Thieme

Motivation and success factors in radiological research in Germany – results of a survey by the Methodology and Research Working Group of the German Radiological Society

Motivation und Erfolgsfaktoren in der radiologischen Forschung in Deutschland – Ergebnisse einer Umfrage der AG Methodik und Forschung

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ABSTRACT

Purpose Investigation of motivation and identification of success factors in radiology research in Germany.

Materials and Methods Using a German online survey (54 questions, period: 3.5 months), demographic aspects, intrinsic and extrinsic success characteristics, as well as personal and organizational success factors were surveyed based on a career success model. The survey results were reported descriptively. The correlations between success factors and success characteristics were examined using linear, binary-logistic, and multinomial regression models.

Results 176 people (164 academically active, 10 not academically active) answered the survey. Most participants (80 %, 139/174) worked at a university hospital. 32 % had privatdozent or professor as their highest academic title (56/173). The researchers' main motivation was intrinsic interest in research (55 %, 89/163), followed by a desire to increase their own career opportunities (25 %, 41/163). The following were identified as factors for intrinsic success: i) support from department management (estimate = β = 0.26, $p < 0.001$), ii) good work-life balance (β = 0.37, $p < 0.001$), and iii) the willingness

to pursue science even after reaching the career goal (β = 0.16, p < 0.016). Relevant factors for extrinsic scientific success were mentoring, protected research time, and activities in professional societies.

Conclusion Researchers in German radiology are mainly intrinsically motivated. Factors known from the literature that determine intrinsic and extrinsic scientific success were confirmed in this study. Knowledge of these factors allows targeted systematic support and could thus increase scientific success in German radiology.

Key Points

- Main motivation for German radiology research is intrinsic interest, followed by career opportunities.
- Factors for intrinsic scientific success are good work-life balance and support by department management.
- Factors for extrinsic scientific success are mentoring, activities in professional societies, and protected research time.

Citation Format

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ZUSAMMENFASSUNG

Ziel Untersuchung der Motivation und Identifikation von Erfolgsfaktoren in der radiologischen Forschung in Deutschland.

Material und Methoden Mittels einer deutschsprachigen Online-Umfrage (54 Fragen, Zeitraum: 3,5 Monate) wurden demografische Aspekte, intrinsische und extrinsische Erfolgsmerkmale sowie persönliche und organisatorische Erfolgsfaktoren auf Basis eines Karriere-Erfolgsmodells abgefragt. Die Umfrageergebnisse wurden deskriptiv beschrieben. Die Zusammenhänge zwischen Erfolgsfaktoren und Erfolgsmerkmalen wurden anhand linearer, binär-logistischer und multinominaler Regressionsmodelle untersucht.

Ergebnisse 176 Personen (164 wissenschaftlich Aktive, 10 nicht wissenschaftlich Aktive) haben an der Umfrage teilgenommen. Die Mehrheit der Teilnehmenden (80 %, 139/174) war an einer Universitätsklinik tätig. 32 % hatten als höchsten akademischen Titel einen Privatdozenten- oder Professorentitel (56/173). Die Hauptmotivation der Forschenden war intrinsisches Forschungsinteresse (55 %, 89/163) gefolgt von der Steigerung der eigenen Karrierechancen (25 %, 41/163). Als Faktoren für intrinsischen Erfolg wurden identifiziert: i) Unterstützung durch die Abteilungsleitung (Estimate = β = 0,26, p < 0,001), ii) gute Work-Life-Balance (β = 0,37, p < 0,001) sowie iii) die Bereitschaft, Wissenschaft auch nach Erreichen des Karriereziels auszuüben (β = 0,16, p < 0,016). Relevante Faktoren für extrinsischen wissenschaftlichen Erfolg waren Mentoring, regelmäßige Freistellungstage und fachgesellschaftliches Engagement.

Schlussfolgerung Forschende in der deutschen Radiologie sind hauptsächlich intrinsisch motiviert. Aus der Literatur bekannte Faktoren, die intrinsischen und extrinsischen wissenschaftlichen Erfolg bedingen, konnten in dieser Arbeit bestätigt werden. Die Kenntnis dieser Faktoren erlaubt eine gezielte systematische Förderung und könnte so den wissenschaftlichen Erfolg in der deutschen Radiologie steigern.

Kernaussagen

- Hauptmotivation radiologischer Forschung in Deutschland ist intrinsisches Forschungsinteresse, gefolgt von Karrierechancen.
- Faktoren für intrinsischen Erfolg sind gute Work-Life-Balance und Unterstützung durch die Abteilungsleitung.
- Faktoren für extrinsischen Erfolg sind Mentoring, fachgesellschaftliches Engagement und regelmäßige Forschungsfreistellung.

Introduction

Scientific activities are extremely important for ensuring the advancement of medical disciplines and high-quality patient care [1, 2]. In addition to patient care and teaching, science is also a central part of academic radiology.

As a result of an increase in workload [3] and an increasing workforce shortage, it can be very difficult to conduct successful and ongoing research activities. In this connection, the knowledge, preparation, and promotion of scientific success factors is decisive for guaranteeing the quality of scientific activities in radiology even in the future.

Objectively measuring scientific success is a challenge and is the subject of an ongoing discussion [4, 5, 6, 7]. The *Comprehensive Career-Success Model for Physician–Scientists* created by *Rubio et al.* describes factors needed for academic success in medicine and characteristics that characterize the resulting success [8]. The authors differentiate between *personal* and *organizational* success factors and between *intrinsic* and *extrinsic* success characteristics.

