ISSI 2023 Proceedings, v1, pp 463–472
DOI: 10.5281/zenodo.8305925 https://cns-iu.github.io/workshops/2023-07-02_issi/

Determinants of cognitive mobility

Charlie Mom[1], Torger Möller[2], Peter van den Besselaar[3]

[1] charlie@teresamom.com
TMC Research, Middenweg 203, Amsterdam, 1098 AN, (Netherlands)

[2] *moeller@dzhw.eu*
German Centre for Higher Education Research and Science Studies (DZHW),
Schützenstrasse 6a, Berlin, 10117, (Germany)

[3] *p.a.a.vanden.besselaar@vu.nl*
Faculty of Social Sciences, Vrije Universiteit Amsterdam, Amsterdam, (Netherlands)

Abstract
Cognitive mobility is the movement of researchers from one set of topics to other topics, and this may stimulate innovation in science. This paper starts with suggesting and further developing a method to measure cognitive mobility as a career property at the individual researcher level. Then we try to identify factors that stimulate or hinder the development of cognitive mobility. Starting with variables representing geographic mobility and virtual mobility, and variables measuring a researcher's productivity and independence, we develop a model explaining the level of cognitive mobility in different career phases. Whereas geographic mobility and virtual mobility have no or even a negative effect on cognitive mobility, the level of productivity and of independence both influence cognitive mobility positively.

Introduction
Cognitive mobility of researcher is defined here as moving towards other research specialties, leading to changes in a research portfolio. For example, if a researcher conducts research in only one topic during the entire career, e.g. science studies, then he or she is *not* cognitive mobile. Of course, this does not preclude changes in a research portfolio, but those changes followed the dynamics of the field it is part of.

Various aspects of cognitive mobility should be distinguished. There are different *levels* of cognitive mobility. On the one hand, if one moves within computer science from AI to data science, this is mobility within a discipline which may be called *local cognitive mobility*. On the other hand, moving from physics to social sciences can be called *global cognitive mobility*. One can also distinguish the *degree* of cognitive mobility: between adding other specialties to the existing portfolio and moving completely to other specialties. And the last distinction to be made is the *timing* of cognitive mobility, which may take place during different career phases. Why is cognitive mobility an interesting phenomenon? This is linked to the discussions about cognitive change and innovation in science.

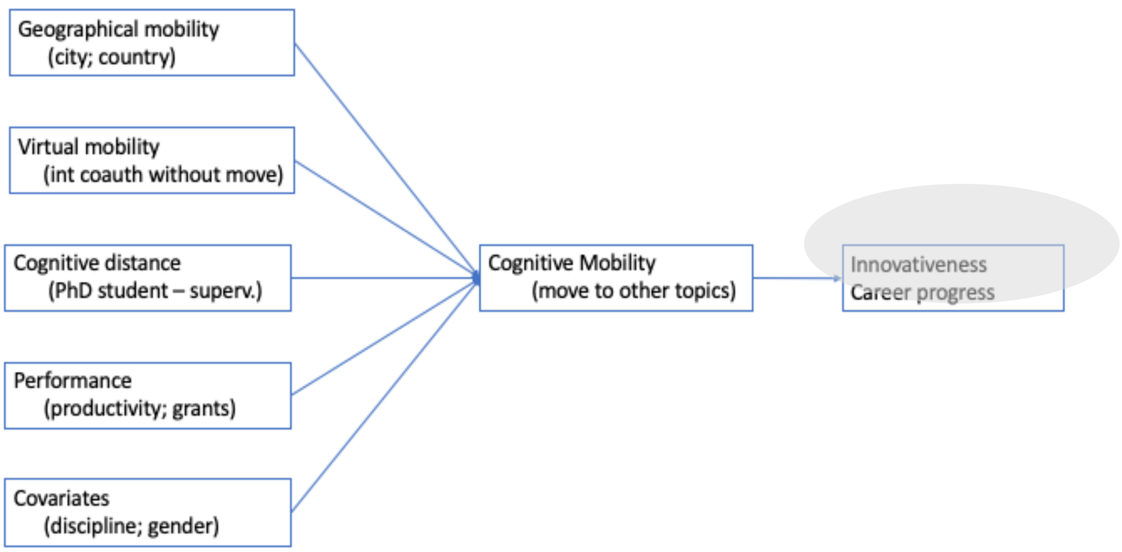
It is often argued that cognitive change and innovation take place at the boundaries between fields, and therefore multidisciplinary and interdisciplinary research would be the carrier of change. In terms of underlying social processes, one then may distinguish two forms: the first one is team science and working in interdisciplinary teams (Bozeman & Youtie 2017). The other process is at the individual level moving to new fields, where one then still may use knowledge and skills from the original field. For example, if computer scientists move to social sciences, they may bring their big data and modelling skills which may change social sciences and a new field of computational social sciences may emerge. As some moment we can assess with hindsight whether this is sustainable development.

