, 1965; Keith & Babchuk, 1998; Long, 1978; Long, Allison, & McGinnis, 1979; Long & McGinnis, 1981; Ramsden, 1994; Reskin, 1979). As long as the criteria used for the distribution of rewards are perceived as legitimate and the organisation provides career opportunities, organisational commitment will be strong (Wallace, 1995). If not, the incongruence between expectations, goals, values and norms of the organisation and of the individual will probably lead to the dominance of professional commitment (Ellemers & Rink, 2005; Meyer, Becker, & Van Dick, 2006). An open question for further research is which characteristics of the organisation encourage organisational and professional commitment of academic leaders, and how these lead to research performance.

Another open question follows from the observation in this study that para-clinical groups have lower research performance and that their leaders appear to behave differently. This is in line with the observations by Reale & Seeber (2011) and De Jong et al (2011) that a different disciplinary environment requires other leadership strategies and other research goals (Reale & Seeber, 2011; De Jong et al., 2011). In view of that, it is recommended to extend this study to other research domains, such as the technical sciences or the humanities, to investigate how scientific discipline, activity profile and the mission of research groups influence the relationship between academic leadership and research performance. The new research questions have been included in the adjusted and extended model of academic leadership and research performance (figure 1).

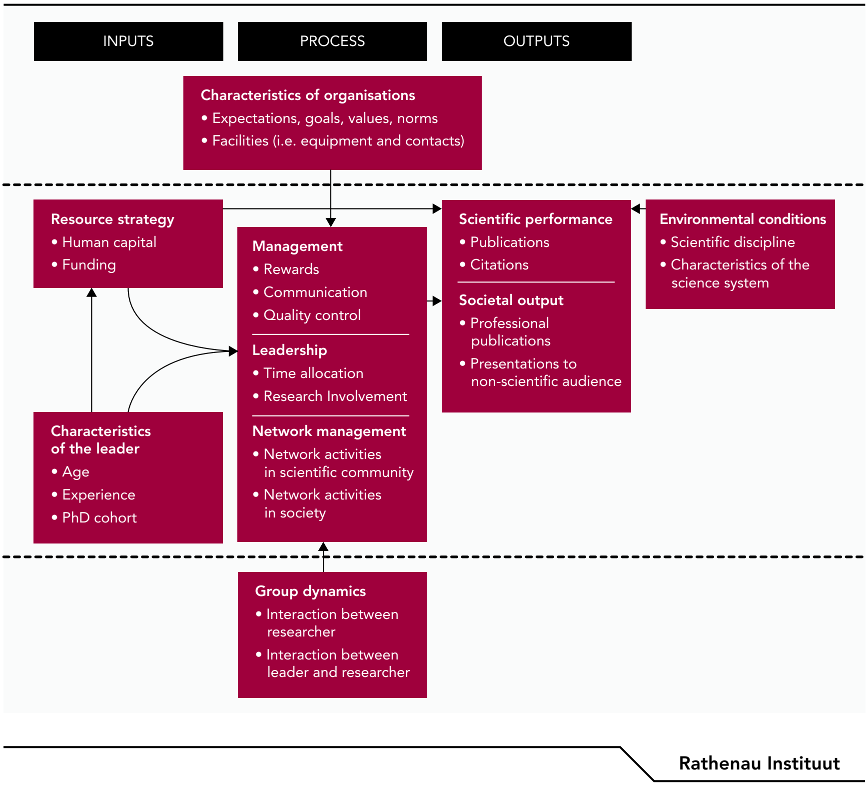
In conclusion, a multi-theoretical approach (Monge & Contractor, 2003) is needed to understand how academic leadership influences research performance. This

2 Other terms are also used for professional commitment, such as career commitment, occupational commitment, career salience and career orientation, or professional role orientations (e.g. Blau, 1988; Cornwall & Grimes, 1987).

3 Apart from being influenced by affective commitment (want to stay), the degree of organisational commitment is also determined by normative commitment (ought to stay) and continuance commitment (need to stay) (Allen & Meyer, 1990).

is no surprise: for most complex social phenomena there is not one theory that can cover all relevant mechanisms. Similarly, it is not likely that one theory only will be able to give an exhaustive explanation of which factors of academic leadership lead to high research performance, and why. This study has made a first effort in this direction.

Figure 1 Conceptual model of academic leadership and performance of research groups. Please note that more indicators of scientific performance and societal output are possible depending on the environmental conditions.



3. Science policy implications and further research questions

In this paragraph, I will combine the different science policy implications from the various empirical studies. My work has implications for the organisation of research groups and research evaluation.

3.1 The organisation of research groups

The findings of the four studies have implications for the organisation of research groups. Surprisingly, the study shows that management tools such as rewards, communication and quality control hardly seem to matter for performance. This is in contrast with earlier studies where a positive relation was found between, for example, rewards and research performance (i.e.

Omta & De Leeuw, 1997; Van der Weijden et al., 2008). Leaders cannot do without managing the research process. Yet, there is no additional effect on performance. Also, we have seen that leaders of top-performing groups put more effort into group management compared to leaders of other groups. Thus, management and leadership are strongly correlated, but apparently it is leadership that makes the difference.

There may be tension between the management of resources and processes and the leading of researchers. Management requires a well-structured organisation, while research leadership requires the kind of open and spontaneous processes that are needed to foster creative and innovative ideas. Given that the roles of academic leaders change in the course of their life cycles, one could argue in favour of bigger groups with multiple leaders who have different tasks and responsibilities. A possibility is to conduct an organisational experiment to investigate whether a group structure with multi-layered leadership – in which leadership and management tasks are divided or split up among different individuals – performs better than groups with one principal research leader. Below, you will find an explanation of how the idea of multi-layered leadership follows from this study.

With multi-layered leadership, less experienced academic leaders can be given an opportunity to explore their own creative research niche in order to set up their own research line, with the support of a more experienced group leader, who mainly secures funding for the group. This trend of increasing co-leadership in research groups can be observed in our sample: in 2002, 47 per cent of the medical research groups had a co-leader, but by 2007 this had increased to 71 per cent (Van der Weijden et al., 2009). Based on recent interviews with academic leaders, it appears that the co-leader is indeed a young person who directs his or her own research line under the management of the principal group leader. The role of highly experienced leaders who are near their retirement age should not be underestimated. In fact, though their role moves from knowledge production to education, they still spend a considerable amount of time on research and they do not lose touch with research practice. Building on many years of research experience, they can fulfil an important role in coaching the new generation of young researchers. Alternatively, they could be of value in higher management (i.e. as department heads, deans or on the board of directors), since their acquired reputation can have the power to attract talented researchers that would like to work in an organisation with such a famous researcher at its top (Goodall, 2009). This makes retirement age a discussion issue: one could think of extending the scientific careers of researchers with a change of responsibilities.

In addition to changes between academic leaders at various stages of their careers, academic leaders also differ between generations. Multi-layered leadership may offer the younger generation of researchers a faster track to independence. This is positive for the dynamics in the science system, because the younger generation seems to be better adapted to changes in the science system. This study, for instance, shows that the younger generation of academic leaders acquires more external funds and is more productive in generating societal output.

An increase in group size has obvious consequences for coordination and management. This suggests that it may be useful to create a separate position for a research manager who can handle administrative and management tasks. The assistance of a research manager would reduce the time that academic leaders would otherwise need to spend on management issues. As a result, academic leaders could devote more time to the core activity that this study has shown to be of crucial importance for high performance: research leadership. In other words, they could be more committed and involved in conducting research. Another promising advantage of larger groups is that it can combine a variety of specialties and skills in one group, which is essential for addressing complex research problems (Börner et al., 2010; Stokols, Hall, Taylor, & Moser, 2008; Stokols, Misra, Moser, Hall, & Taylor, 2008). This might result in research groups operating in a more self-sufficient way, like small enterprises do, expanding their autonomy in relation to the university or research institute. How multi-layered leadership works in practice should be investigated in further (experimental) research.

The leader is dominant in deciding how the group responds to environmental demands (Gornitzka, 1999; Pfeffer & Salancik, 1978; Reale & Seeber, 2011). This study supports a resource-based strategy in which leaders reduce their dependency on one or a few funding sources in order to increase visibility and produce higher-quality output. However, if a research group acquires a high proportion of external funding, this is probably not always encouraged by the research organisation. Funding received from Dutch or European funding sources often does not include all overhead costs. As a result, acquiring much external funding can be quite expensive for a research organisation. The organization might even discourages their research groups from doing so. Given that acquiring funds from various external sources seems to be positive for visibility and higher-quality output, one might advocate full funding – including all research and overhead costs – of research projects from, for instance, the Dutch Research Council (NWO). In this way, research groups that acquire external funds contribute to the infrastructure costs of the organisation they belong to. A follow-up study will have to examine whether countries with full funding of research projects and those without differ in the quality of their scientific output.

