Christina Elhalaby* and Nurith Epstein**

Collaboration and Competition in Academic Research

Experiences of Postdoctoral Researchers in the Life Sciences***

Abstract: While academic research often requires collaboration, the German academic career system is highly competitive due to the scarcity of permanent positions and follows a "winner takes it all" principle. Empirical research has shown both the positive and negative aspects of scientific collaboration. Within this qualitative interview study, we investigate how postdocs in the life sciences (medicine and biology) describe their experiences with collaborations. What are the benefits and the pitfalls, and what aspects predominate? Further, drawing on the concept of social capital and the theory of social interdependence, we analyze the situations in which conflicts arise, and those in which they do not. Our results suggest that it is the benefits of collaboration that are predominant; the postdocs often describe them as indispensable for their work. Access to human capital, i.e., knowledge, skills and experience of others, and in many cases, research projects are only made possible through the collaboration of scientists with different disciplinary backgrounds and expertise. However, postdocs also report conflicts regarding the order of authors, (fears of) being scooped by project partners and free riding. These problems were primarily expressed in relation to external project partners. Here, there is likely a weaker bond and less network closure, making it more difficult to sanction misconduct.

Keywords: Postdocs, Life Sciences, Scientific Collaboration, Social Capital, Social Interdependence

* Bayerisches Staatsinstitut für Hochschulforschung und Hochschulplanung (IHF), Lazarettstr. 67 in 80636 München, E-Mail: elhalaby@ihf.bayern.de.

** Institut für Didaktik und Ausbildungsforschung in der Medizin (DAM), Klinikum der LMU, Pettenkoferstr. 8a in 80336 München, E-Mail: nurith.epstein@med.uni.muenchen.de.

*** We would like to thank Dr. Maike Reimer for her constant support and advice.

Kollaboration und Wettbewerb in der akademischen Forschung

Erfahrungen von Postdocs in den Lebenswissenschaften

Zusammenfassung: Obwohl die akademische Forschung häufig wissenschaftliche Kollaborationen erfordert, ist das deutsche akademische Karrieresystem, aufgrund der Knappheit an unbefristeten Stellen, sehr wettbewerbsorientiert und folgt dem "winner takes it all"-Prinzip. Empirische Untersuchungen haben sowohl die positiven als auch die negativen Aspekte wissenschaftlicher Kollaborationen aufgezeigt. In dieser qualitativen Interviewstudie untersuchen wir, wie Postdocs in den Lebenswissenschaften (Medizin und Biologie) ihre Erfahrungen mit Kollaborationen beschreiben. Was sind die Vorteile und die Fallstricke, und welche Aspekte überwiegen? Unter Einbezug des Konzepts von Sozialkapital und der Theorie der sozialen Interdependenz analysieren wir außerdem, in welchen Situationen Konflikte auftreten und in welchen nicht. Unsere Ergebnisse weisen darauf hin, dass die Vorteile von Kollaborationen überwiegen; die interviewten Postdocs beschreiben sie oftmals als unverzichtbar für ihre Arbeit. Der Zugang zu Humankapital, d. h. zu Wissen, Fähigkeiten und Erfahrungen anderer, und in vielen Fällen auch zu Forschungsprojekten wird erst durch die Kollaboration von Wissenschaftler/innen mit unterschiedlichem disziplinärem Hintergrund und Fachwissen möglich. Aber auch Konflikte, über die Autorenreihenfolge, (Angst vor) Ideendiebstahl und Trittbrettfahren, werden von Postdocs berichtet. Diese wurden vor allem in Bezug auf externe Projektpartner/innen geäußert. Hier ist die vermutlich eine schwächere Bindung und geringere Geschlossenheit des Netzwerkes vorhanden, sodass Fehlverhalten schlechter sanktioniert werden kann.