Numerous past studies have confirmed aspects of the described model in international, non-radiological environments. Therefore, for example, mentoring, networks, and protected research times were able to be identified as relevant *organizational* success factors [8, 9, 10, 11]. The motivation of researchers was described as a relevant *personal* success factor [7]. Knowledge of such factors allows them to be taken into consideration and integrated in existing scientific and interpersonal structures, thereby increasing the success of scientific activities. There has not yet been a study on scientific success factors for radiology.

The goal of this study was to identify the motivation and success factors for researchers in German radiology.

▶ **Table 1** Career success model for physician scientists according to *Rubio et al.*[8].

Success factors	Success characteristics
Personal factors: Demographic factors (age, gender, family structure), psychosocial milieu (not examined), education (degrees/title, research experience), personality (motivation, interest) **Organizational factors:** Institutional resources (infrastructure, support of science), training (didactic programs, research experience), relationship factors (mentoring as mentee, networks), conflicts of interest (clinical responsibilities or protected research time)	**Extrinsic characteristics:** Leadership positions (title), external funding, publications **Intrinsic characteristics:** Professional satisfaction, career satisfaction, life satisfaction

Factors and characteristics recorded in this questionnaire are specified in parentheses.

Materials and Methods

Questionnaire

A structured German questionnaire with 54 questions was developed (see supplementary files) for data collection. The first part of the questionnaire included questions about personal characteristics like age, gender, and current job position. If a participant was not currently involved in any scientific activities, the questionnaire was ended after recording of the personal characteristics.

For participants actively involved in scientific activities, questions about *personal* and *organizational* success factors and *intrinsic* (e. g. satisfaction) and *extrinsic* (e. g. number of scientific publications) success characteristics were asked in the second part based on the career success model created by *Rubio et al.* [8] (▶ **Table 1**). According to the model, it is assumed that success characteristics are determined or supported by success factors. Multiple choice questions with only one possible response or questions to be answered using a 7-point Likert scale (1: strongly disagree; 7: strongly agree) were used to examine this relationship. Prior to sending the final questionnaire to participants, *cognitive pretesting* [12] was performed with five persons with different levels of scientific and clinical experience.

Data acquisition

Data was collected during the period of 17.03.2023 to 30.06.2023 as an anonymous *online* cross-sectional questionnaire (Microsoft Forms, Microsoft, Redmond, USA). The link to the questionnaire was sent to all members of the German Radiological Society and the Young Radiology Forum as part of the monthly newsletter. In addition, participation was promoted via the social media accounts of the German Radiological Society (LinkedIn: 5,267 followers, Instagram: 1,765 followers, as of 3/1/2024) and the Young Radiology Forum (Instagram: 1,655 followers, as of 3/1/2024).

Statistics

Data was analyzed with R (Version 4.3.1, R Foundation for Statistical Computing, Vienna, Austria). In the descriptive data analysis, continuous variables were provided as mean, standard deviation (SD), and range. Categorical variables were provided as absolute values and relative percentages. Responses using the Likert scale were presented as relative percentages for all seven categories. To increase understandability, categories 1–3 of the seven-point Likert scale were categorized as "disagree" and categories 5–7 as "agree" in the results report [13].

Regression analyses were performed for continuous variables via a linear regression model, for binary variables via a binary-logistic regression model, and for multicategorical variables via a multinomial logistic regression model. The confounder variables age (except in the analysis of habilitation age), gender, number of children, job position, and place of work, as well as all predictor variables (success factors) were included in the regression model. All possible answers on the 7-point Likert scale (including indifferent – 4) were taken into consideration in the regression analyses.

Prior to implementation of the binary-logistic and multinomial regression models, the most relevant predictor variables were selected based on content-related considerations in order to limit the number of predictor variables to those with the greatest measurable influence. Individual categories were combined for some variables for the analyses. (Category "highest title": Dr., PD, Prof., "less advanced" than a Dr. title; category "motivation": career opportunities, intrinsic interest in research, other; category "protected research days": 0, 1–2, more than 2; category "research in freetime": 0–40 %, 41–80 %, > 80 %; category: "original articles as first author": 0, 1–5, and 6–10, > 10; category "original studies as last author": 0, 1–5, and 6–20, > 20; category "acquisition of external funding as the primary applicant": 0, at least 1).

Since there were only a few missing values in individual variables, an *available case analysis* was performed. This means that all available responses were included in the analysis. Since "diverse" was specified only once in the gender category, this person's results were not included in the regression analyses. In addition, the personal characteristics of this person were not included in ▶ **Table 2** in order to protect anonymity.

The results of the regression analyses were reported as *estimate* (β) with p-values or *odds ratio* (OR) with specification of the 95 % confidence interval (95 % CI). Due to the explorative study design, the data were not adjusted for multiple tests and all p-values are to be interpreted as descriptive.

Results

Characteristics of the study collective

The personal characteristics of 173 participants were able to be analyzed (▶ **Table 2**).

▶ **Table 2** Personal characteristics of participants stratified according to gender.