At the individual level, the picture may be more complex, as cognitive mobility may not be beneficial in all career phases. For example, cognitive mobility in the early postdoc phase may work detrimental, as it may hinder to exploit the PhD research, whereas cognitive mobility later on may work out positively in terms of new scientific contributions and innovations. If cognitive mobility is beneficial for the contributions to science, one may expect that it also has a positive effect on the academic career which we aim to test in a later study.

Some remarks on earlier research

Mobility of researchers has been investigated intensively for many decades. The earlier studies had a focus on geographic mobility, more specifically in relation to brain drain (Vlachý 1979). There is also older work on cognitive mobility, for example studies of the mobility between the field of the PhD and the later research field, using data on research and teaching staff in academic institutions (Vlachý 1978). Recent studies - using bibliometric databases - on the geography of research collaboration do not address cognitive mobility, but focus on issues like the distance between collaborators (e.g. Frenken et al. 2009; Hoekman et al. 2009) and how geographic mobility supports knowledge transfer between countries (Aman 2020).

Bibliometric data are also a useful source for investigating cognitive mobility, but only a few examples of those studies are available, such as Helsten et al. (2007), Zhang & Glänzel (2012), Horlings & Gurney (2013), and Gläser and Laudel (2015). Although these studies use bibliometric data for studying cognitive mobility, they generally do this for mapping the cognitive mobility of a single or a few researchers. Here we are less interested in the cognitive career of single researchers, but aim to understand the causes and consequences of cognitive mobility, and how cognitive mobility relates to other forms of mobility, such as (inter)national geographic mobility and virtual mobility, the latter referring to distance collaboration without physically moving to other locations. This requires large scale studies, and a method to measure cognitive mobility that allows for upscaling, which seems rather difficult with the methods used in the forementioned studies.



Aim of this paper

In this paper we develop a method to measure cognitive mobility for large sets of researchers. After having done this, we address the question whether cognitive mobility depends on geographic mobility and virtual mobility, both to be defined below. Furthermore, we include several relevant covariates, such as the publication performance, and level of the researcher's independence[1]. In a next paper, we will include more covariates that may affect cognitive mobility, and analyze what *the effects* of cognitive mobility are, such as on career progress, and on scientific innovation. The model above illustrates the approach that is used, and it consists of the variables that are expected to influence the level of cognitive mobility of researchers.

Data and operationalization

The data

We have a dataset of all PhD graduates at a Dutch university from 2000 to 2005 in all fields. From the dataset, we take only those disciplines whose publications are mainly recorded in bibliometric databases and for which bibliometric indicators are reasonable to calculate. Data types used are articles, reviews, and letters. We have included in our study the following disciplines/faculties: natural sciences, life sciences, medicine, dentistry, mathematics and computer science, economics and psychology. In total we have a sample of 987 doctoral graduates, 366 of whom are from medical faculty. Of those, 285 have been active in all career phases, and the other 81 only in some.

For all PhD graduates we have collected and calculated various variables. Some of these variables are time independent, such as gender and faculty, while others may change over time. Our observation period covers about 20 years and is divided into four periods: (t_1) the PhD period, (t_2) the postdoc period, (t_3) the assistant professor period, and (t_4) the senior period. The definition of the periods are in the method section.