Stichworte: Postdocs; Lebenswissenschaften; Wissenschaftliche Kollaborationen; Sozialkapital; Soziale Interdependenz

1 Introduction

While academic research merits individual achievements, it is increasingly performed by teams (e.g., Wuchty et al. 2007); a development fostered by increasing specialization of researchers, complexity of research problems, and policy makers (summarized in Leahey 2016). Collaboration has been shown to have many positive effects, such as on the visibility and productivity of individual researchers: Recognition in academia is predominantly awarded by the respective scientific community, e.g., through peer review and citations (Gläser/Laudel 2015). Being referenced by other scientists leads to a higher visibility and increases the impact of the scientific work. This is also the case if co-authors share joint publications (Bikard et al. 2015). Collaboration seems to be a necessity not only for successful

funding (Abramo et al. 2014; Leahey 2016) but also for the research productivity of teams and individuals who can add to their publication list, e.g., through co-authorships (Wieczorek et al. 2020). This is specifically true in disciplines in which many (sub)disciplines need to work together to address complex research questions (Aldrich/Al-Turk 2018; Greene 2007; Wuchty et al. 2007), as in the life sciences; here, multi- or interdisciplinary work is rather the rule than the exception.

However, the scarcity of (permanent) positions inevitably turns postdocs, who are responsible for the bulk of research (Kreckel 2016), into competitors. This aspect is particularly important for German academia, in which—traditionally—permanent positions have been almost exclusively available for full professors (e.g., Afonso 2015; Kreckel 2016; Ullrich 2019), who constitute approximately 10 percent of the academic workforce (Kreckel 2017). This situation presents a dilemma, since collaboration is often necessary for achieving a mutual goal, e.g., to successfully manage a joint research project, but the goal of achieving a permanent position—in this case professorship—is only possible for a few. Empirically, competition has been negatively associated with knowledge-sharing within teams (Blumenthal et al. 2006). Moreover, collaborations may entail other conflicts and problems, such as free riding (Leahey 2016) or unfair distribution of work (Aldrich/Al-Turk 2018).

Another important aspect of collaboration may be the status of collaborators; not all scientific collaborations are equal as scientists differ with respect to their status, prestige and experience. Professors are central members of the scientific community. They hold a twofold powerful position as superiors with a quasi-employer function and as supervisors who evaluate scientific work. They decide whom to hire, to promote and to recommend (Gallas 2018; Ullrich 2019). In addition, they also function as gatekeepers to their scientific communities and can provide postdocs with access to their networks (Jungbauer-Gans/Gross 2013). Due to the above-described duality of the German academic labor market, postdocs are in a position in which they are very dependent on their superior professor until they reach full professorship themselves.

In this study, we use qualitative data to examine the ways in which scientists benefit from collaborations, but also to examine the pitfalls that collaborations may entail. In contrast to quantitative studies, which mainly focus on the bibliometric analysis of co-authorship (e.g., Lee/Bozeman 2005; Scaffidi/Berman 2011; Wieczorek et al. 2020), we aim to explore a broader spectrum of collaboration experiences, and we understand collaboration as any (informal) form of *professional* exchange between scientists and not only as formalized collaboration that becomes visible only after it has been successful through joint publications. We focus specifically on postdocs in the life sciences (physician scientists[1] and biologists), a traditional team science discipline in which the number of authors per paper has increased even further in

1 Physician scientists (also known as "clinician scientists" or "translational scientists") are physicians who are also engaged in academic research. As active (laboratory) researchers and clinical

recent decades (Schmidt et al. 2017; Vermeulen/Penders 2010). Research in the life sciences is predominantly conducted in an interdisciplinary manner, as the expertise of different sub-disciplines is needed to address important research questions. Medicine, e.g., translational research, that brings findings from basic research to the bedside/to the patient (and vice versa), relies on collaboration between basic life scientists and physician scientists (Deutsche Forschungsgemeinschaft [DFG] 2015; Epstein/Fischer 2017; Hendriks et al. 2019). Accordingly, we consider the life sciences to be particularly suitable and interesting when investigating collaboration.