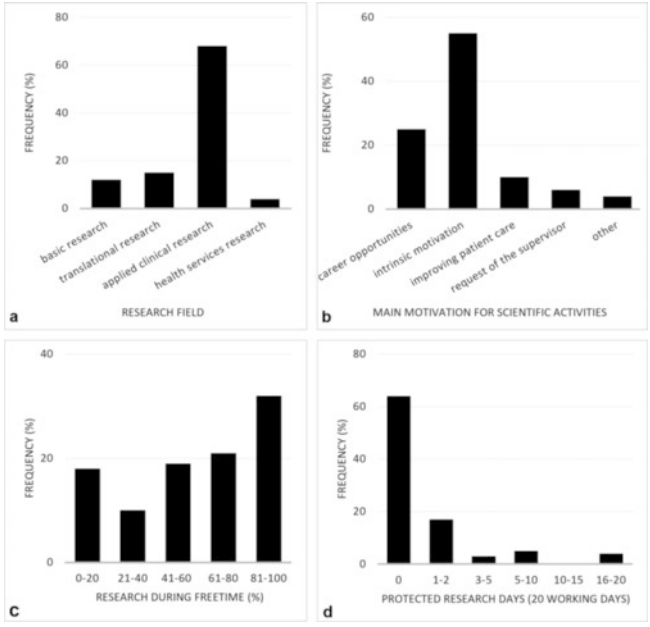
	Female (N = 58)	Male (N = 115)	Total (N = 173)
Age (in years)			
Mean ± SD	37.4 ± 9.6	40.7 ± 10.6	39.6 ± 10.4
Range	26–70	22–78	22–78
Number of children			
Mean ± SD	0.8 ± 1.0	1.1 ± 1.2	1.0 ± 1.1
Range	0–4	0–4	0–4
Highest academic title			
No title	7 (12.1 %)	16 (14.0 %)	23 (13.4 %)
B. Sc.	1 (1.7 %)	0 (0.0 %)	1 (0.6 %)
Dr.	45 (77.6 %)	48 (42.1 %)	93 (54.1 %)
PD	3 (5.2 %)	20 (17.5 %)	23 (13.4 %)
Prof.	2 (3.4 %)	30 (26.3 %)	32 (18.6 %)
Age at the time of habilitation (in years)			
Mean ± SD	35.7 ± 10.0	35.8 ± 3.3	35.7 ± 4.3
Range	27–54	30–43	27–54
Job position			
Resident	29 (50.0 %)	33 (28.7 %)	62 (35.8 %)
Specialist	4 (6.9 %)	14 (12.2 %)	18 (10.34)
Attending	17 (29.3 %)	35 (30.4 %)	52 (30.1 %)
Head physician	6 (10.3 %)	20 (17.4 %)	26 (15.0 %)
Exclusively research	2 (3.4 %)	3 (2.6 %)	5 (2.9 %)
Practice owner	0 (0.0 %)	2 (1.7 %)	2 (1.2 %)
Employee at a practice	0 (0.0 %)	3 (2.6 %)	3 (1.7 %)
No longer working	0 (0.0 %)	1 (0.9 %)	1 (0.6 %)
Other	0 (0.0 %)	4 (3.6 %)	4 (2.4 %)
Place of work			
University hospital	50 (86.2 %)	88 (76.5 %)	138 (79.8 %)
Non-university hospital	6 (10.3 %)	14 (12.2 %)	20 (11.6 %)
Private practice	2 (3.4 %)	8 (7.0 %)	10 (5.8 %)
Other	0 (0.0 %)	5 (4.5 %)	5 (3.0 %)
Work hours (per week)			
Mean ± SD	44.8 ± 18.0	53.6 ± 11.4	50.7 ± 14.5
Range	0–80	3–80	0–80
Research hours (per week)			
Mean ± SD	9.8 ± 13.9	10.1 ± 12.2	10.0 ± 12.8
Range	0–65	0–70	0–70

164 of the 174 participants were actively involved in scientific activities and 10 were not. The following results and analyses relate to the available responses from participants actively involved in scientific activities.

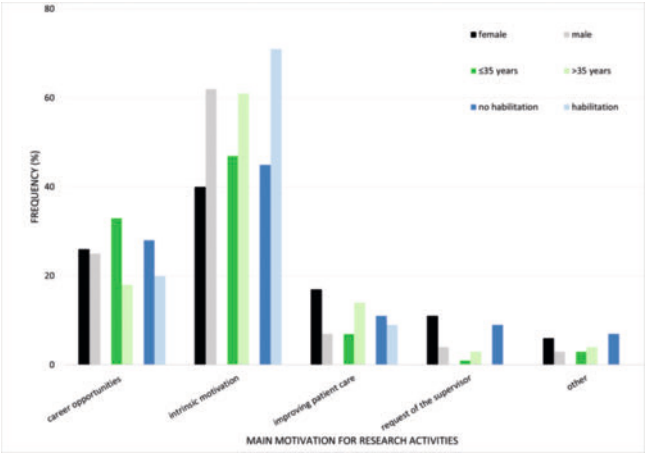
Success factors

Personal success factors

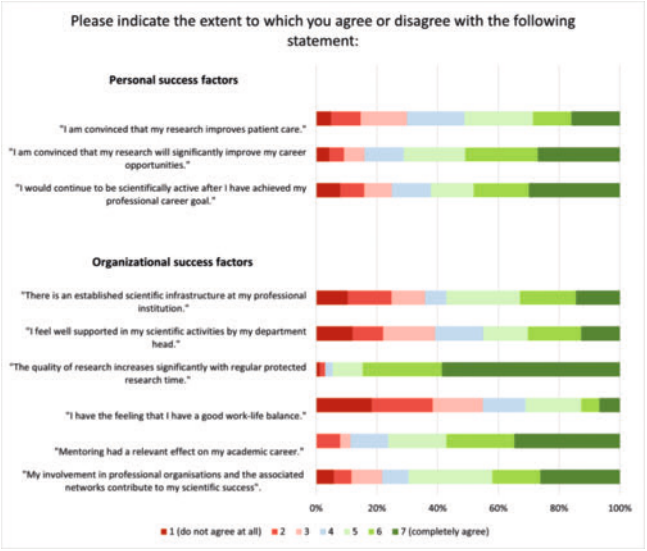
Survey participants were on average 39.6 years old (± 10.4) and had 1 child (± 1.1). 34 % of participants were female (58/173) and 66 % male (11/173). The majority of those surveyed (68 %, 110/161) were involved in applied clinical research (▶ **Fig. 1a**).