We are interested in the factors that influence the cognitive mobility of researchers over his or her career. The dependent variable in our models is 'cognitive mobility', which we measure by using the Scival's topic cluster classification, assigning every publication to one of 1,500 topic clusters (Elsevier 2022)[2]. In each of the four periods, we count the number of new topic clusters, which are the topic clusters in which a researcher published for the first time. The new topics clusters reflect the cognitive mobility of an author over time, who extends his or her oeuvre by adding further research topics.

Based on a dataset with the paper output of our population we can count the number of topics active in a timeframe. And if a topic cluster did not appear in the earlier career phases, we count such a topic cluster as new. The number of new topic clusters in a period constitutes our cognitive mobility indicator per career phase.

Core variables

In our models we include as core independent variables: (1) *Geographic mobility*, measured by the number of distinct cities in which the researcher has worked. Geographic mobility can be gauged in various ways. The (bibliometric) starting point is the address specified by the author on the publication. This usually contains the name of the organization, city and country. The limitation of this approach is that due to the publication delay we do not know if the person was still employed in the organization in the year of publication. In addition, the different organizational spellings and hierarchies create a challenge in unifying the data, even when using

[1] In the next version we will also include the number of prestigious grants, the grade for the PhD thesis, age, gender and year of PhD, plus interaction terms.
[2] https://service.elsevier.com/app/answers/detail/a_id/35065/supporthub/scival/kw/Topic+Cluster/

the Scopus affiliation ID. As data on cities and countries are much more unified and valid, we measure geographic mobility by cities rather than by organizations. (2) *Virtual mobility*, measured by the number of international publications (full count), which means publications in which organizations from different countries were involved. (3) *Cognitive distance*, measured by the number of independent topic clusters in a period divided by all topic clusters of the respective researcher up to that period. Independent topic clusters are those in which the researcher has not published jointly with his/her supervisor during the doctoral period. (4) *Output*, measured by the number of publications (full count). For linking the publications to the respective researcher, we use the Scopus author IDs and have made some corrections where needed (e.g., assigning multiple author IDs to one person).

Apart from those, we have various covariates in the dataset which are not yet included in the analysis: (5) *Gender*, (6) *Age* at the time of receiving the doctoral degree, and (7) *Cum laude*, which in the Dutch context means that the doctoral thesis was been awarded with the highest grade. Finally, we have for each of the participants the (8) *Faculty* where they graduated, in terms of the disciplines mentioned above. In this paper we restrict the analysis to the medical field, as this is the largest in the sample.

We have calculated the above mentioned bibliometric indicators for all four periods, allowing us to predict cognitive mobility by the behavioral variables of each of the career phases. In addition, we have calculated further bibliometric indicators in full and fractional count and we have calculated the bibliometric impact indicators size-dependent and size-independent, but these indicators are not yet integrated into the different models presented in this paper. However, we tested the model with these alternative performance indicators, but the full counted papers – which are used here –had the best predictions.

Method

We firstly calculated the correlations between the used variables. This gives a first impressing as to whether the forms of mobility (geographic, virtual and cognitive) do correlate positively or not.

Then we use General Linear Models[3], and more specifically a Repeated Measures ANCOVA model. The dependent variable 'cognitive mobility' is measured at four moments in time for each of the study participants: t_1 = the about five years until the PhD degree was granted; t_2 = the five years period after the PhD was granted; t_3 = the period between six and ten years after the PhD; and t_4 = eleven till fifteen years after the PhD. In total we cover about 20 years of the career, and these four phases correspond roughly with four career phases: the PhD student period, the postdoc period, the assistant professor period and the senior period.[4]

We predict the level of cognitive mobility (CM) at each of the four moments CM_{t1}, CM_{t2}, CM_{t3}, and CM_{t4}, using the independent variables in each of the earlier career phases as predictors. The next table summarizes the analysis.

[3] SPSS 26 for Windows

[4] In this senior phase, academics are often associate professor or (in case of a fast career) full professor. In the Netherlands, the average time to full professor is about 18 years, and our sample includes those that did become professor early.