Whereas a few (qualitative) studies have focused on collaboration specifically in the life sciences (Müller 2012; Parker et al. 2010), we aim to explore postdocs' collaboration experiences drawing on the concept of social capital (e.g., Coleman 1988, 1990; Granovetter 1973; Nahapiet/Ghoshal 1998) and the theory of social interdependence (Deutsch 2011; Johnson/Johnson 2005). In addition to previous studies, our aims are further:

1. to explore whether postdocs perceive positive or negative aspects of collaboration as predominant.
2. to specify the situations in which conflicts occur and competition prevails.
3. to specifically investigate postdocs' collaboration experiences with professors in general and the career support they receive from their superior professor.

This paper is structured as follows: In section two, we present the theoretical background of our study. In section three, we discuss previous empirical findings on the benefits and pitfalls of scientific collaborations in general and in the last subsection, specifically with senior scientists/professors. Section four describes the research methods and contains a description of the interview sample and the qualitative analysis. The results are presented in section five, and their implications and limitations are discussed in sections six and seven.

2 Theoretical Considerations: Social Capital and Social Interdependence

2.1 The Role of Social Capital in Academia

As already described in the introduction, collaboration is central to academic research—and continues to grow in importance—in order to address complex research questions and problems, and is important for the individual scientist's career. In the context of our study, we focus on the consequences that social capital has for the individual scientist. Therefore, we refer to authors who (also) focus on individual outcomes related to social capital, such as Coleman (1988, 1990), Nahapiet and Ghoshal (1998) and Burt (2001). While there are significant differences between these theorists, there is a common understanding that social capital describes resources that one can only access through social relations: "The

healthcare providers, they can bridge the gap between (biomedical) basic research and its application in health care (e.g., Hendriks et al. 2019; Vignola-Gagne 2014).

social capital metaphor is that people who do better are somehow better connected" (Burt 2001: 32). Nahapiet and Ghoshal (1998: 243) define social capital as "the sum of the actual and potential resources embedded within, available through, and derived from the network of relationships possessed by an individual or social unit".

Furthermore, these resources can be appropriated and transferred into other forms of capital, e.g., to human capital (Coleman 1988). By being connected to other scientists, postdocs, who are central in our study, can learn from the experiences and knowledge of others and increase their own human capital through learning. This may be specifically true, if the collaborators come from different (sub)disciplines or have different specializations. Aside from acquiring new knowledge themselves, postdocs also gain access to the human capital of their collaborators. This shared human capital might be needed to make a project successful, or to increase productivity (more publications). Postdocs may also gain access to other technical resources, i.e., research equipment. In addition, collaborating with and being known by others is important for the visibility of scientists, as the reception of their work by the scientific community is decisive for their career development (Leahey et al. 2016).

Also relevant to collaborations in academic research are the dimensions of social capital described by Nahapiet and Ghoshal (1998): the structural dimension, the relational dimension and the cognitive dimension. The *structural dimension* is a prerequisite for the emergence of collaborations and concerns the access to and the position within a network. The *relational dimension* develops out of experiences within a group/network and describes the personal relationship that people have developed over time (Nahapiet/Ghoshal 1998). Hence, the relational dimension describes the qualities of a relationship, which are actually important to explain and predict behavior. For example, through repeated interactions, individuals develop resources that can be beneficial for collaboration, such as trust/trustworthiness, commitment, expectation, and reciprocity (Coleman 1988; Nahapiet/Ghoshal 1998). These resources, which stem from strong ties and network/group closure, are important for collaborations because they facilitate coordination and knowledge sharing, and enable the enforcement of norms, e.g., via more opportunities for sanctions (Coleman 1988; Granovetter 1973). On the other hand, weak ties or structural holes are more likely to bring in new information (Granovetter 1973; Burt 2001). Out of these theoretical considerations, one might expect that repeated or internal collaborations are characterized by fewer instances of adverse behavior, like free riding and scooping. However, external collaborations may hold a higher potential for innovation.