▶ **Fig. 1** Overview of **a** the distribution of various research fields, **b** the main motivation for scientific activities, **c** the percentage of scientific activities performed by participants during their free time, and **d** the number of protected research days per month.



▶ **Fig. 2** Subgroup analysis of the main motivation for research activities.



▶ **Fig. 3** Evaluation of questions regarding personal and organizational success factors answered using 7-point Likert scales.

In response to the question about their main motivation for performing scientific activities, participants stated an intrinsic interest in research (55 %, 89/163) followed by better career opportunities (25 %, 41/163) (▶ **Fig. 1b**). Half (50 %, 82/164) of those surveyed stated that they felt that their research improved patient care. 71 % (116/163) felt that performing scientific activities increases their career opportunities. In addition, 62 % (107/164) of participants stated that they wanted to continue to conduct scientific activities even after reaching their own career goals.

In a subgroup analysis, differences with respect to gender (male, female), age (≤ 35, > 35 years), and academic title (no habilitation, habilitation) regarding the main motivation for scientific activities were examined (▶ **Fig. 2**). Male survey participants gave intrinsic motivation as a response more frequently than female participants (62 % vs. 40 %). Female participants cited improving patient care as their main motivation more often than male participants (17 % vs. 7 %). Career opportunities were the main motivation more frequently among younger participants than older participants (33 % vs. 18 %). Intrinsic interest as the main motivation was more common among older participants than younger participants. This trend could also be observed in the case of habilitation vs. no habilitation.

Organizational success factors

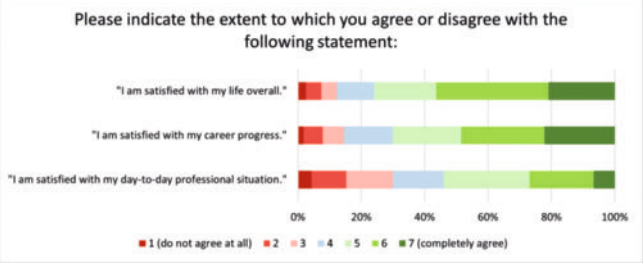
57 % (99/173) of participants gave a positive response regarding the existence of an established scientific infrastructure in their department (▶ **Fig. 3**). However, 39 % (62/158) of those surveyed stated that they do not feel that they receive sufficient support from department management for scientific activities.

The number of work hours per week (including protected research time) was on average 50.7 h (± 14.5). The number of hours per week for scientific activities was 10.0 h (± 12.8). 95 % (156/164) of participants agreed with the statement "*the quality of research increases significantly with regular protected research time*". However, 64 % (105/163) of participants actively involved in scientific activities stated that they do not receive protected research time (▶ **Fig. 1d**). 53 % (86/163) of participants performed more than 60 % of their total scientific activities in their free time (▶ **Fig. 1c**). 31 % (51/164) of those surveyed agreed with the statement "*I feel like I have a good work-life balance*" (▶ **Fig. 3**).

124 of 164 participants (76 %) stated that they have not participated in a structured scientific program (▶ **Table 3**). However, 55 % (90/164) of those surveyed participated in scientific mentoring. 67 % (60/90) of mentors were attendings. 76 % (68/89) of those surveyed agreed with the statement "*mentoring had a relevant effect on my scientific career*". 43 % (70/164) of the participants were actively involved in radiological societies. 70 % (48/

▶ **Table 3** Overview of organizational success factors.

Success factor	Total (N = 164)
Participation in structured programs	
No	124 (75.6 %)
Yes	40 (24.4 %)
Scientific mentoring	
No	74 (45.1 %)
Yes	90 (54.9 %)
Position of the mentor	
Head physician	14 (15.7 %)
Attending	60 (67.4 %)
Specialist	2 (2.2 %)
Resident	5 (5.6 %)
Scientist	7 (7.9 %)
Other	1 (1.1 %)
Involved in professional societies	
No	94 (57.3 %)
Yes	70 (42.7 %)



▶ **Fig. 4** Responses regarding intrinsic success characteristics (satisfaction with life, career progress, and professional situation) using 7-point Likert scales.

69) of those involved in professional societies found this involvement and the associated networks beneficial for their own scientific success.

Success characteristics

Intrinsic success characteristics

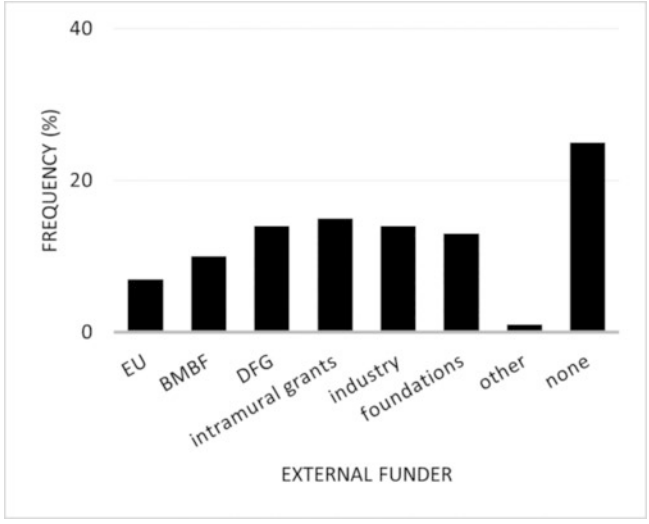
54 % (88/163) of those surveyed stated that they were satisfied with their day-to-day professional situation (▶ **Fig. 4**). 71 % (116/163) agreed with the statement "*I am satisfied with my career progress*". 77 % (125/163) of those surveyed stated that they were satisfied with their life in general.