Table 1. The analyses

Indep. Variables	Dependent variable: cognitive mobility in each of the career phases: PhD student	Postdoc	Assistant professor	Senior positions
PhD student	Indep. Var_{t1} -> CM_{t1}	Indep. Var_{t1} -> CM_{t2}	Indep. Var_{t1} -> CM_{t3}	Indep. Var_{t1} -> CM_{t4}
Postdoc		Indep. Var_{t2} -> CM_{t2}	Indep. Var_{t2} -> CM_{t3}	Indep. Var_{t2} -> CM_{t4}*
Assistant prof			Indep. Var_{t3} -> CM_{t3}	Indep. Var_{t3} -> CM_{t4}

For example, this should be read as: the independent variables are measured in the postdoc period, and are used to predict cognitive mobility in the senior period.

Findings

In this paper, we perform the analysis for the Medical and Life Science. The correlation between the core variables has been done for each of the four moments defined above. Table 2 shows the results.

Table 2. Correlations for the medical and life sciences field

	PhD cogmob	Postdoc cogmob	Assistant prof cogmob	Senior cogmob	PhD productivity	PhD geographic mobility	PhD virtual mobility	PhD cognitive distance	Postdoc productivity	Postdoc geographic mobility	Postdoc virtual mobility
Postdoc cogmob	.940**										
Assistant prof cogmob	.872**	.838**									
Senior cogmob	.709**	.644**	.826**								
PhD productivity	.789**	.727**	.702**	.587**							
PhD geographic mobility	.356**	.384**	.291**	.228**	.405**						
PhD virtual mobility	.445**	.420**	.429**	.356**	.689**	.411**					
PhD cognitive distance	.288**	.334**	.252**	.149**	.125**	.237**	0.091				
Postdoc productivity	.343**	.188**	.438**	.535**	.445**	.189**	.341**	0.065			
Postdoc geographic mobility	.163**	0.095	.192**	.219**	.099*	.196**	.194**	.165**	.300**		
Postdoc virtual mobility	.223**	.110*	.311**	.367**	.354**	.220**	.466**	0.069	.782**	.355**	
Postdoc cognitive distance	.103*	.180**	.258**	.216**	-0.060	0.028	-0.051	.379**	0.016	.100*	-0.003

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

First of all, the levels of cognitive mobility in the four phases correlate strongly, and – not unexpected – the more distant the phases are, the lower the correlation. The correlation between cognitive mobility and the other forms of mobility (virtual mobility and geographic mobility) in the PhD phase is moderate, and in the postdoc phase relatively weak and not always statistically significant. Productivity in the PhD period correlates strongly with cognitive distance in all the four career phases. This is much less the case for productivity postdoc phase, where the correlation is moderate. Finally, productivity correlates strongly with virtual mobility, in the PhD phase as well as in the postdoc phase.

Figure 1 shows for each of the four career phases the distribution of the (medical and life sciences) participants in terms of the number of new topics researched in that phase. Figure 2 summarizes this and shows the averages in those four phases.