Yet, when groups become less dependent on institutional funding, research institutes lose their ability to influence research groups top-down. All that is probably left for institutes to do is to recruit and select group leaders

(Strandholm, Kumar, & Subramanian, 2004). As a result, leaders develop an entrepreneurial attitude which makes them independent from the organisational environment by acquiring funds from a diverse set of sources (Etkowitz, 1998; Etkowitz & Leydesdorrf, 2000; Gulbrandsen & Smeby, 2005; Hessels, 2010). This raises the question whether and how this changes the relationship between group leaders and higher level management. As researchers are generally more committed to their profession than to their organisations, organisations must find ways to commit researchers to their organization. On the other hand, academic leaders are challenged to respond to organisational demands. They can only protect their autonomy if they are able to deal with organisational conditions in an optimal way. For instance, the tendency to create 'focus and mass' at all levels of Dutch science policy (i.e. individuals, groups, organisations and government) requires academic leaders to fit their research programme into larger research themes and to participate in larger collaboration networks.

The entrepreneurial attitude may not only manifest itself in the role of group leaders, but is also expected from researchers at a much younger age. In view of the increasing dependence of researchers on funding and the greater focus in general on research, past changes in research evaluation and funding have forced researchers into a more entrepreneurial attitude. Current developments might intensify this entrepreneurial attitude. For example, new prestigious grants for talented young researchers provide opportunities for young researchers to explore their own creative research niches. At the same time, these grants may create an 'obligatory point of passage' in the route towards an academic career. A potential risk is that one loses talented researchers, as a lot of applicants who are rejected for these grants are good performers as well (Bornmann, Leydesdorff, & Van den Besselaar, 2010; Van den Besselaar & Leydesdorff, 2009). The new grant schemes which force researchers at different stages of their careers into independence possibly lead to a radicalisation of competition. How this will affect scientific careers and research leadership in the future remains an open question. But it certainly draws attention to the current trend in research organisations to institutionalise specific supervision programmes that deal with applications for such prestigious research grants. This trend might lead to a neglect of other funding sources, whereas this study shows that diversity of funding sources is good for the quality of output.
In addition, the trend to apply for individual grants raises the question how, on the one hand, the independence of researchers – that these grants aim to stimulate – relates to the tendency, on the other hand, to conduct research in larger teams and collaboration networks. In other words, are individual researchers who obtain grants in order to explore their innovative ideas more difficult to manage? If Dutch career grants were based on full funding (including overheads), this might provide individual researchers with the flexibility to search for the right academic environment to set up their own research line.

3.2 Research evaluation

Our findings introduce some new perspectives on the evaluation of research groups and researchers. One of the key factors for achieving high research performance is good network management. More specifically, academic leaders need to acquire resources – including attracting PhDs to their group – and they need to be externally active, for instance at conferences and in editorial boards. Young academic leaders who have less experience also have less developed networks and, as a consequence, lower performance. This implies that the development of academic leaders at the various stages of their careers should be taken into account when evaluating research groups. Furthermore, the output of research groups is not stable over time but can be influenced by such events as the appointment of a new leader (Braam & Van den Besselaar, 2010). This calls for a more dynamic approach in evaluation assessments.

Yet, current evaluation criteria are still largely based on a narrow definition of scientific performance. The increasing emphasis on quantitative indicators of performance is raising the pressure to 'publish or perish' (Hessels, 2010). A stronger emphasis on rewarding publication volume will have serious consequences for other performance indicators. Research groups that adjust to higher publication norms will change their strategy, possibly to the detriment of their visibility (citations), productivity (papers per person), quality and creativity (citations per paper) because, as this study shows, these research goals require other strategies.

Only a small selection of excellent research groups has such unique qualities that they perform well on any sort of indicator. All-roundness appears to be a vital skill for leading high-performing research groups. Leaders of high-performing groups are good at acquiring resources, leading researchers, management of the research process and management of their network. Previous research by Pelz and Andrews (1966; 1979b) showed that all-roundness also positively affects the performance of individual researchers, which implies that researchers should also develop an ability to perform wide-ranging activities.

Given that research output varies along the life cycle of research groups and that different research goals (output, visibility, productivity and quality) require different strategies, it should be questioned whether a strong emphasis on evaluating publication output and impact is the right way to improve research quality. Moreover, the outcomes of research are uncertain, even in the case of excellent research. This study suggests some additional performance indicators besides the easy-to-measure bibliometric indicators. Instead of a focus on the outcomes of research, a focus on the organisation of the research process might help to improve the quality of research. In that case, the evaluation of groups should include the quality of academic leadership (such as the presence of an intensive communication structure), diversity in funding sources, group composition (including the proportion of PhD students), research focus of the group, and intensity of network activities both in the scientific community and with societal stakeholders.

This study shows that there is a relatively strong orientation towards societal impact. This suggests that research groups can be held accountable for the effort they put into knowledge transfer to society. Leaders of research groups reported that the increased emphasis on societal impact has resulted in societal research goals, communication with stakeholders and knowledge dissemination to stakeholders. Furthermore, research groups generate a wide variety of societal output, including presentations to a non-scientific public, contributions to public media and education for professionals. Yet, neither a positive attitude towards societal relevance nor a high scientific productivity will automatically result in higher societal output or higher societal productivity. This is probably caused by the lack of incentives that might encourage a focus on societal relevance.

The findings of this study concerning the relationship between funding type and societal productivity imply that assessment criteria in funding allocation might be a strong incentive for generating societal output. To be more precise, research groups that apply for grants more often and receive more grants from the Medical and Health Research Council (ZonMw) were also more productive in generating societal output. This did not apply to other divisions of the Dutch Research Council (NWO) where our respondents applied for money, as these did not include societal relevance in selection procedures. Institutional funding correlates positively with societal productivity, which might be a result of the mission of UMCs that aim to transfer knowledge from bench to bedside. Charity funding correlates negatively with societal output, probably because their main selection criterion is scientific quality. Perhaps charities perceive the creation of new knowledge about a specific disease as socially relevant in itself. Also, they might have decided to disseminate this new knowledge to society at large themselves rather than leave this to the research group. For funding from industry and ministries, no relationship was found. It is likely that the research commissioned by these stakeholders already has a societal or economic goal. Therefore, funding received from industry and ministries can be considered as an indicator for societal output.

Stimulating socially relevant activities cannot solely depend on incentives in the funding system. Appreciation for socially relevant activities of a researcher should also be granted by the organisation itself and by the scientific community. It will certainly take some time before the associated cultural change will take effect. But in the end, the use of broader indicators that assess the research process does more justice to the variety of duties and responsibilities of research groups than narrower indicators that focus on research outcomes.

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Nederlandse samenvatting

Dynamiek van academisch leiderschap in onderzoeksgroepen

Als we zeer complexe wetenschappelijke en maatschappelijke problemen (zoals klimaatverandering, de economische crisis en infectieziekten) willen oplossen, kunnen we niet gewoon wachten op de antwoorden van slimme wetenschappers die werken vanuit hun ivoren torens. Deze uitdagingen vereisen een multi-, inter-, of transdisciplinaire aanpak, waarin meer en verschillende specialiteiten en vaardigheden van onderzoekers worden gecombineerd in grotere teams (Borner et al., 2010; Stokols, Hall, Taylor & Moser, 2008; Stokols, Misra, Hall & Taylor, 2008). Het eenzame genie dat slimme oplossingen verzint in zijn eigen wereld, wordt steeds meer, of is al, een uitgestorven soort. Wetenschappelijk onderzoek wordt steeds vaker uitgevoerd in groepen, vooral in de (bio)medische en gezondheidswetenschappen (de focus van deze studie).

Als we excellent onderzoek willen uitvoeren dat bijdraagt aan het oplossen van complexe wetenschappelijke en maatschappelijke vraagstukken, zijn talentvolle, creatieve, innovatieve en enthousiaste onderzoekers cruciaal. Onderzoekers kunnen echter alleen excelleren, als de omgeving waarin ze opereren, de juiste condities biedt (e.g. Allison & Long, 1990; Andrews, 1979; Heinze, Shapira, Rogers & Senker, 2009; Hemlin, Allwood & Martin, 2008; Pelz & Andrews, 1966). De werkomgeving voor onderzoekers is de onderzoeksgroep. Onderzoeksgroepen zijn organisatie-eenheden die deel uitmaken van een onderzoeksorganisatie (een universiteit, onderzoeksinstituut of universitair medisch centrum) met onderzoekers en ondersteunend personeel als leden van de groep, met een onderzoeksagenda en onderzoeksfinanciering, en onder leiding van een academische groepsleider (e.g. Andrews, 1979; Beaver, 2001; Cohen, Kruse & Anbar, 1982; De Haan, 1994; Laredo, 2001; Laredo & Mustar, 2001; Rey-Rocha, Martin-Sempere & Garzon, 2002, Stankiewicz, 1976).