Extrinsic success characteristics

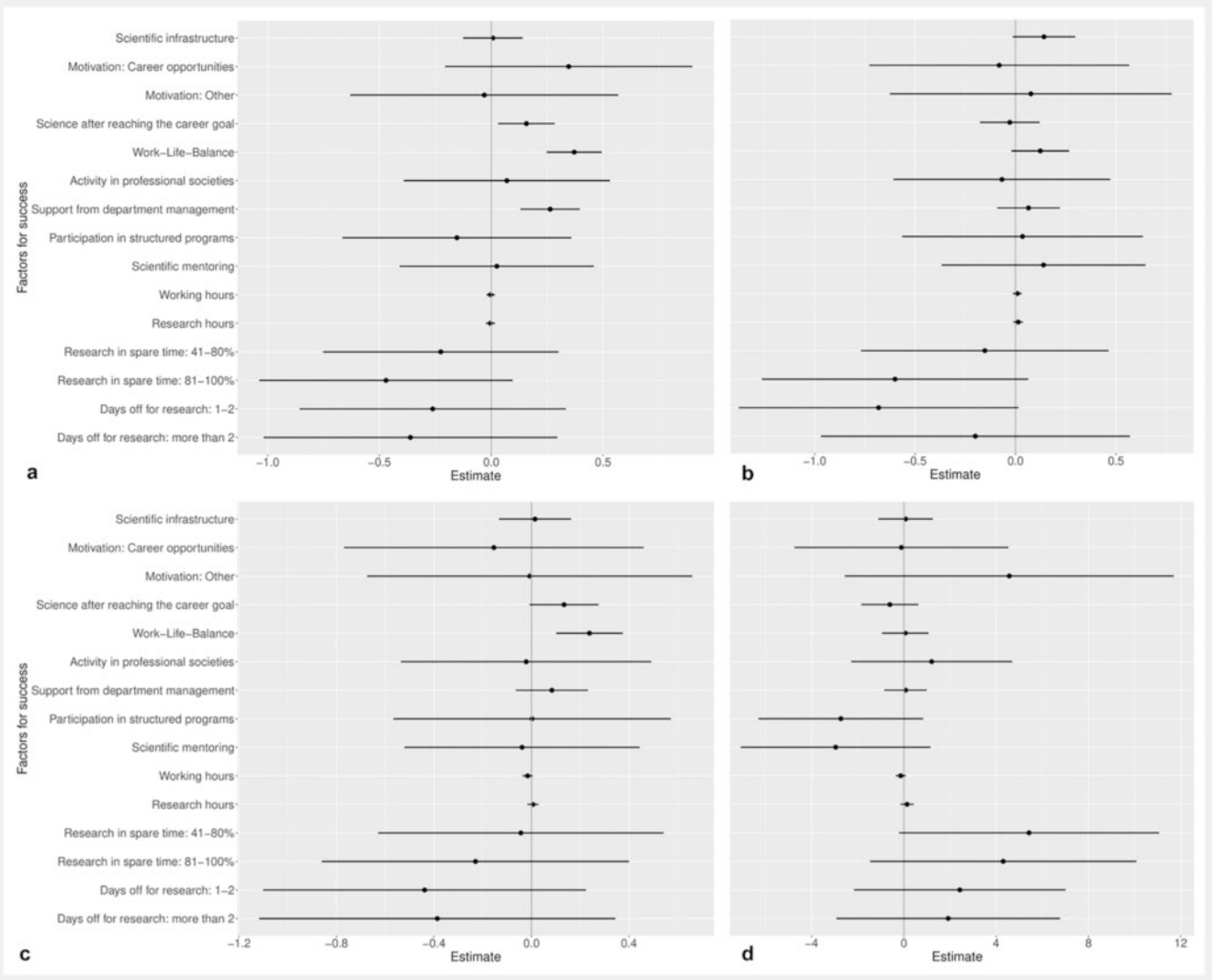
54 % (93/163) had a doctorate as their highest academic title, 14 % (23/163) held the title of privatdozent, and 19 % (32/163) held the

▶ **Table 4** Responses regarding extrinsic success characteristics: external funding and original articles.

Success characteristic	Total (N = 164)
Acquisition of external funding as the primary applicant	
0	91 (55.5 %)
1–2	43 (26.2 %)
3–5	16 (9.8 %)
>5	14 (8.5 %)
External funding acquired on the basis of one's own research studies	
Yes	60 (36.6 %)
No	104 (63.4 %)
First author of original articles	
0	29 (17.8 %)
1–5	58 (35.6 %)
6–10	22 (13.5 %)
11–20	21 (12.9 %)
>20	33 (20.2 %)
Last author of original articles	
0	76 (46.6 %)
1–5	34 (20.9 %)
6–10	15 (9.2 %)
11–20	11 (6.7 %)
>20	27 (16.6 %)



▶ **Fig. 5** Overview of external project funding acquired by participants.



▶ **Fig. 6** Forest plots regarding the influence of success factors on intrinsic success characteristics: **a** Satisfaction with professional situation, **b** satisfaction with career progress, **c** satisfaction with life and the extrinsic success characteristic **d** age at the time of habilitation. The analyses were adjusted for gender, age, number of children, job position, and place of work. The correlation coefficient (estimate) is shown as a black dot and the 95 % confidence interval is shown at a black line. If the total confidence interval is greater than or less than zero, a significant relationship can be assumed.

title of professor (▶ **Table 2**). The age at the time of habilitation was 35.7 ± 4.3 years.