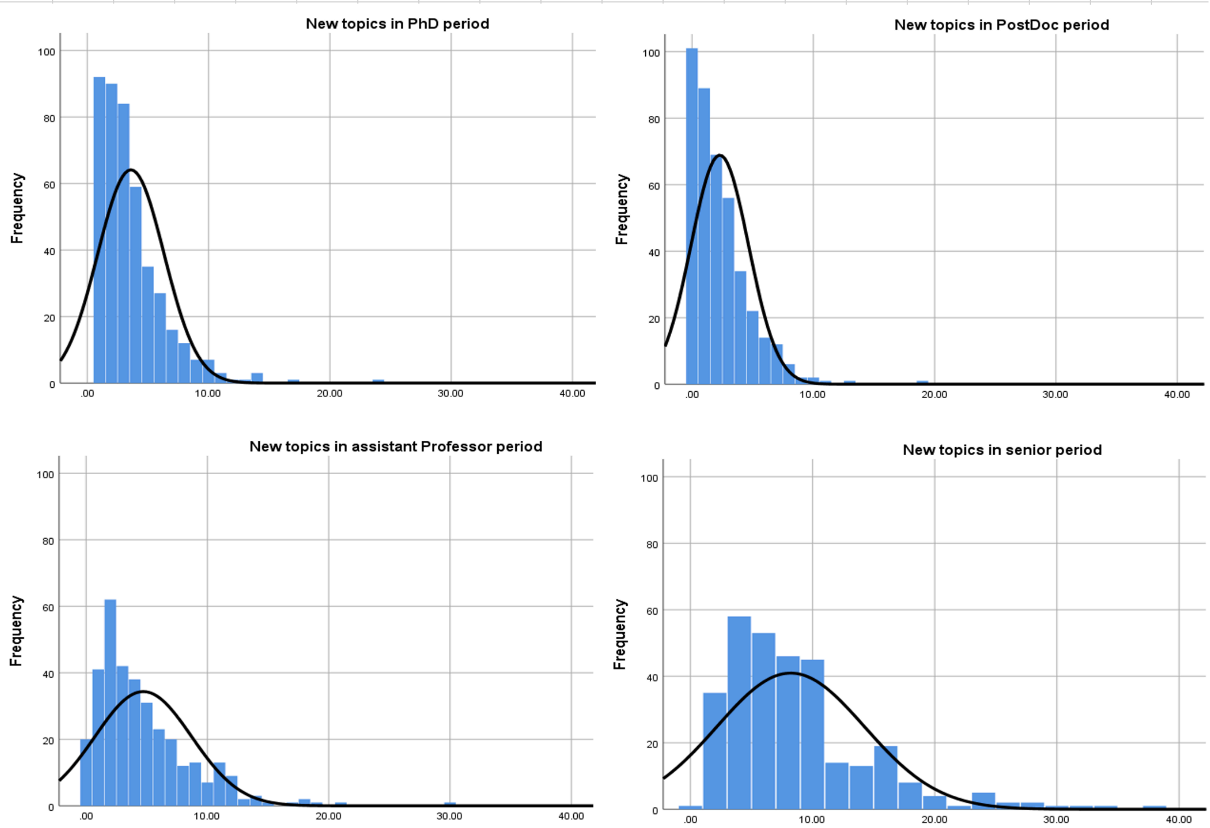


Figure 1. Distribution of new topics by career phase, medical and life sciences

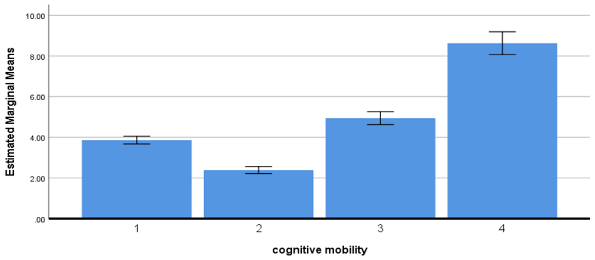


Figure 2. Average cognitive mobility by career phase, medical and life sciences

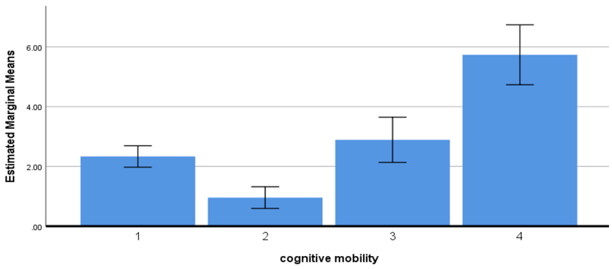


Figure 3. Average cognitive mobility by career phase, psychology

Figure 2 shows that the later in the career, the higher the level of cognitive mobility, defined as the number of new research topics covered in that phase. The only exception is career phase 1, the PhD phase. In that phase all research topics are new, as this is generally the start of the academic research. In the postdoc phase, the trajectory towards independent research starts with some new topics, and that increases over the career.

Figure 3 gives a first result of the extension of the study to other research fields and shows for psychology a similar picture as for medical and life sciences, although the averages in each phase are lower than in medical and life sciences.