Academische groepsleiders vormen de kern van de onderzoeksgroep. Vooral hun leiderschap- en managementtaken zijn belangrijk om onderzoeksprestaties te bereiken, omdat groepsleiders de condities voor een productieve onderzoeksomgeving beïnvloeden (Bland & Ruffin, 1992). Hun uitdaging is een werkomgeving creëren die bijdraagt aan het behalen van zowel individuele als collectieve onderzoeksdoelen en daarmee excellente onderzoeksprestaties.

Recente veranderingen in het wetenschapssysteem beïnvloeden de rol van academische groepsleiders. Zo stijgt de nadruk op wetenschappelijke excellentie, neemt de concurrentie voor onderzoeksfinanciering toe, stijgt de behoefte aan toegang tot dure en grootschalige onderzoeksfaciliteiten, wil men onderzoek organiseren in grote samenwerkingsverbanden, en is er steeds meer vraag naar onderzoek met een maatschappelijk relevantie. Deze ontwikkelingen verzwaren de traditionele taken van groepsleiders en vragen om een uitbreiding naar ondernemerschapsactiviteiten. En dat vraagt weer om nieuwe vaardigheden van onderzoeksleiders (Hansson & Monsted, 2008). De rol van leiders verandert dus. Naast hun interne rol – waar zij zich onder andere richten op onderzoeksbijeenkomsten faciliteren, junior onderzoekers begeleiden en spannende nieuwe ideeën genereren – wordt hun externe rol groter. Ze moeten in toenemende mate onderzoeksmiddelen verwerven, samenwerkingsverbanden onderhouden en kennis verspreiden in de samenleving. Deze ontwikkeling leidt tot de vraagstelling van dit onderzoek: *Hoe is het academisch leiderschap van invloed op de prestaties van onderzoeksgroepen?*

In deze studie hebben we onderzoek gedaan naar de dynamiek van academisch leiderschap en hoe dit de prestaties van onderzoeksgroepen beïnvloedt. Academisch leiderschap is gedefinieerd als het managen en leiden van onderzoekers en de onderzoeksgroep; het verwijst naar een verscheidenheid aan meningen, taken en werkwijzen van academische groepsleiders. Op basis van de literatuur zijn vier componenten van academisch leiderschap onderscheiden:

1. Leiderschap in strikte zin: hoe onderzoekers worden aangestuurd en gestimuleerd door de visie en de inspiratie van de leider.
2. Groepsmanagement: de tools die de leider gebruikt om het onderzoeksproces te managen.
3. Netwerkmanagement: de activiteiten die de leider onderneemt om de onderzoeksgroep te positioneren in de academische en maatschappelijke omgeving om legitimiteit, reputatie en zichtbaarheid te verkrijgen.
4. Resourcestrategie: de taak om middelen voor de groep te verwerven en te combineren.

Vier afzonderlijke studies zijn uitgevoerd om te onderzoeken hoe academisch leiderschap de prestaties van onderzoeksgroepen beïnvloeden. Het empirische materiaal is verzameld met twee vragenlijstonderzoeken onder medisch onderzoeksleiders (paraklinisch, preklinisch en klinisch) in Nederland in 2002 (n = 137) en 2007 (n = 188). De vragenlijsten zijn ontworpen op basis van interviews en een literatuurstudie (Van der Weijden, 2007; 2008). De items in de vragenlijst verwijzen naar de vier verschillende componenten van academisch leiderschap zoals hierboven beschreven. Data over de prestaties van onderzoeksgroepen zijn verzameld van PubMed (US National Library of Medicine's search service) en Thomson Reuters (voorheen ISI) Web of Knowledge. De conclusies van de vier studies zijn in de volgende paragrafen samengevat.

1. Kenmerken van leiders van toppresterende en zwakpresterende groepen[1]

In de eerste studie is een uitgebreid literatuuronderzoek gedaan naar de relatie tussen academisch leiderschap en onderzoeksprestaties. Op basis hiervan is een werkbare definitie van academische excellentie geconstrueerd. Voor de periode 2004-2006 is een multidimensionale academische prestatie-index gemaakt en gebruikt om toppresterende onderzoeksgroepen te identificeren. Het academisch leiderschap van toppresterende onderzoeksgroepen (n = 34) is vergeleken met de overige onderzoeksgroepen (n = 151) uit het vragenlijstonderzoek van 2007. Hieruit blijkt dat leiders van toppresterende groepen 'allrounders' zijn. Ze geven het voorbeeld door een sterke onderzoeksbetrokkenheid te tonen. In vergelijking met andere groepsleiders gedragen ze zich meer als een co-onderzoeker dan als een manager, beschouwen ze zichzelf als highly-skilled wetenschappers, bepalen ze een hoge kwaliteitsstandaard, worden ze minder afgeleid door niet-onderzoekstaken en hebben ze een groter aandeel promovendi in hun groep. Leiders van toppresterende groepen zijn ook meer dan andere groepsleiders toegewijd aan intern groepsmanagement. Zij organiseren vaker interne bijeenkomsten en geven onderzoekers meer vrijheid, zodat die hun individuele onderzoeksinteresse kunnen volgen. Naast de interne managementtaken, spannen ze zich meer in voor het netwerkmanagement dan de andere groepsleiders. Ze besteden relatief veel aandacht aan zichtbaarheid en reputatie krijgen (bijvoorbeeld door congressen te bezoeken en deel te nemen aan beoordelingscommissies) en aan het verkrijgen van middelen uit verschillende bronnen – vooral competitieve financieringsbronnen.

Ten slotte is de kwestie van de zwakpresterende groepen besproken. De bevindingen suggereren dat zwakpresterende groepen worden geleid door minder ervaren groepsleiders. Dat is de reden waarom de volgende studie zich richt op de kenmerken van academische leiders (zoals leeftijd, ervaring en generatie) en veranderingen in de tijd.

2. Kenmerken van academische leiders[2]

Hoe beïnvloedt generatie en de levenscyclus (academische carrière) van onderzoeksleiders hun academisch leiderschap? Deze vraag staat centraal in de tweede studie. De studie laat zien dat zowel generatie als carrièrefase het gedrag van de academische groepsleiders beïnvloeden. De generaties zijn bepaald door het jaar waarin een doctoraat is verkregen (PhD-cohort lidmaatschap) op basis van omgevingsveranderingen in het Nederlandse

1 Deze studie 'Academic Leadership of High-Performing Research Groups' is ingediend als hoofdstuk voor het boek S. Hemlin, C. M. Allwood, B. Martin & M. Mumford (Eds.), *Creativitiy and leadership in science, technology, and innovation*.

2 Deze studie 'Generation and Life Cycle Effects on Academic Leadership' is geaccepteerd als hoofdstuk voor het boek S. Hemlin, C. M. Allwood, B. Martin & M. Mumford (Eds.), *Creativitiy and leadership in science, technology, and innovation*.

wetenschapssysteem. Deze veranderingen zijn de institutionalisering van onderzoeksevaluaties en de toename van de projectfinanciering. Beide ontwikkelingen vonden plaats in het midden van de jaren tachtig. Het gedrag van academische leiders die zijn gesocialiseerd als onderzoeker in een tijd voordat deze veranderingen van kracht waren (n = 105), zijn vergeleken met academische leiders die zijn gesocialiseerd nadat deze veranderingen van kracht waren (n = 30). De hypothese was dat dit zou worden weerspiegeld in hun gedrag als academisch leider. De resultaten van de studie ondersteunen dit. De jongere generatie groepsleiders besteedde meer tijd aan onderzoek en het interne management, maar minder aan onderwijs. De jongere generatie verkreeg een groter aandeel externe onderzoeksfinanciering uit meer verschillende bronnen en ze hadden een lager percentage vast aangesteld personeel. Bij agendasetting vinden zij de mogelijkheden en interesses van junior onderzoekers minder belangrijk dan de oude generatie. Mogelijk vanwege de grotere afhankelijkheid van projectfinanciering: dit laat minder ruimte voor de ideeën van junior onderzoekers.

Met cross-sectionele analyse van de data uit de 2002-vragenlijst[3] zijn academische groepsleiders op verschillende punten in hun carrière (minder ervaring n = 22, ervaren n = 69, vertrekkend n = 45) vergeleken, om verschillen in hun gedrag te onderzoeken. De hypothese was dat academische leiders die in verschillende stadia van hun loopbaan zijn, verschillende doelen, belangen en verantwoordelijkheden hebben die worden weerspiegeld in hun leiderschapsgedrag. Voor weinig ervaren groepsleiders (met vijf jaar of minder ervaring) is het nog noodzakelijk om reputatie op te bouwen en dit resulteerde in een lagere netwerkactiviteit; ze hebben meer tijd nodig om zichtbaarheid te verkrijgen. Ze motiveren hun onderzoekers ook minder vaak met immateriële beloningen. Tot slot geven ze hoge prioriteit aan het ontwikkelen van creatieve onderzoeksthema's; dit zou wel eens hun belangrijkste strategie kunnen zijn om reputatie te verwerven. Voor ervaren groepsleiders (met meer dan vijf jaar ervaring) is het belangrijk om hun reputatie vast te houden door de levensvatbaarheid van hun onderzoeksgroep te behouden en verbeteren.