Finally, the *cognitive dimension* of social capital refers to resources that enable shared understanding within groups/networks, such as shared languages and codes (Nahapiet/Ghoshal 1998). In reference to collaboration, a shared language and understanding will be more likely to occur in well-established teams (rather internal

than external collaborations) and with researchers that share research domains and/or come from similar disciplinary backgrounds.

Coming back to the structural dimension of social capital (Nahapiet/Ghoshal 1998), the status and prestige of scientists may play an important role. Professors, on average, are likely to hold central positions (Burt 2001) within their scientific community. Actors who hold central positions "carry more valued resources and exercise greater power" (Lin 1999: 31) and hold more opportunities. One could also argue that professors are, on the one hand, part of the scientific community, and on the other hand, part of a further network of professors, to which postdocs do not belong. Therefore, professors can act as brokers and hold information that other members of the scientific community do not possess. In addition, professors are more experienced and may possess higher human capital, but also knowledge regarding political aspects of academia, such as how to negotiate within projects, how to talk with other professors, navigate delicate issues and competing interests. In that sense, professors may possess a habitus (Bourdieu 1983) that postdocs do not. As a result, postdocs could benefit from collaborating with professors in myriad ways, from their human capital/professional advice, but also from career advice and input, e.g., on research specializations, positions to apply to, with whom to collaborate, and where to ask for funding. They can also benefit from professors' social capital for their own visibility through joint publications, and receive access to new information and to other scientists or scientific networks.

2.2 Social Interdependence: Collaboration and Competition

Team endeavors often require the expertise and knowledge, or just the workforce, of different team members. This renders team members interdependent; they must work together to achieve their personal goals, which are overlapping with the common team goal. According to Deutsch (2011) and Johnson and Johnson (2005) *social interdependence* exists when the realization of the collaborator's goals is influenced by the action of others. According to the theory, there are two types of goal interdependence: positive (cooperation/collaboration) and negative (competition). *Positive interdependence* occurs when individuals' success is bound to the success of others. For instance, postdocs can only publish research results of a project if the project as a whole is carried out successfully. On the contrary, *negative interdependence*, describes a condition in which only one person can achieve a goal, i.e., the success of one person is linked to the failure of others (Deutsch 2011; Johnson/Johnson 2005), e.g., only one team member can be listed as first-author.

Positive interdependence results in promotive interaction, i.e., individuals encourage and facilitate each other's efforts in order to reach a common goal. Negative interdependence results in oppositional or contrient interaction, i.e., individuals discourage and obstruct each other's efforts in order to reach their own individual goals (Deutsch 2011; Johnson/Johnson 2005). In accordance with social capital

theories (see Chapter 2.1), collaboration is usually based on mutual support, exchange/sharing of resources and trust (Deutsch 2011). This leads to the conclusion that social capital cannot be optimally mobilized in competitive settings. In order to secure their own advantage and to reach their individual goals, individuals do not make their resources (e.g., their knowledge) (fully) available to the other team members.

Furthermore, there may also exist asymmetries in the degree of interdependence in collaborative relationships, depending on who is working together. This is the case when the collaborators are dependent on each other to a different extent. As a consequence, one person has more power in the relationship than the other (Deutsch 2011). This could apply to whole institutions or to individual scientists who collaborate with each other. At the institutional level, asymmetries may occur if, e.g., one institution receives more financial resources for a third-party-funded project, which may lead to different priorities. At the individual level, power imbalances may exist, e.g., due to the status of the collaboration partners. Professors have greater decision-making power through their role as superiors and can, e.g., decide what research priorities are set.