The next step is to predict the cognitive mobility in the four phases, using the behavioral variables in the three preceding phases, as explained in table 1. Table 3 shows how behavior in the PhD phase predicts cognitive mobility in the PhD period, the postdoc period, the assistant professor period, and the senior period respectively. We tested for interaction effects, but these were not existent in the current set of independent variables.

Table 3. PhD behavior influencing cognitive mobility in four career phases

		B	Std. Error	t	Sig.	95% Conf. Interval LB	UB	Partial Eta Squared
PhD behavior	Intercept	0.007	0.036	0.183	0.855	-0.064	0.077	0.000
->	Productivity	0.933	0.046	20.433	0.000	0.843	1.023	0.599
PhD cognitive	Geogr. mobility	0.001	0.040	0.037	0.971	-0.077	0.080	0.000
mobility	Virtual mobility	-0.236	0.046	-5.174	0.000	-0.325	-0.146	0.087
	Cognitive distance	0.210	0.038	5.545	0.000	0.136	0.285	0.099
PhD behavior	Intercept	-0.038	0.038	-1.004	0.316	-0.112	0.036	0.004
->	Productivity	0.795	0.048	16.423	0.000	0.700	0.890	0.491
Postdoc cogn.	Geogr.mobility	0.054	0.042	1.272	0.204	-0.029	0.137	0.006
mobility	Virtual mobility	-0.207	0.048	-4.297	0.000	-0.303	-0.112	0.062
	Cognitive distance	0.226	0.040	5.615	0.000	0.147	0.305	0.101
PhD behavior	Intercept	-0.016	0.041	-0.380	0.704	-0.097	0.066	0.001
->	Productivity	0.727	0.053	13.740	0.000	0.623	0.831	0.403
Assistant prof	Geogr. mobility	-0.019	0.046	-0.412	0.681	-0.110	0.072	0.001
cogn. mobility	Virtual mobility	-0.135	0.053	-2.552	0.011	-0.238	-0.031	0.023
	Cognitive distance	0.187	0.044	4.260	0.000	0.101	0.274	0.061
PhD behavior	Intercept	0.008	0.048	0.174	0.862	-0.086	0.102	0.000
->	Productivity	0.613	0.061	10.005	0.000	0.493	0.734	0.263
senior cognitive	Geogr. mobility	-0.022	0.054	-0.410	0.682	-0.127	0.083	0.001
mobility	Virtual mobility	-0.112	0.061	-1.836	0.067	-0.233	0.008	0.012
	Cognitive distance	0.115	0.051	2.255	0.025	0.015	0.215	0.018

The analysis gives a consistent picture. For each of the phases, the most important predictor in the PhD phase of cognitive mobility is productivity, and not unexpected the effect decreases over time. Cognitive distance to the PhD supervisors (researcher independence) is also a positive predictor of cognitive mobility, whereas virtual mobility (the number of foreign co-authors) is a negative predictor. Why would this be the case? PhD students with a large international network may be less free to move to other topics, bounded by a strong existing network. Or the other way around, the not so cognitively mobile doctoral student has focused on international collaborations within his field rather than going into new research fields. One career strategy could then be to go deep and network internationally in limited fields of research, while the other career strategy is to go broad and expand one's thematic research profile. Finally, geographic mobility within the PhD period is completely unrelated to cognitive mobility.

Table 4 shows how postdoc behavior influences cognitive mobility in three subsequent career phases. Here we find a consistent pattern indicating that productivity and cognitive distance have a positive effect on cognitive mobility, albeit less strong as in the previous analysis. Virtual mobility and geographic mobility in the postdoc phase do not have a positive statistically significant effect on cognitive mobility in each of the three phases. This is interesting, as it is often said that mobility in the Postdoc phase is important for learning new things. However, the results suggest that this is not necessarily the case.