De hoogste prioriteit is daarom nieuwe onderzoeksfinanciering verkrijgen. Ze hebben een groter aandeel externe onderzoeksfinanciering. Maar ze dienen ook vaker onderzoeksvoorstellen in bij de medische onderzoeksfinancier ZonMw. Ook hechten ze meer waarde aan de kwaliteitscontrole van de onderzoeksvoorstellen die hun groepsleden indienen. De bijna uitstromende groepsleiders (57 jaar of ouder, die bijna met pensioen gaan) hebben de neiging om hun onderzoeksactiviteiten te verminderen (hoewel ze nog steeds ongeveer de helft van hun tijd aan onderzoeksactiviteiten besteden en dus

3 De vragenlijst in 2002 gaf informatie over het jaar waarin het doctoraat is verkregen. Hierdoor was het mogelijk om generaties van academische onderzoeksleiders te definiëren. Deze informatie was niet opgenomen in de vragenlijst van 2007.

nog steeds feeling hebben met de onderzoekspraktijk). Zo lijken ze hun vertrek als groepsleider voor te bereiden. Ze besteden minder tijd aan onderzoek en het interne management. Ook vinden ze het verwerven van zichtbaarheid in toptijdschriften minder belangrijk. Daarentegen neemt hun coachende en onderwijsgevende rol toe. Ze besteden meer tijd aan onderwijs. Verder vinden de oudere onderzoeksleiders het belangrijker dat promovendi de kans krijgen om hun eigen interesses te volgen en hun eigen onderzoeksthema's te bepalen.

3. Academische leiderschapsstrategieën en onderzoeksdoelen[4]

In de vierde studie wordt een conceptueel model geïntroduceerd van de relatie tussen academisch leiderschap en onderzoeksprestaties. Dit model is gebaseerd op de twee hiervoor genoemde studies, op Gladstein's (1984) inputs-proces-output-model van groepseffectiviteit en op de resource dependence theory (Pfeffer & Salancik, 1978). Het model is getest om de vraag te beantwoorden hoe combinaties van verschillende academisch leiderschapsgedrag, onderzoeksprestaties beïnvloeden. Door de data uit beide vragenlijsten te combineren, kon de steekproef worden vergroot (n = 325). Hierdoor zijn meer geavanceerde analyses mogelijk met negatieve binomiale regressie. In het algemeen kon worden geconcludeerd dat de onderzoeksdoelen (bereiken van veel output, een grote zichtbaarheid, hoge productiviteit en hoge kwaliteit) die een groep wil bereiken, bepalend zijn voor de strategie die de groep moet volgen.

Verschillende doelen vragen om verschillende leiderschapsstrategieën. Om precies te zijn: hoe groter het aandeel promovendi en hoe meer tijd wordt besteed aan netwerkactiviteiten, hoe groter de output (publicaties), de zichtbaarheid (citaties) en de productiviteit (publicaties per groepslid) zal zijn. Om de kwaliteit te verhogen (gemeten met het aantal citaties per publicatie) zijn echter andere strategieën nodig: een quality-minded leider die relatief veel tijd besteedt aan onderzoek. Grote zichtbaarheid vereist leiders die zichzelf meer zien als co-onderzoekers dan als managers en die een groter aandeel senior onderzoekers in de groep hebben. Veel output realiseren vraagt om leiders die zichzelf zien als high-skilled wetenschappers. In vergelijking met de leiderschapsrol, is het management een bijzaak voor het bereiken van grote onderzoeksprestaties. Managementtools zoals beloningen, de mate van interne communicatie en kwaliteitscontrole hebben geen additioneel effect op onderzoeksprestaties.

Verschillende doelen vragen ook om verschillende resources. Een grotere groep vergroot de output en de zichtbaarheid, maar verlaagt de gemiddelde productiviteit als gevolg van de afnemende meeropbrengsten van arbeid. Diversiteit in financieringsbronnen zorgt voor meer zichtbaarheid en betere kwaliteit.

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4 Deze studie 'Addressing Leadership and Management of Research Groups: A Multivariate Study' is ingediend bij *Research Policy*.

4. Naar bredere onderzoeksdoelen[5]

Tot slot worden de effecten van de toenemende nadruk op de maatschappelijke relevantie van wetenschappelijk onderzoek besproken. In deze studie is de maatschappelijke oriëntatie van academische leiders en de relatie tussen maatschappelijke en wetenschappelijke productiviteit onderzocht. Hieruit blijkt dat academische leiders over het algemeen positief zijn over de maatschappelijke oriëntatie van hun onderzoeksagenda, over de communicatie met stakeholders en over de mate van kennisverspreiding naar stakeholders. Ook genereren ze een grote diversiteit aan maatschappelijke output. Toch leidt deze positieve kijk op maatschappelijke oriëntatie niet automatisch tot meer maatschappelijke output. Bovendien zijn leiders niet gewend om over de hoeveelheid van maatschappelijke output te rapporteren. Dit is niet verwonderlijk, aangezien het meten van maatschappelijke output niet is geïmplementeerd in het onderzoeksevaluatiesysteem. In ieder geval niet in dezelfde mate als gebruikelijk is bij wetenschappelijke output.

De drie medische disciplines (paraklinisch, preklinisch en klinisch) verschillen in de maatschappelijke oriëntatie en output. Paraklinische groepen zijn het actiefst en productiefst in het genereren van maatschappelijke output. Ze worden gevolgd door de klinische groepen. Preklinische groepen zijn het minst maatschappelijk georiënteerd en het minst productief. Ook hebben ze een iets neutralere houding ten aanzien van maatschappelijke oriëntatie. Toch verspreiden de preklinische onderzoeksgroepen – zoals aangetoond met de virologiecase – wel nieuwe kennis naar belanghebbenden via wetenschappelijke output. Het lijkt erop dat de preklinische groepen hun maatschappelijke oriëntatie indirect uiten. Zij dragen indirect bij aan de wetenschappelijke kennis in plaats van rechtstreeks via de meetbare maatschappelijke output op groepsniveau. Sommige preklinische groepen leveren echter ook een bijdrage aan de meer directe overdracht van kennis. Het blijkt namelijk dat preklinische groepen die tijd besteden aan patiëntenzorg, – het zogenoemde translationele onderzoek – ook meer maatschappelijke output genereren. Blijkbaar stimuleert het translationele onderzoek een maatschappelijke oriëntatie.

Wetenschappelijke en maatschappelijke productiviteit correleren niet. Dit suggereert dat er specifieke stimulansen nodig zijn om maatschappelijk output te stimuleren. Maatschappelijke relevantie volgt niet simpelweg uit beleid dat erop gericht is om een hoge wetenschappelijke kwaliteit te stimuleren.

5. Dit alles samennemend

De vier empirische studies tezamen pogen een antwoord te geven op de onderzoeksvraag: *Hoe is het academisch leiderschap van invloed op de prestaties van onderzoeksgroepen?* Twee belangrijke factoren die een positieve invloed

5 Deze studie 'From Bench to Bedside: The Societal Orientation of Research Leaders' is geaccepteerd door *Science and Public Policy*.

hebben op de prestaties van onderzoeksgroepen kunnen worden aangewezen. Leiderschap blijkt cruciaal te zijn voor topprestaties. Academische leiders geven het voorbeeld door een sterke onderzoeksbetrokkenheid te tonen en de kwaliteitsnorm te bepalen. Zoals een van de geïnterviewde experts toelicht:

"Als je geconfronteerd word met excellence, [zoals wanneer je op] een goed congres bent, dan ben je zelf ook beter, [of wanneer je op] een goede werkbespreking bent waar mensen scherp zijn, waar mensen lateraal kunnen denken, dat maakt dat de groep ook lateraal denkt. Dus het is echt schaatsen achter iemand. Als je nou rondje A rijdt, en dan krassen, krassen, krassen en daarna rijd je achter iemand en gaat het zoveel soepeler, wat is er dan veranderd aan je? Ja, eigenlijk niets, maar je hebt het goede voorbeeld en je gaat kennelijk doen wat goed is. Als je samen muziek maakt met iemand die heel goed speelt, ga je ook beter spelen en dan is ie weer weg en dan ... Die incubatie van talent en de incubatie van het bovengemiddelde dat maakt dat mensen zonder dat je er iets bij doet, ook beter gaan."