3 Literature Review: Collaboration in Academic Research

3.1 Development and Status Quo

A steady increase in scientific collaborations can be observed in academia, as research continues to move away from being conducted by single scientists and towards projects that are carried out in teams and whose results are published collaboratively (Aldrich/Al-Turk 2018; Greene 2007; Leahey 2016; Wuchty et al. 2007). Not only is there an increase in the number of articles that scientists publish as co-authors, but also an increase in the size of research teams (Wuchty et al. 2007). This undisputed trend towards team science is evident across all scientific disciplines and is also apparent in sciences that have traditionally been a team endeavor, such as the life sciences (Schmidt et al. 2017; Vermeulen/Penders 2010). Apart from the rise of collaborations within single academic institutions, there has also been an increase in collaborations across institutional, national and disciplinary boundaries (Jones et al. 2008; Leahey 2016; Mosbah-Natanson /Gingras 2014). This trend could be attributed to the immense progress in science which has led to a greater degree of specialization among scientists (Aldrich/Al-Turk 2018) and an increase in the complexity of research questions, many of which cannot be investigated by individual scientists or disciplines (Hara 2003; Jones et al. 2008).

3.2 Benefits of Collaboration: Productivity/Visibility and Learning Opportunities

Publications and the dissemination of one's work are essential for research careers. In fact, the number of publications seems to be the most important factor in achieving full professorship (Lutter/Schröder 2016; Moosa 2018; Plümper/Schim-

melfennig 2007). The impact of collaborations for scientists' career development is reflected in the empirical link between the number of collaborations and scientists' productivity, i.e., their number of publications (Lee/Bozeman 2005; Scaffidi/Berman 2011; Wieczorek et al. 2020). In addition, scientists who work collaboratively produce more high-impact articles, i.e., receive more citations (Acedo et al. 2006; Bikard et al. 2015; Lee/Bozeman 2005). Also Wuchty et al. (2007: 1037) discover "[…] a broad tendency for teams to produce more highly cited work than individual authors". This could be explained by the larger number of co-authors who share their work with their various contacts which increases visibility (Bikard et al. 2015). However, it could also be attributed to the higher quality of the articles resulting from scientists' collaborative work as they, e.g., cross-check each other's work and apply complementary skills (Clark/Llorens 2012; Leahey 2016). Working in teams could also foster creativity and result in more novel ideas (Bikard et al. 2015). This seems to be attributed to the so called "Medici-Effect" that occurs when new ideas emerge from the interaction of scientists from different perspectives and various disciplines and backgrounds (Bikard et al. 2015; Johansson 2004). Studies have shown that atypical scientific ideas (as measured by which journal a paper cites) lead to a higher impact of research articles (Mukherjee et al. 2017; Uzzi et al. 2013). These results are also in line with the theoretical assumptions, that collaborating with other scientists can increase productivity through the access to their human capital or technical resources that facilitate the realization of research projects.

Moreover, collaborations can provide learning opportunities for scientists through professional exchange with other scientists (Aldrich/Al-Turk 2018). This aligns with the idea that scientists can expand their own human capital. Accordingly, the results of Freeman et al. (2015: 30) suggest that scientists are particularly interested in collaborations with other scientists from whom they can learn, in order to complement their "knowledge, expertise and capabilities".

In general, scientific collaborations might improve the overall research experience by enhancing motivation and discipline. Freeman et al. (2015), for instance, show that scientists perceive the research experience in teams to be more pleasant.