Table 4. Postdoc behavior influencing cognitive mobility in three career phases

		B	Std. Error	t	Sig.	95% Conf. interval LB	UB	Partial Eta Squared
Postdoc behavior	Intercept	-0.011	0.061	-0.183	0.855	-0.130	0.108	0.000
->	Productivity	0.302	0.085	3.545	0.000	0.134	0.470	0.043
Postdoc cogn.	Geogr. mobility	0.040	0.057	0.706	0.481	-0.071	0.151	0.002
mobility	Virtual mobility	-0.129	0.085	-1.522	0.129	-0.296	0.038	0.008
	Cognitive distance	0.167	0.064	2.590	0.010	0.040	0.293	0.023
Postdoc behavior	Intercept	-0.043	0.052	-0.822	0.412	-0.146	0.060	0.002
->	Productivity	0.470	0.074	6.387	0.000	0.325	0.615	0.127
assistant prof	Geogr.mobility	0.048	0.049	0.985	0.326	-0.048	0.144	0.003
cogn. mobility	Virtual mobility	-0.077	0.073	-1.053	0.293	-0.221	0.067	0.004
	Cognitive distance	0.295	0.056	5.307	0.000	0.185	0.404	0.091
Postdoc behavior	Intercept	-0.047	0.050	-0.927	0.355	-0.146	0.053	0.003
->	Productivity	0.552	0.071	7.781	0.000	0.412	0.692	0.178
Senior cogn.	Geogr. mobility	0.066	0.047	1.410	0.160	-0.026	0.159	0.007
mobility	Virtual mobility	-0.103	0.071	-1.465	0.144	-0.242	0.036	0.008
	Cognitive distance	0.202	0.054	3.779	0.000	0.097	0.308	0.049

Table 5. Assistant professor behavior influencing cognitive mobility in two career phases

		B	Std. Error	t	Sig.	95% Conf. Interval LB	UB	Partial Eta Squared
Assistant prof	Intercept	-0.007	0.058	-0.115	0.909	-0.121	0.108	0.000
behavior	Productivity	0.110	0.096	1.145	0.253	-0.079	0.299	0.005
->	Geographic mobility	0.006	0.058	0.101	0.920	-0.108	0.119	0.000
Assistant prof	Virtual mobility	0.170	0.093	1.826	0.069	-0.013	0.353	0.011
cognitive mobility	Cognitive distance	0.128	0.063	2.039	0.042	0.004	0.251	0.014
Assistant prof	Intercept	-0.028	0.050	-0.554	0.580	-0.126	0.070	0.001
behavior ->	Productivity	0.417	0.082	5.066	0.000	0.255	0.579	0.082
senior cognitive	Geographic mobility	-0.010	0.049	-0.197	0.844	-0.107	0.088	0.000
mobility	Virtual mobility	0.155	0.080	1.948	0.052	-0.002	0.312	0.013
	Cognitive distance	0.207	0.054	3.850	0.000	0.101	0.313	0.049

Table 5 shows a somewhat different result. Productivity in the assistant professor phase does not relate to cognitive mobility in that phase, but is a strong positive predictor of cognitive mobility in the senior (associate or full professor) phase. Again, geographical mobility is not related to cognitive mobility, but virtual mobility is – and now positively. And similar to the other analysis, cognitive distance in the assistant professor phase is a positive predictor of cognitive mobility in the assistant professor and in the senior phase.

Conclusions

Geographical mobility seems to have no significant effect on cognitive mobility, which was unexpected. This may indicate that geographically mobile researchers prefer to go to places where they connect to researchers with a similar, and not a different, topical profile. We did not distinguish between domestic mobility and international mobility, but an initial test suggested that this has no effect in the analysis. Another explanation could be that also the quality of the origin and the destination of the geographic mobility may have a strong influence. If a mobile researcher moves to a less good environment, this may not help cognitive mobility, as no challenging new research questions may come up. We have not taken that into account, but in a follow-up study this could be tested by e.g. using the Leiden Ranking[5] as indicator for the quality of the involved organizations.

Virtual mobility, that is collaboration with researchers abroad without going there does have a negative effect on cognitive mobility in the early career phase. This changes to a positive effect when virtual mobility occurs later on. A too large network in the early career seems to make cognitive mobility more difficult, as the early career researcher may be too occupied by the demands of many strong international relationships, leaving no time for exploring new topics. In that phase a smaller network may be more beneficial. However, such a smaller network should not be too strong and to local, limiting researchers to explore different topics than those that are covered by the local environment. We find that in all career phases cognitive distance from the supervisors (*independence*) has a positive effect on cognitive mobility.