De andere belangrijke factor is netwerkmanagement. Hierbij gaat het om de manier waarop academische leiders hun groep positioneren in de wetenschappelijke en maatschappelijke omgeving en hoe ze reageren op mogelijkheden en beperkingen in hun omgeving. Aan de ene kant verwijst netwerkmanagement naar het verkrijgen van resources uit een grote diversiteit aan externe financieringsbronnen (in het bijzonder competitieve financiering). Hiermee worden de autonomie en het menselijk kapitaal (in het bijzonder promovendi) vergroot. Aan de andere kant verwijst netwerkmanagement naar zichtbaarheid en reputatie verkrijgen door middel van bijvoorbeeld congresbezoek en commissielidmaatschap.

Bovendien lijkt ook de productie van maatschappelijke output afhankelijk te zijn van netwerkmanagement. Er is geen relatie gevonden tussen de houding die leiders hebben ten aanzien van maatschappelijke oriëntatie dan wel hun wetenschappelijke productiviteit en het genereren van maatschappelijke output. Het is de manier waarop leiders inspelen op vereisten en incentives van onderzoeksfinanciers die bepalend is voor hun activiteit en productiviteit van maatschappelijke output. Een van de geïnterviewde experts licht toe waarom wetenschappelijke en maatschappelijke samenwerking noodzakelijk is en wat het creëert:

"De tijd is voorbij dat je als eenling in het lab kon staan en even wat experimenten kon doen. Het is allemaal zo multidisciplinair geworden dat je altijd afhankelijk bent van andere mensen, je kan bijna niets meer helemaal zelf. Technologisch of klinisch moet je altijd samenwerken. Mensen die het helemaal in hun eentje willen doen, die passen niet meer in deze maatschappij, omdat het veel te complex is geworden. [...] Je ziet het in Nederland op steeds grotere schaal gebeuren, dat het heel veel meerwaarde kan hebben, als je

onderzoeksgroepen bundelt. Als je zorgt dat je elkaar niet zit te beconcurreren, maar elkaar stimuleert om grensverleggend onderzoek te doen. [...] Ik geef regelmatig praatjes voor patiënten, via de patiëntenvereniging, omdat ze willen weten wat we daar doen en of we iets voor hen kunnen betekenen, dat is een leuke spin-off. [...] Door consortium wordt je beter zichtbaar en dat werkt ook omgekeerd. Want op het moment dat je patiëntenvereniging zich aan ons committeert, krijg je makkelijker toegang tot patiënten. Als je een studie wilt doen en je zegt dat dat binnen het consortium wordt uitgevoerd, dan weten patiënten waar je het over hebt en dan kan je dus mensen bereiken en vragen of ze mee willen werken aan onderzoek. Dat werkt heel goed en gaat dus beide kanten uit."

Samenvattend kan worden gezegd dat leiderschap en netwerkmanagement de belangrijkste factoren zijn die de prestaties van onderzoeksgroepen beïnvloeden. Daarnaast worden onderzoeksprestaties indirect beïnvloed door de kenmerken van academische leiders, zoals ervaring, leeftijd en (generatie) cohort lidmaatschap.

Appendix 1

ALGEMENE VRAGEN

Wilt u uw geslacht invullen? 1 ☐ Man
2 ☐ Vrouw

Vraag 1 Wat is uw geboortejaar? 19_____

Vraag 2 Waar bent u werkzaam? 1 ☐ UMC/Universiteit

2 ☐ Onderzoeksinstelling

Vraag 3 Hoe lang bekleedt u uw huidige functie als onderzoeksgroepleider?

Ongeveer ______ jaar

Deel 1: ONDERZOEKSMANAGEMENT

BELONINGEN

Vraag 4 Welke van onderstaande mogelijkheden biedt **uw onderzoeksgroep** haar medewerkers?

	Niet=1	Beperkte mate=2	Ruime mate=3
Volgen van (internationale) cursussen en opleidingen	1	2	3
Deelname aan (internationale) congressen	1	2	3
Werkervaring opdoen in buitenlandse onderzoeksgroep	1	2	3
Begeleiden van studenten en promovendi	1	2	3
Verstrekken van financiële bonussen	1	2	3
Verstrekken van eervolle vermeldingen of prijzen	1	2	3
Thuiswerken	1	2	3
Flexibele werktijden	1	2	3
Anders, namelijk	1	2	3

ONDERZOEKSBESPREKINGEN

Vraag 5 Kunt u de regelmaat van onderstaande bijeenkomsten binnen **uw onderzoeksgroep** aangeven?

	Zelden tot nooit=1	Min. Eén keer per jaar=2	Min. één keer per half jaar=3	Min. één keer maand=4	Min. één keer per week=5
Literatuur besprekingen	1	2	3	4	5
Voortgangsbesprekingen van lopende projecten	1	2	3	4	5
(Proef) presentaties van onderzoekers over eigen onderzoek	1	2	3	4	5
Besprekingen van concept artikelen & papers voor congressen	1	2	3	4	5
Presenteren van onderzoeksvoorstellen	1	2	3	4	5
Overig, namelijk	1	2	3	4	5

ONDERZOEKSBELEID

Vraag 6 Organiseert **u** in de onderzoeksgroep bijeenkomsten waarbij het (lange termijn) onderzoeksbeleid van de onderzoeksgroep ter discussie staat?

1 ☐ Ja
2 ☐ Nee → **Ga verder naar vraag 8**

Vraag 7 Wie participeren in de bijeenkomsten over het onderzoeksbeleid? *Meerdere antwoorden mogelijk*

1 ☐ Onderzoekers van de eigen onderzoeksgroep
2 ☐ Onderzoekers werkzaam in dezelfde universiteit / instelling als onderzoeksgroep
3 ☐ Onderzoekers werkzaam in dezelfde onderzoekschool als onderzoeksgroep
4 ☐ Onderzoekers werkzaam in andere universiteit / instelling als onderzoeksgroep
5 ☐ Buitenlandse onderzoekers

BEOORDELINGEN MEDEWERKERS

Vraag 8 Worden **uw medewerkers** beoordeeld door middel van functionerings- of beoordelingsgesprekken?

1 ☐ Ja
2 ☐ Nee → **Ga verder naar vraag 11**

Vraag 9 Met welke regelmaat vinden de gesprekken plaats?

1 ☐ Minimaal een keer per half jaar
2 ☐ Minimaal een keer per jaar
3 ☐ Minimaal een keer per twee jaar
4 ☐ Minimaal een keer per vijf jaar

Vraag 10 Wat is (zijn) het (de) doel(en) van de functionerings- of beoordelingsgesprekken? *Meerdere antwoorden mogelijk*

1 ☐ Evalueren van de output aan de hand van eerder gemaakte afspraken
2 ☐ Ontwikkelingsmogelijkheden van medewerker in kaart brengen
3 ☐ Maken van jaarafspraken met medewerker
4 ☐ Mogelijkheid voor medewerker om reflectie op het leiderschap van leidinggevende te geven
5 ☐ Het verbeteren van de relatie tussen medewerker en leidinggevende
6 ☐ Anders, namelijk ….

BEOORDELINGEN ONDERZOEKSVOORSTELLEN

Vraag 11 Worden onderzoeksvoorstellen vóórbeoordeeld voordat ze ingediend worden bij externe onderzoeksfinanciers? *Meerdere antwoorden mogelijk*

1 ☐ Nee → **Ga verder naar vraag 14**
2 ☐ Ja, op het niveau van de onderzoeksgroep/afdeling
3 ☐ Ja, op het niveau van het onderzoeksinstituut binnen het UMC/onderzoeksinstelling
4 ☐ Ja, op het niveau van de UMC/onderzoeksinstelling

Vraag 12 Voor welke externe onderzoeksfinanciers geldt deze interne voorbeoordeling van projectvoorstellen?

	Naam onderzoeksfinancier
Beoordeling op niveau van de onderzoeksgroep/afdeling:	1. 2. 3.
Beoordeling op niveau van het onderzoeksinstituut binnen UMC/onderzoeksinstelling	1. 2. 3.
Beoordeling op niveau van de UMC/onderzoeksinstelling:	1. 2. 3.