3.3 Competition in Academic Research: Secrecy and Credit Allocation

While most articles on the topic of competition in academic research are theoretical, Hong and Walsh (2009) find that competitiveness has increased among experimental biologists over a time span of 30 years. They further linked competitiveness to secrecy, i.e., withholding relevant knowledge due to "concerns about being anticipated" (Hong/Walsh 2009: 146). In line with these results, Blumenthal et al. (2006) find that data withholding is common in genetics and other life sciences, especially in environments in which scientists perceive a higher level of competition. Scientists, for example, omitted information from a manuscript

and delayed publication in order to secure their own scientific lead. Furthermore, results of focus-group discussions support that competition negatively influences the exchange of information. The study participants reported the omission of relevant information in presentations and publications to prevent anticipation. The participants also voiced concerns about competitors interfering with peer-review processes and stealing their intellectual property (Anderson et al. 2007). These results match expectations according to the theory of social interdependence, that negative interdependence (only one group/scientist can publish the results) leads to contrient interactions (Deutsch 2011; Johnson/Johnson 2005).

Competition within research teams can revolve around credit allocation. When scientists work and publish alone they are the sole recipients of credit, whereas working in research teams forces scientists to share credit and individual authors only receive a fractional amount of credit, based on the number of co-authors (Aldrich/Al-Turk 2018; Bikard et al. 2015). While collaboration has a positive impact on scientists' overall publication record, empirical evidence regarding the influence of team science on the fractional publication count is less clear (Bikard et al. 2015; Lee/Bozeman 2005). Bikard et al. (2015) even find that collaboration can eventually decrease scientists' fractional productivity by over 30 %. One qualitative study indicates that postdocs may prefer to work alone in order to "[…] ensure first authorship, avoid authorship conflicts and keep the number of co-authors low" (Müller 2012: 289). Hence, the anticipation of conflicts or the competitive nature of the academic career may prevent some collaborations from the outset.

3.4 Coordination and Communication Challenges

One major source of pitfalls within collaborations can be coordination and communication challenges, which can be very time-consuming and can have various origins, such as conflicting goals, time horizons and communication difficulties due to different disciplinary or cultural backgrounds. Increased needs for coordination and communication can negatively affect the productivity of research teams and thus the productivity of individual scientists (Aldrich/Al-Turk 2018; Bikard et al. 2015). This observation was made above all in connection with multidisciplinary teams and collaborations between different institutes or universities (Cummings/Kiesler 2016). Freeman et al. (2015: 39) find that two of the biggest hurdles for scientists, who work collaboratively, are "insufficient time for communication" and "problems coordinating with team member's schedule". Collaborations can further hinder scientists' individual autonomy due to "less flexibility in how the research was carried out".

While on the one hand it is assumed that collaboration between scientists from different backgrounds and disciplines has a positive effect on the creation of novel ideas, there are also opposing views; working in multidisciplinary teams might entail more conflicts and challenges due to the diverse background and working habits

of the collaborators. Understanding ideas and perspectives from other scientific fields can further be challenging and it might be difficult for reviewers to grasp and evaluate cross-disciplinary work. This could lead to a lengthening of the review process and thus to delayed publication, which could negatively affect scientists' productivity (Leahey et al. 2016). Based on these assumptions, Leahey et al. (2016) analyzed data from around 900 scientists and their 32,000 published articles and found that interdisciplinary research is associated with cognitive challenges and hurdles in peer review and lower productivity, but not with lower article quality.

3.5 Collaboration with Senior Scientists/Professors

Even from the very early stages, personal relationships with professors can help ease the transition into an academic career. Studies have shown that early personal contact (such as working as tutor or student assistant) with university lecturers increases the likelihood of transitioning into a doctorate (Jaksztat/Lörz 2018; Konsortium Bundesbericht Wissenschaftlicher Nachwuchs 2021).

While there is still no research on the influence of superior professors on their postdocs' careers, studies point to a career-enhancing effect of relationships with senior scientists and professors. Studies have shown that former PhD supervisors can increase postdocs' chances of reaching tenure (Combes et al. 2008; Godechot 2016; Lang/Neyer 2004). Moreover, empirical evidence supports the idea that being connected to senior scientists as a PhD student increases the chances of getting employment as a postdoc (Fuchs et al. 2001; Lang/Neyer 2004; Schubert/Engelage 2011). Lang and Neyer (2004), for instance, find that the supervisor's productivity increases the chances of finding a postdoc position. These findings support the idea that professors are well connected and can use their ties to support their (former) protégés in finding new positions.