56 % (91/164) of those surveyed stated that they did not acquire any external funding as the primary applicant (▶ **Table 4**). However, 26 % (43/164) of participants were able to acquire one or two externally funded projects as the primary applicant. 18 % (30/164) acquired three or more externally funded projects. 37 % (60/164) of participants were able to acquire external funding based on their own research.

The distribution of external funding sources for projects was homogeneous with the majority being intramural grants (15 %) (▶ **Fig. 5**). 20 % (33/164) of those surveyed were the first author of more than 20 articles (▶ **Table 4**). In contrast, 18 % (29/164) of those surveyed had not yet published any original articles as first author. 47 % (76/164) of participants had not published any original articles as last author. In contrast, 21 % (34/164) were listed as last author on one to five articles.

Relationships between success factors and success characteristics

There was a positive correlation between satisfaction with the professional situation and support from department management ($\beta = 0.26$, $p < 0.001$), work-life balance ($\beta = 0.37$, $p < 0.001$), as well as readiness to continue performing scientific activities even after achieving career goals ($\beta = 0.16$, $p < 0.016$) (▶ **Fig. 6a**). No correlation between satisfaction with career progress and the success factors included in the questionnaire was seen (▶ **Fig. 6b**). Life satisfaction was significantly associated with a good work-life balance ($\beta = 0.24$, $p < 0.001$) (▶ **Fig. 6c**). Protected research time had a non-significant negative correlation with satisfaction

▶ **Table 5** Regression analyses of extrinsic success characteristics.

Success factor	Success characteristic	
	External funding acquired on the basis of research studies OR [95 % CI]	**Acquisition of external funding as the primary applicant OR [95 % CI]**
Scientific infrastructure	1.32 [0.89–2.04]	1.14 [0.82–1.63]
Motivation: Career opportunities *Ref: intrinsic interest*	1.10 [0.16–7.82]	1.83 [0.37–9.57]
Motivation: Other *Ref: intrinsic interest*	0.19 [0.03–1.11]	0.10 [0.01–0.52]
Science after reaching the career goal	**1.52 [1.01–2.43]**	1.33 [0.92–1.98]
Involvement in professional societies *Ref: no activity*	**4.54 [1.33–17.81]**	**6.50 [2.04–24.77]**
Mentoring *Ref: no mentoring*	2.16 [0.61–8.39]	2.18 [0.69–7.30]
Work hours	1.06 [1.00–1.14]	1.00 [0.96–1.05]
Research hours	0.93 [0.85–1.00]	1.04 [0.98–1.11]
Research in free time: 41–80 % *Ref: ≤ 40 %*	0.70 [0.10–4.39]	3.76 [0.79–20.58]
Research in free time: 81–100 % *Ref: ≤ 40 %*	0.62 [0.10–3.73]	1.61 [0.34–8.37]
Protected research days: 1–2 *Ref: 0*	**6.67 [1.02–56.69]**	1.74 [0.36–8.78]
Protected research days: more than 2 *Ref: 0*	**17.93 [2.69–166.05]**	0.90 [0.15–4.77]

Comment: Reference (Ref) for the success characteristics for calculating the odds ratio (OR): no external funding acquired. No reference categories are given for continuous variables. The analyses were adjusted for gender, job position, and place of work.

(▶ **Fig. 6a–c**). There was no significant correlation between habilitation age and the examined success factors (▶ **Fig. 6d**).

There was a correlation between the acquisition of external funding on the basis of one's own research studies and involvement in radiological societies (OR 4.54 [95 % CI 1.33–17.81]) and the provision of one to two (OR 6.67 [95 % CI 1.02–56.69]) or more than two protected research days per month (OR 17.93 [95 % CI 2.69–166.05]) (▶ **Table 5**). Participants, who acquired external funding as the primary applicant, were also active in radiological societies significantly more often than people who had not acquired external funding (OR 6.50 [95 % CI 2.04–24.77]).

Persons with a doctor, privatdozent, or professor title were involved in mentoring relationships as a mentee significantly more often than participants without a title (OR 5.97 [95 % CI 1.18–30.25], OR 16.39 [95 % CI 1.51–178.40], OR 18.24 [95 % CI 1.43–232.71]) (▶ **Table 6**). The probability of mentoring increased with a higher academic title. Participants with a professor title were significantly more frequently involved in professional societies than people without a title (OR 22.93 [95 % CI 1.28–410.08]).

Participants listed as first author on one to five articles or more than ten articles or as last author on over 20 articles were more active in radiological societies than participants without first/last authorship (OR 21.33 [95 % CI 1.29–352.83], OR 49.29 [95 % CI 2.40–1012.04], OR 27.68 [95 % CI 2.85–268.70]) (▶ **Table 7**). Participants listed as last author on one to five articles or as first author on more than ten original articles were given one to two protected research days per month significantly more frequently than persons without any first authorships (OR 11.67 [95 % CI 1.02–134.00], OR 45.59 [95 % CI 1.95–1067.83]). Participants listed as last author on one to five articles were provided with more than two protected research days per month significantly more often than persons without first authorship of a published original articles (OR 12.31 [95 % CI 1.06–143.41]).

Discussion

The present questionnaire was used to examine motivation and success factors as well as their association with success characteristics of radiologists performing research in Germany. An intrinsic interest in research followed by greater career opportunities were the main motivation. *Extrinsic* scientific success was primarily associated with mentoring and regular protected time for research activities. *Intrinsic* success like satisfaction was associated in particular with a good work-life balance and the support of scientific activities by department management.