Vraag 13 Wilt u aangeven in hoeverre **u** het met onderstaande beweringen eens bent

	Helemaal mee oneens=1	Mee oneens=2	Niet eens, niet oneens=3	Mee eens=4	Helemaal mee eens=5
Onderzoekers werkzaam in mijn onderzoeksgroep zijn niet verplicht het commentaar en aanbevelingen van vóór-beoordelaars te verwerken in het definitieve onderzoeksvoorstel	1	2	3	4	5
Ik (de onderzoeksleider) bepaal uiteindelijk of het onderzoeksvoorstel ingediend wordt bij een externe onderzoeksfinancier	1	2	3	4	5
De faculteit /instelling moet de mogelijkheid hebben om onderzoeksvoorstellen van onderzoeksgroepen te selecteren en deze in te dienen bij externe onderzoekfinanciers	1	2	3	4	5
Interne vóórbeoordelingen van onderzoeksvoorstellen leiden in het algemeen tot een verhoogde kans op financiering bij externe onderzoeksfinanciers	1	2	3	4	5

EVALUATIES ONDERZOEKSOUTPUT

Sinds 2003 is het Standard Evaluation Protocol (SEP) het nieuwe evaluatie systeem voor al het publiek gefinancierd onderzoek. Het SEP is ontwikkeld door de VSNU, KNAW en NWO. Het vervangt het Discipline Advies Geneeskunde, dat in 1998 (DAG1998) voor het laatst heeft plaatsgevonden. Uitgangspunt van SEP is dat onderzoekers zoveel mogelijk van hun tijd moeten kunnen besteden aan onderzoek. Het SEP stelsel zal dus moeten leiden tot een substantiële vermindering van de beoordelingslast. Twee elementen staan centraal:
(1) regelmatige interne zelfevaluatie van de onderzoekseenheid en
(2) zesjaarlijkse externe evaluatie van het uitgevoerde wetenschappelijk onderzoek van de onderzoekseenheid met behulp van peer review. Dit vindt plaats op basis van de regelmatige zelfevaluaties. Onderzoeksgroepen zorgen op eigen initiatief voor regelmatige zelfevaluatie van het onderzoek en de sturing ervan.

Worden de evaluaties van de onderzoeksoutput binnen uw onderzoeksinstituut / UMC uitgevoerd volgens de richtlijnen van het SEP?

1 ☐ Ja
2 ☐ Nee; alternatieve methode wordt gehanteerd
3 ☐ Weet niet

ZELFEVALUATIE: *Denk bij het invullen van onderstaande vragen aan de meest recente zelfevaluatie*

Vraag 14	*zeer intensief--niet intensief*				
In hoeverre bent u betrokken geweest bij de meest recente zelfevaluatie	1	2	3	4	5
Hoe worden volgens u de resultaten, conclusies en aanbevelingen van de zelfevaluatie verwerkt?	1	2	3	4	5
	zeer waardevol-------------------------neutraal----------------------zonder waarde				
Hoe ervaart u de uitkomsten, conclusies en aanbevelingen van de zelfevaluatie?	1	2	3	4	5

EXTERNE EVALUATIE: *Denk bij het invullen van onderstaande vragen aan de meest recente externe evaluatie*

Vraag 15	*zeer intensief--niet intensief*				
In hoeverre bent u betrokken geweest bij de meest recente externe evaluatie	1	2	3	4	5
Hoe worden volgens u de resultaten, conclusies en aanbevelingen van de externe evaluatie verwerkt?	1	2	3	4	5
	zeer waardevol-------------------------neutraal----------------------zonder waarde				
Hoe ervaart u de uitkomsten, conclusies en aanbevelingen van de externe evaluatie?	1	2	3	4	5

Onderstaande vraag alleen beantwoorden als u ervaring heeft met het SEP .
Vraag 16 Op basis van mijn eigen ervaring ben ik van mening dat de uitkomsten van de zelfevaluatie en de externe evaluatie volgens de richtlijnen van het SEP vergeleken met de procedure en uitkomsten van het DAG 1998 leiden tot:

	Helemaal mee oneens=1	Mee oneens=2	Niet eens, niet oneens=3	Mee eens=4	Helemaal mee eens=5
Betere besluiten over de richting van het onderzoek	1	2	3	4	5
Betere besluiten over de uitvoering van het onderzoek	1	2	3	4	5
Minder zware bureaucratische lasten voor onderzoekers	1	2	3	4	5

EVALUATIE ONDERZOEKSCHOLEN

Denk bij het invullen van onderstaande vragen aan de meest recente externe evaluatie van de onderzoekschool waarin uw onderzoeksgroep participeert:

Vraag 17	Zeer waardevol----------------------- Neutraal--------------------Zonder waarde				
Hoe ervaart u de uitkomsten, conclusies en aanbevelingen van de externe evaluatie van de onderzoekschool	1	2	3	4	5
	Zeer intensief---Niet intensief				
Op welke wijze worden de resultaten, conclusies en aanbevelingen van de externe onderzoekschoolevaluatie verwerkt?	1	2	3	4	5

Deel 2: TIJDSBESTEDING VAN TAKEN

Vraag 18 Hoeveel tijd (als percentage van uw feitelijke werktijd) besteedt **u** naar schatting gemiddeld per jaar aan:

	Geen =1	1-10% =2	11-20% =3	21-30% =4	31-40% =5	41-50% =6	51-100% =7
Uitvoeren en ontwikkelen van (lab)experimenten en of analyses	1	2	3	4	5	6	7
Geven en ontwikkelen van onderwijs	1	2	3	4	5	6	7
Patiëntenzorg	1	2	3	4	5	6	7
Begeleiden van AIO's, OIO's en of junior onderzoekers	1	2	3	4	5	6	7
Onderzoeksmanagement (incl. onderzoeksbesprekingen) binnen de onderzoeksgroep	1	2	3	4	5	6	7
Onderzoeksmanagement buiten de onderzoeksgroep	1	2	3	4	5	6	7
Overige onderzoeksactiviteiten (schrijven van onderzoeks-voorstellen en artikelen, houden van presentaties)	1	2	3	4	5	6	7

Vraag 19 Hoeveel tijd besteedt **u** naar schatting gemiddeld per jaar aan de onderstaande externe (=buiten de onderzoeksgroep) onderzoeksactiviteiten?
Één werkdag staat voor 8 uur

	Geen =1	1-10 dagen =2	11-20 dagen =3	21-30 dagen =4	31-40 dagen =5	41-50 dagen =6	>50 dagen =7
Werkbezoeken	1	2	3	4	5	6	7
Begeleiden van promovendi werkzaam buiten de onderzoeksgroep	1	2	3	4	5	6	7
Houden van lezingen	1	2	3	4	5	6	7
Bezoeken van symposia en congressen	1	2	3	4	5	6	7
Organiseren van symposia en congressen	1	2	3	4	5	6	7
Deelname in redactie van (bio)medische tijdschriften	1	2	3	4	5	6	7
Deelname in beoordelingscommissies en of bestuurlijke activiteiten van onderzoeksfinanciers	1	2	3	4	5	6	7
Deelname in auditcommissies	1	2	3	4	5	6	7

Vraag 20a Zijn er, naast u zelf, nog andere leden van uw onderzoekgroep die leidinggevende taken hebben?

1 ☐ Ja, er is tenminste één andere formele leidinggevende
2 ☐ Ja, maar alleen informeel
3 ☐ Nee → **Ga verder naar vraag 21**

Vraag 20b Zo ja, waar houden deze andere (formele of informele) leidinggevenden zich mee bezig?

	Helemaal niet--Zeer intensief				
Uitvoeren en ontwikkelen van (lab)experimenten en of analyses	1	2	3	4	5
Geven en ontwikkelen van onderwijs	1	2	3	4	5
Patiëntenzorg	1	2	3	4	5
Begeleiden van AIO's, OIO's en of junior onderzoekers	1	2	3	4	5
Onderzoeksmanagement (incl. onderzoeksbesprekingen) binnen de onderzoeksgroep	1	2	3	4	5
Onderzoeksmanagement buiten de onderzoeksgroep	1	2	3	4	5
Overige onderzoeksactiviteiten (schrijven van onderzoeksvoorstellen en artikelen, houden van presentaties)	1	2	3	4	5

DEEL 3: ONDERZOEKSFINANCIERING

Vraag 21 Hoeveel onderzoeksfinanciering verkrijgt **uw onderzoeksgroep** op dit moment van onderstaande financiers (uitgedrukt als percentage van het gehele onderzoeksbudget)?

a. Universiteit Percentage: _____ (0 – 100%)
b. Instelling Percentage: _____ (0 – 100%)
c. NWO Percentage: _____ (0 – 100%)
d. ZonMw Percentage: _____ (0 – 100%)
e. KNAW Percentage: _____ (0 – 100%)
f. Ministeries Percentage: _____ (0 – 100%)
g. Collectebusfondsen Percentage: _____ (0 – 100%)
h. Bedrijven/industrieën Percentage: _____ (0 – 100%)
i. Europese Fondsen Percentage: _____ (0 – 100%)
j. Overig Percentage: _____ (0 – 100%)

Vraag 22 Geef aan in hoeverre onderstaande beweringen op uw onderzoeksgroep van toepassing zijn. Ten opzichte van vijf jaar geleden is:

	Verminderd =1	Onveranderd =2	Verhoogd =3	Weet niet =4
De hoeveelheid eerste geldstroom financiering die uw onderzoeksgroep verkrijgt	1	1	3	4
De hoeveelheid NWO/ZonMw financiering die uw onderzoeksgroep verkrijgt	1	2	3	4
Het aantal onderzoeksvoorstellen die uw onderzoeksgroep indient bij NWO/ZonMw	1	2	3	4
De hoeveelheid financiering die uw onderzoeksgroep verkrijgt van collectebus fondsen	1	2	3	4
Het aantal onderzoeksvoorstellen die uw onderzoeksgroep indient bij collectebusfondsen	1	2	3	4
De hoeveelheid financiering die uw onderzoeksgroep verkrijgt van ministeries in Nederland	1	2	3	4
Het aantal onderzoeksvoorstellen die uw onderzoeksgroep indient bij EU fondsen	1	2	3	4
De hoeveelheid financiering die uw onderzoeksgroep verkrijgt van EU fondsen	1	2	3	4
De hoeveelheid financiering dat uw onderzoeksgroep verkrijgt van bedrijven, (farmaceutische) industrieën en zorgverzekeraars	1	2	3	4

DEEL 4: BETROKKENHEID BIJ ONDERZOEK

Vraag 23 Wilt u aangeven in hoeverre **u** het met onderstaande beweringen eens bent.

	Helemaal mee oneens =1	Mee oneens=2	Niet eens, niet oneens=3	Mee eens=4	Helemaal mee eens=5
Ik voel me meer een onderzoeker dan een manager	1	2	3	4	5
Ik voel me nog steeds betrokken bij de inhoud van het onderzoek van mijn onderzoeksgroep	1	2	3	4	5
Ik ben goed op de hoogte van de laatste ontwikkelingen binnen mijn vakgebied	1	2	3	4	5
Ik houd vakliteratuur zorgvuldig bij	1	2	3	4	5
Ik lever door het genereren van nieuwe ideeën een concrete bijdrage aan de inhoud van het onderzoek van mijn onderzoeksgroep	1	2	3	4	5
Ik ben intensief betrokken bij een of meerdere onderzoeksprojecten binnen mijn onderzoeksgroep	1	2	3	4	5
Ik kom regelmatig naar onderzoeksbijeenkomsten die binnen de onderzoeksgroep georganiseerd worden	1	2	3	4	5
Ik publiceer nog regelmatig als eerste auteur in internationale tijdschriften	1	2	3	4	5
Mijn medewerkers zien mij als een 'high-skilled' scientist	1	2	3	4	5
Ik fungeer als vraagbraak voor het oplossen van onderzoeksproblemen en -vragen van mijn medewerkers	1	2	3	4	5

Vraag 24 In welke mate spelen onderstaande **inhoudelijke overwegingen** bij u een rol in het kiezen van een (nieuw) onderzoeksonderwerp?

	Niet belangrijk---------------------Neutraal--------------------Zeer belangrijk				
Mate van samenhang met mijn voorgaand onderzoek	1	2	3	4	5
Voortzetting van locale onderzoeksthema's in mijn discipline	1	2	3	4	5
Internationaal in de belangstelling staande onderzoek-sthema's	1	2	3	4	5
Theoretisch uitdagende onderzoeksthema's die vernieuwend zijn	1	2	3	4	5
Mogelijkheid om nieuwe onderzoekslijnen uit te proberen	1	2	3	4	5
Belangstelling en mogelijkheden van junior onderzoekers	1	2	3	4	5
Uitvoerbaarheid door junior onderzoekers	1	2	3	4	5
Zekerheid dat er resultaat geboekt wordt dmv. promoties	1	2	3	4	5
Mening van collega's in mijn vakgebied in Nederland	1	2	3	4	5
Mening van collega's in mijn vakgebied in Europa	1	2	3	4	5
Aandachtsgebieden van onderzoeksprogramma's in Nederland	1	2	3	4	5
Aandachtsgebieden van onderzoeksprogramma's in Europa	1	2	3	4	5
Mogelijkheid om in de Nederlandse gezondheidszorg toepassingen van nieuwe ontwikkelingen te vinden	1	2	3	4	5
Mogelijkheid om zichtbaarheid te verwerven in tijd-schriften zoals bijvoorbeeld Nature, Sciene, the Lancet	1	2	3	4	5
Toepassingsmogelijkheden van aanwezige of nieuwe laboratorium apparatuur	1	2	3	4	5

DEEL 5: MAATSCHAPPELIJKE IMPACT VAN GEZONDHEIDSONDERZOEK

Vraag 25 De toenemende aandacht voor maatschappelijke impact van gezond-heidsonderzoek leidt ertoe dat het onderzoek binnen mijn groep beter en/of meer:

	helemaal mee oneens-----------------------------------helemaal mee eens				
Afgestemd is op medische problemen in de samenleving	1	2	3	4	5
Bruikbare vernieuwingen voor de praktijk oplevert	1	2	3	4	5
Rekening houdt met het maatschappelijk belang	1	2	3	4	5
Relevant is voor de maatschappij	1	2	3	4	5
Extern gecommuniceerd wordt naar publiek (via media)	1	2	3	4	5
Extern gecommuniceerd wordt naar professionals in de preventie en zorg	1	2	3	4	5
Extern gecommuniceerd wordt naar patiënten(organisaties)	1	2	3	4	5
Extern gecommuniceerd wordt naar professionals in beleid	1	2	3	4	5
Extern gecommuniceerd wordt naar professionals in het bedrijfsleven	1	2	3	4	5
Vertaald wordt in mogelijke beleidsimplicaties	1	2	3	4	5

Vraag 26 De toenemende aandacht voor maatschappelijke impact van gezondheidsonderzoek leidt in mijn onderzoeksgroep tot beter en/of meer:
Nb. Doelgroepen zijn: algemeen publiek (via media), patiënten(organisaties), professionals in de preventie en zorg, professionals in beleid en professionals in het bedrijfsleven)

	helemaal mee oneens-----------------------------------helemaal mee eens				
Kennisprodukten gericht op de doelgroepen	1	2	3	4	5
Kennisoverdracht naar de doelgroepen	1	2	3	4	5
Kennisgebruik door de doelgroepen	1	2	3	4	5
Middelen (werfkracht) uit de doelgroepen	1	2	3	4	5

Vraag 27 Kunt u aangeven of uw onderzoeksgroep in de periode 2004 tot en met 2006 onderstaande maatschappelijke outputproducten gerealiseerd heeft. Zo ja kunt u een (ruwe) schatting geven van het aantal.

	Ja=1	Nee=2	Schatting aantal:
Klinische richtlijnen	1	2	
Beleidsrapport	1	2	
Publicaties in tijdschriften gericht op beleid of professionals	1	2	
Bijdragen aan publieke media (tv, radio, krant)	1	2	
Presentaties voor niet-wetenschappelijk publiek (professionals, beleidsmakers, patiënten)	1	2	
Bijdragen aan symposia en conferenties gericht op maatschappelijke doelgroepen	1	2	
Onderwijs of bijscholing voor beleidsmedewerkers of professionals	1	2	
Lidmaatschap van commissies die gericht zijn op richtlijnontwikkeling of het opstellen van beleidsadviezen	1	2	
Lidmaatschap van commissies die maatschappelijk gericht onderzoek betalen	1	2	
Editorships van maatschappelijke tijdschriften (gericht op professionals)	1	2	

DEEL 6: FEITELIJKE VRAGEN OVER UW ONDERZOEKSGROEP

Vraag 28 Kunt u aangeven hoeveel **medewerkers** (fte) er werkzaam zijn in uw onderzoeksgroep (inclusief u zelf)?

	Aantal fte's
Hoogleraren	
Gepromoveerde onderzoekers	
Promovendi	
Analisten	
Technisch personeel	
Overige wetenschappelijke medewerkers	

Vraag 29a Door welke **disciplines** kan uw onderzoeksgroep gekarakteriseerd worden? *Meerdere antwoorden mogelijk*

1	☐	Cel- en ontwikkelingsbiologie	15	☐	Biomedische Technologie
2	☐	Genetica	16	☐	Farmacologie en Toxicologie
3	☐	Bio-informatica/Epidemiologie	17	☐	Endocrinologie
4	☐	Immunologie	18	☐	Stofwisseling
5	☐	Microbiologie	19	☐	Basale Neurowetenschappen
6	☐	Virologie	20	☐	Neurologie
7	☐	Oncogenese	21	☐	Psychiatrie
8	☐	Cardiovasculair systeem	22	☐	Psychologisch gezondheidsonderzoek
9	☐	Bloed en bloedvorming	23	☐	Voeding, milieu, arbeid en gezondheid
10	☐	Nierfunctie	24	☐	Gerontologie en Geriatrie
11	☐	Ademhaling	25	☐	Jeugd en gezondheid
12	☐	Huid	26	☐	Sociale Geneeskunde
13	☐	Bewegingsapparaat	27	☐	Huisartsgeneeskunde
14	☐	Maag, darm, lever	28	☐	Gezondheidszorgonderzoek

Vraag 29b Welke van de bovenstaande disciplines speelt de **belangrijkste rol** in uw onderzoeksgroep?