/Finally, *productivity* has by far the strongest positive effect on cognitive mobility. If one takes productivity as indicator for creativity, as has been extensively argued by Simonton (2004), this finding is not surprisingly. One would expect that creative researchers are intensive explorers, and the more one explores, the more often one may move to new topics, and the more one publishes and the more impact one has (Sandström & Van den Besselaar 2016).

Limitations and further work

This analysis is restricted to the domain of life sciences and medical sciences. In a follow up study, the analysis will be extended to other fields. Also several other variables will be included, as well as interaction effects. We are especially interested whether mobility works different for men than for women in the different career phases.

Another limitation of this study is that we have not yet distinguished between fully moving into new topics versus only marginally getting involved into new topics, whereas the core activities remain in one's traditional topics. Related to this, one may distinguish between prominent and less prominent topics.[6] Is cognitive mobility following the main trends, or is it exploring new directions that are not yet recognized as the main research topics of the future?

Several follow-up questions can be mentioned. It would be interesting to understand whether cognitive mobility in the early career has positive or negative effects on staying in or leaving academia. Cognitive mobility may work out differently depending on the career phase where it occurs.

Finally, it would be interesting relate cognitive mobility to changes in the scientific landscape and in the overall system of scientific knowledge production (e.g., new topics and demands due to Covid 19 pandemic). In this way we can distinguish between cognitive mobility that follows the topical trends that make up the dynamics of science versus cognitive mobility that deviates from the trends and moves into undeveloped research areas.

Acknowledgments

This study has received funding from the European Union's Horizon 2020 research and innovation program under grant number 824574 (GRANteD project, 2019-2023). The bibliometric data were obtained from the German Competence Network for Bibliometrics

[5] https://www.leidenranking.com/ranking/2022/list
[6] https://service.elsevier.com/app/answers/detail/a_id/28428/supporthub/scival/kw/Topic+Cluster/

funded by the Federal Ministry of Education and Research (Grant: 16WIK2101A). A reviewer of the paper provided interesting references to older work.

References

Aman V (2020). Transfer of knowledge through international scientific mobility: Introduction of a network-based bibliometric approach to study different knowledge types. *Quantitative Science Studies* **1** (2) 565-581.

Bozeman B & J Youtie (2017). *The strength of numbers. The new science of team science.* Princeton University Press.

Frenken K, J Hoekman, S Kok, R Ponds, F van Oort, J van Vliet (2009). Death of distance in science? A gravity approach to research collaboration. In: *Innovation networks: New approaches in modelling and analyzing*, 43-57.

Gläser J. & G Laudel (2015). A bibliometric reconstruction of research trails for qualitative investigations of scientific innovations. *Historical Social Research / Historische Sozialforschung* **40**, 3, 299-330

Helsten I, R Lambiotte, A Scharnhorst, M Auloos (2007), Self-citations, co-authorships and keywords: a new approach to scientists' field mobility. *Scientometrics* **72**,3 469-486

Hoekman J, K Frenken, RJW Tijssen (2010). Research collaboration at a distance: Changing spatial patterns of scientific collaboration within Europe. Research policy 39 (5), 662-673

Horlings E & T Gurney (2013). Search strategies along the academic life cycle. *Scientometrics* **94**, 1137-1160

Sandström U, P van den Besselaar (2016) Quantity and/or Quality? The Importance of Publishing Many Papers. PLoS ONE 11(11): e0166149.

Simonton DK (2004). *Creativity on science; chance, logic genius and zeitgeist*, Cambridge University Press

Vlachý J (1978). Field mobility in Czech physics-related institutes and faculties. *Czech J Phys* **28**, 237–240 (1978).

Vlachý J (1979). Mobility in science - bibliography of scientific career migration, field mobility, international academic circulation and brain-drain. *Scientometrics* **1**, 2, 201-228

Zhang L & W Glänzel (2012). Where demographics meets scientometrics: towards a dynamic career analysis. *Scientometrics* **91**, 2, 617-630