▶ **Table 6** Regression analyses for the success characteristic academic title.

Success factor	Success characteristic		
	Doctor OR [95 % CI]	**Privatdozent OR [95 % CI]**	**Professor OR [95 % CI]**
Scientific infrastructure	0.55 [0.30–0.99]	0.57 [0.26–1.22]	0.65 [0.28–1.47]
Motivation: Career opportunities *Ref: intrinsic interest*	0.51 [0.07–3.69]	1.45 [0.04–50.39]	2.72 [0.07–101.53]
Motivation: Other *Ref: intrinsic interest*	0.06 [0.01–0.53]	0.01 [0.00–0.18]	0.00 [0.00–0.25]
Science after reaching the career goal	0.80 [0.51–1.27]	1.06 [0.53–2.14]	0.95 [0.44–2.03]
Involvement in professional societies *Ref: no activity*	2.00 [0.26–15.13]	15.02 [0.88–256.58]	**22.93 [1.28–410.08]**
Mentoring *Ref: no mentoring*	**5.97 [1.18–30.25]**	**16.39 [1.51–178.40]**	**18.24 [1.43–232.71]**
Work hours	1.00 [0.95–1.06]	0.95 [0.86–1.05]	0.92 [0.82–1.02]
Research hours	0.97 [0.90–1.05]	0.95 [0.84–1.07]	0.98 [0.86–1.12]
Research in free time: 41–80 % *Ref: ≤ 40 %*	2.26 [0.35–14.71]	19.80 [0.82–480.52]	9.48 [0.43–208.69]
Research in free time: 81–100 % *Ref: ≤ 40 %*	1.37 [0.22–8.45]	21.59 [0.63–734.35]	9.41 [0.32–279.54]
Protected research days: 1–2 *Ref: 0*	2.35 [0.24–22.71]	46.87 [0.77–2844.30]	13.31 [0.16–1089.94]
Protected research days: more than 2 *Ref: 0*	7.44 [0.28–197.42]	14.15 [0.21–933.66]	6.03 [0.07–505.56]

Comment: Reference (Ref) for the success characteristics for calculating the odds ratio (OR): no title. No reference categories are given for continuous variables. The analyses were adjusted for gender, job position, and place of work.

This survey was based on the *Comprehensive Career-Success Model for Physician-Scientists* [8]. Numerous studies have confirmed various partial aspects of the model in the past. *Robinson et al.* examined the career success of clinical and translational investigators [10]. They were able to identify persistence, resilience, initiative, autonomy, and personal and professional balance as *personal* success factors. In the literature, the motivation of researchers is also described as a *personal* success factor. In particular, resilience is dependent on motivation [7]. In our survey, the personal balance or work-life balance was confirmed as a *personal* scientific success factor. A relationship between the type of motivation and scientific success was not observed in our study. There was no differentiation between the type of research and motivation. However, there were gender-dependent motivation differences for scientific activities. Men mentioned an intrinsic motivation more frequently than women. In contrast, women stated that they were motivated by a desire to improve patient care. Gender-specific promotion of these different motivators could contribute to more effective support of young scientists.

We were able to identify mentoring, involvement in professional societies, support of scientific activities by department management, and protected research time as *organizational* success factors. This observation confirms the *organizational* success factors described by *Robinson et al.* [10]. Moreover, the fact that systemic support for further qualification is also expected by radiologists working in Germany was able to be shown in a current questionnaire [14]. In a study examining the careers of 31 *physician scientists* in the USA, organizational support, work-life balance, autonomy, and mentoring were identified as success factors [9]. However, there seem to be geographical differences regarding scientific success factors. Therefore, in contrast to other parts of the world, a study from Singapore showed that study participants did not find work-life balance to be an obstacle or reason for leaving an academic career path [11]. However, in Germany, the ability to schedule work times is considered important by all radiologists except head physicians [14] so that the provision of protected research times during work hours will presumably become increasingly important for promoting research activities. The observed relationships between scientific success and involvement in professional societies may be subject to a bias since the survey was performed within the German Radiological Society.

Mentoring was also able to be identified as a relevant success factor in the past. In addition to personal development, *extrinsic* success characteristics like publications and the acquisition of external funding are also supported by mentoring [15]. This relationship was confirmed in our survey with respect to the number of publications. Moreover, the effect of mentoring was primarily observed in relation to academic title. Mentoring was also named

▶ **Table 7** Regression analyses for the success characteristic number of original articles with first or last authorship.