Discipline _________

Vraag 30 Hoeveel procent van het onderzoek van uw onderzoeksgroep beschouwt u als **discipline doorsnijdend**?

1	☐	0-20%	3	☐	41-60%	5	☐	81-100%
2	☐	21-40%	4	☐	61-80%			

Vraag 31 Op welk **onderdeel van gezondheidsonderzoek** richt het onderzoek van uw onderzoeksgroep zich voornamelijk *(maximaal 2 antwoorden mogelijk)*?

1 ☐	Sub cellulair	3 ☐	Orgaan niveau	5 ☐	Patiënten
2 ☐	Cel niveau	4 ☐	Ziekteprocessen	6 ☐	Volksgezondheid / Gezondheidszorg-systeem

Vraag 32 Wat zijn de belangrijkste (maximaal drie) **onderzoeksdoelen** van uw onderzoeksgroep?

1 ☐	Wetenschappelijke publicaties	7 ☐	Ontwikkeling van nieuwe producten
2 ☐	Exploitatie van kennis	8 ☐	Nieuwe collegiale interactie
3 ☐	Ontwikkeling van een methodologie	9 ☐	Kennis overdracht naar gebruikers
4 ☐	Training van jonge onderzoekers	10 ☐	Verzamelen van empirisch materiaal
5 ☐	Ontwikkeling van onderzoekscapaciteiten	11 ☐	Internationale contacten
6 ☐	Ontwikkeling van nieuwe kennis	12 ☐	Verkrijgen van onderzoeksfinanciering

Vraag 33 Geef aan welk van onderstaande antwoorden het meest overeen komt met de mate waarin de **basissamenstelling** (=vaste stafleden) van uw onderzoeksgroep de afgelopen vijf jaar veranderd is:

1 ☐ Onderzoeksgroep ligt in principe voor meerdere jaren vast
2 ☐ Onderzoeksgroep ligt meestal voor een jaar vast
3 ☐ Onderzoeksgroep ligt voor niet meer dan een half jaar vast
4 ☐ Onderzoeksgroep verandert zeer vaak van samenstelling

HARTELIJK DANK VOOR UW MEDEWERKING

Appendix 2

Expert meeting Management, Organisation and Performance of Biomedical Research Groups – 14 November 2008

In addition to the quantitative data, preliminary results were presented on a four-hour expert meeting with 27 participants. The goal of this meeting was to get feedback on the results and policy recommendations. Participants were academic group leaders and experts from various organizations such as UMCs, non-university research institutes, NFU, ZonMw, NWO, KNAW, RGO, QANU en charity funds.

Participants

dr. Edvard Beem, *ZonMw*
prof.dr R. Benner, *Erasmus MC*
prof.dr. Peter van den Besselaar, *Rathenau Instituut* and *VU*
prof.dr. Geert Blijham, *UMCU* en *NFU*
dr. Gijs Boerrigter, *KWF Kankerbestrijding*
prof.dr. Piet Borst, *NKI* en *Innovatieplatform*
prof.dr. R. Friele, *Nivel*
mw dr. Saskia Ebeling, *Utrecht Life Sciences*
prof.dr. Peter Groenewegen, *VU*
prof.dr. Eduard Klasen, *LUMC*
prof.dr Gabriel Krestin, *Erasmus MC*
drs. Ruud Kukenheim, *LUMC*
mw dr. Sandy Litjens, *RGO*
mw dr. Sonja Meeuwsen, *Instituut Beleid, Management* and *Gezondheidszorg*
mw prof.dr. Christine Mummery, *LUMC*
prof.dr. Peter Nijkamp, *NWO*
mr. Chris Peels, *QANU*
drs. Jan Willem Smeenk, *Sanquin Research*
mw dr. Marianne van Stipdonk, *Nederlands Vaccin Instituut*
mw dr. Christine Teelken, *VU*
mw dr. Esther van Tienhoven, *KNAW, Raad van de Medische Wetenschappen*
mw dr. Gepke Uiterdijk, *Stafbureau RvB AMC*
drs. Wim van Velzen, *Rathenau Instituut*
mw drs. Maaike Verbree, *Rathenau Instituut*
dr.ir. Cees Vos, *Ministerie VWS*
mw dr. Inge van der Weijden, *Rathenau Instituut*
prof.dr. Ben van der Zeijst, *Nederlands Vaccin Instituut*

Dankwoord

Voor goed onderzoek is de juiste werkomgeving essentieel. Ik heb het genoegen dat ik word (werd) omringd door een groep creatieve, enthousiaste, georganiseerde, gezellige, innovatieve, inspirerende, kritische en talentvolle mensen. Al deze personen hebben op hun eigen wijze bijgedragen aan het ontstaan van dit proefschrift. Hiervoor wil ik iedereen dan ook hartelijk bedanken.

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Peter wil ik graag bedanken voor zijn rol als promotor. Ik had me geen betere promotor kunnen wensen. Jouw enthousiasme, nieuwsgierigheid en kritische vragen inspireerden mij na ieder gesprek – en dat zijn er heel wat geweest – om weer verder op onderzoek uit te gaan. Jij hebt me laten zien hoe leuk het is om onderzoek te doen. Maar ik heb ook veel geleerd van je methodische en inhoudelijke kennis. Inge, mijn copromotor, wil ik natuurlijk allereerst bedanken voor de mogelijkheid die je me hebt gegeven om op jouw eigen werk voort te bouwen. Je hebt me de volledige vrijheid gegeven om er mijn eigen werk van te maken; hiervoor ben ik je ontzettend dankbaar. Ook had je altijd goede organisatorische en strategische adviezen. Deze hebben zeker geholpen om het gehele traject soepel te laten verlopen. Bovenal wil ik Peter en Inge bedanken voor de zeer prettige en productieve samenwerking, ik hoop dat we dat in de toekomst kunnen voortzetten.

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Instituut. Ik hoop dat er nog vele mogen volgen. Speciale dank aan Clara, die dit geweldig heeft gecoördineerd.

Natuurlijk wil ik ook mijn collega's van de afdeling Science System Assessment bedanken voor de geweldige werksfeer in de afgelopen jaren. Het is een feest geweest om met jullie samen te werken. In het bijzonder wil ik Floortje bedanken, die vanaf het allereerste uur mijn steun en toeverlaat is geweest. Mijn teamgenoten Pleun en Rosalie wil ik extra bedanken voor hun feedback tijdens onze team-meetings, maar vooral natuurlijk voor de enorme gezelligheid en emotionele ondersteuning. Mijn kamergenoot Stefan dank ik voor al onze gesprekken over de echt belangrijke zaken in het leven. Thomas and Pleun, we had a great time in Essex but please do not go anywhere without your GPS. I also really enjoyed our Ju-Sci meetings; the best preparation for the future as highly-skilled scientist.

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Who was Rathenau?

The Rathenau Institute is named after Professor G.W. Rathenau (1911-1989), who was successively professor of experimental physics at the University of Amsterdam, director of the Philips Physics Laboratory in Eindhoven, and a member of the Scientific Advisory Council on Government Policy. He achieved national fame as chairman of the commission formed in 1978 to investigate the societal implications of micro-electronics. One of the commission's recommendations was that there should be ongoing and systematic monitoring of the societal significance of all technological advances. Rathenau's activities led to the foundation of the Netherlands Organization for Technology Assessment (NOTA) in 1986. On 2 June 1994, this organization was renamed 'the Rathenau Institute'.

In order to conduct excellent research that contributes to solving complex scientific and societal issues, the availability of talented, creative, innovative, and enthusiastic researchers is crucial. However, researchers can excel only in an adequate environment. Increasingly, the work environment for researchers is their research group. And the challenge for academic group leaders is to create adequate conditions for meeting individual and collective goals, such as high research performance. Group leaders facilitate research meetings, supervise junior researchers and generate exciting new ideas. Their external activities are increasingly important, such as acquiring funding, maintaining collaboration networks and disseminating knowledge to society at large. The research question of this study is, *'how does academic leadership affect performance of research groups?'*

Two key factors are identified that positively influence the performance of research groups. The first is academic leadership: the way researchers are guided and stimulated by the vision and inspiration of the group leader. The other key factor is network management: the way academic leaders position their groups in scientific and societal environments and how they respond to environmental opportunities and constraints.

The study ends with a discussion on the implications for organising research and for science policy.

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