Success factor	Success characteristic		
	1 to 5 first authorships/ 1 to 5 last authorships OR [95 % CI]	**6 to 10 first authorships/ 6 to 20 last authorships OR [95 % CI]**	**More than 10 first authorships/ More than 20 last authorships OR [95 % CI]**
Scientific infrastructure	0.54 [0.30–0.98] 0.77 [0.51–1.17]	0.46 [0.23–0.92] 0.84 [0.52–1.37]	0.61 [0.31–1.22] 0.95 [0.52–1.73]
Motivation: Career opportunities *Ref: intrinsic interest*	0.82 [0.11–6.05] 0.81 [0.09–6.95]	0.85 [0.06–11.59] 0.84 [0.07–9.84]	3.14 [0.20–48.23] 0.74 [0.04–14.37]
Motivation: Other *Ref: intrinsic interest*	0.40 [0.05–3.06] 0.51 [0.08–3.16]	0.09 [0.01–1.35] 0.32 [0.03–3.55]	0.09 [0.01–1.46] 0.05 [0.00–1.49]
Science after reaching the career goal	0.96 [0.63–1.47] 0.90 [0.57–1.42]	0.85 [0.49–1.49] 0.92 [0.56–1.53]	1.45 [0.82–2.58] 1.11 [0.56–2.17]
Involvement in professional societies *Ref: no activity*	**21.33 [1.29–352.83]** 2.87 [0.59–14.01]	7.02 [0.29–171.12] 5.19 [0.87–31.13]	**49.29 [2.40–1012.04]** **27.68 [2.85–268.70]**
Mentoring *Ref: no mentoring*	2.00 [0.36–11.23] 2.45 [0.52–11.50]	3.17 [0.38–26.40] **8.92 [1.53–52.20]**	6.58 [0.76–56.81] 5.42 [0.67–44.13]
Work hours	1.01 [0.95–1.07] 0.97 [0.92–1.03]	1.06 [0.97–1.16] 0.98 [0.90–1.06]	0.99 [0.91–1.07] 0.91 [0.83–1.01]
Research hours	1.10 [0.94–1.29] 1.00 [0.94–1.06]	1.11 [0.94–1.31] 1.02 [0.96–1.09]	1.14 [0.97–1.34] 0.99 [0.88–1.12]
Research in free time: 41–80 % *Ref: ≤40 %*	3.85 [0.61–24.36] **21.86 [2.09–228.97]**	**89.99 [3.32–2442.53]** 4.58 [0.32–65.26]	**22.91 [1.77–295.93]** 9.78 [0.42–229.66]
Research in free time: 81–100 % *Ref: ≤40 %*	2.71 [0.47–15.74] 6.47 [0.54–77.68]	**68.80 [2.33–2032.56]** 6.96 [0.42–115.90]	**26.19 [1.91–358.96]** 13.49 [0.45–404.27]
Protected research days: 1–2 *Ref: 0*	7.67 [0.62–94.68] **11.67 [1.02–134.00]**	12.90 [0.58–289.51] 6.59 [0.50–86.69]	**45.59 [1.95–1067.83]** 1.65 [0.06–44.91]
Protected research days: more than 2 *Ref: 0*	1.55 [0.06–39.17] **12.31 [1.06–143.41]**	6.40 [0.17–242.24] 2.26 [0.15–33.93]	4.18 [0.11–152.08] 5.90 [0.26–134.96]

Comment: Reference (Ref) for the success characteristics for calculating the odds ratio (OR): no first authorships or last authorships. No reference categories are given for continuous variables. The analyses were adjusted for gender, job position, and place of work.

by the majority of participants (76 %) as a decisive factor for the scientific career. Aspects determining a successful mentoring relationship in radiology are described in detail in a recent study [16]. The study also describes bilateral character as an essential part of successful mentoring relationships. In addition to individual mentoring relationships, supportive personal relationships in terms of a network may also be relevant for academic success [17].

In surveys of residents in Germany, a small number of protected research days was described [17, 18]. Thus, a survey in rheumatology showed that more than 70 % of those surveyed performed their scientific activities in their free time [18]. In a survey of radiology residents, 87 % stated that they perform the majority of their research in their free time [19]. Our survey confirms this observation in a collective including the entire clinical hierarchy. Two thirds of participants stated that they do not receive protected research time. However, almost all participants were convinced of the positive effect of protected research days on scientific success. This opinion is supported by the results of the regression analyses. In particular, there was a significant correlation between protected research time and the number of publications and the successful acquisition of external funding based on their own research studies. Thus, the success factor defined in the studies above, i. e., protected research time, is also a decisive criterion for successful scientific work in German radiology.

Our questionnaire has some limitations. In particular, the sample size in relation to the number of people contacted (German Radiological Society has more than 10,000 members) means that the results are less representative. There seems to be a selection bias due to the objective of the survey. Since the title already includes the phrase “radiological research”, the questionnaire may have primarily targeted those performing scientific activities. The large number of participants with the title privatdozent or professor confirms this assumption and also indicates that a disproportionate number of people with scientific success participated in the questionnaire. The main motivation of participants for performing scientific activities was intrinsic research interest followed by greater personal career opportunities. In this connection, social desirability could have an effect on the provided re-

sponses [20]. In addition, the causality of the observed relationships cannot be justified by the selected questionnaire design. Complex quantitative longitudinal studies, particularly on the effect of individual success factors on scientific success characteristics, are needed in the future.

Summary and practical implications

We were able to identify intrinsic interest in research as a main motivation for scientific activities. The most important success factors were mentoring and protected research time. Therefore, factors known from the literature for scientific success in international academic systems were able to be confirmed in German radiology. Information for practical implementation can be derived from this survey to increase the scientific success of our discipline.

The systematic initiation and structured implementation of mentoring relationships could be highly beneficial due to the major influence on scientific success. Attendants perform the majority of mentoring. However, the high level of experience of head physicians makes them particularly suitable for mentoring resulting in significant potential for the lasting effect of mentoring relationships.

Moreover, protected research time is necessary to ensure continuous and productive scientific activities. Therefore, structured programs, such as the *Clinician Scientist* programs established at German university hospitals, should be increasingly used as an effective tool [21]. However, since most funding requires prior studies, protected research time independent of external funding is extremely important for research primarily in the initial phase of a scientific career [22]. With this form of initial aid, the publication requirement for self-acquired external funding can be overcome. In addition, the integration of research activities in daily professional life increases work-life balance. This aspect proved to be an important factor for the satisfaction of researchers in the questionnaire.

Conclusion

In addition to individual personal factors, infrastructure aspects support the success of scientific activities in radiology and thus play a significant role of the future of radiology.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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