In the context of mentoring, Davis (2009) shows that postdocs whose supervisors work with them on a research plan submit and publish more articles and are more successful in obtaining external funding. Scaffidi and Berman (2011) report a link between the quality of supervision and the publication output of postdocs. These findings support that professors' human capital, and experience within the academic context can affect the productivity and success of their postdocs. In the context of an interview study, both the interviewed professors and the young scientists described the dyadic relationship between professor and young scientist as decisive for the success or failure of academic careers (Richter/Reul 2016).

Despite these positive aspects of collaborating with senior scientists and professors, there can be negative aspects, too. Professors are often (informal) supervisors and at the same time superiors of their staff (e.g., Ullrich 2019). Since the many roles they incorporate are mainly informal, they face no sanctions for poor performance. They can leave the task of promoting their postdocs' careers unattended without personal consequences: "There is no systematic or organizational, let's say structu-

red support. It's all individual, decentralized. If I am a nice person, I take care of my people, yes, if I am not, they are in the woods"[2] (quote from a professor in Richter/Reul 2016: 323). Another negative aspect of collaborating with senior scientist/professors can be free riding: Bikard et al. (2015) find that collaborating with higher rank scientists has a negative impact on the quality gain (measured by the number of citations) and on the fractional productivity of young scientists' publications. In this context, Hu et al. (2014) discover that scientists at a later career stage benefit more from collaborations than scientists at earlier career stages. In addition, junior scientists may not always receive adequate recognition for their contribution to a senior scientist's project. Studies suggest that particularly female junior scientists may profit less from collaborating in terms of publications as co- and lead author (Feldon et al. 2017, Epstein/Lachmann 2018). Moreover, Al-Herz et al. (2014) investigated the practice of adding honorary authors in biomedical journals in a survey study and found that one third of their respondents added authors to their publications even though they did not deserve authorship credit. Reasons for this practice include avoiding conflicts and facilitating acceptance of the article. These examples underline the effects that asymmetries in interdependence/power imbalance (Deutsch 2011; Johnson/Johnson 2005) can entail. Due to their inexperience or dependence on senior scientists/professors, there may be little that early career scientists can do against these malpractices.

4 Methods

4.1 Sample

This study is based on qualitative data from the E-Prom project[3] (phase 2, 2016–2019), which was funded by the "Bundesministerium für Bildung und Forschung (BMBF)". The project aimed to analyze the career paths of postdocs in the life sciences (primarily in the fields of biology and medicine) in Germany. Of particular interest were scientific careers that continued at the university, as opposed to research careers in the private sector.

The interviewees were selected from a previous longitudinal online survey in which postdocs at universities in Bavaria, Saxony and North Rhine-Westphalia participated (for details see project report[3]). For the qualitative interviews, participants who provided their contact details and who indicated that they continued their careers in academic research were contacted. When selecting the interview participants,

2 This quote is originally from a German interview study from Richter and Reul (2016) and was translated to English for the purpose of this article and is thus not quoted verbatim.

3 German title „Einflussfaktoren auf die Karriere Promovierter in den Lebenswissenschaften (E-Prom 2)", English title: "Factors influencing postdocs careers in the life siences" (Epstein et al. 2020).

attention was also paid to a balanced gender and subject (biology and medicine[4]) ratio.

Within this project, 22 qualitative interviews with postdocs from the life sciences (eight physician scientists and 14 biologists) were conducted between February and June 2017. Table 1 shows an overview of the study participants. Half of the respondents were female, the other half male. At the time of the interview, the interviewees were mainly working in various biological and medical sub-disciplines in academic research. However, two of the interviewees, contrary to their earlier statements, had already left academic research and were working in the pharmaceutical industry (ID9) and as medical technical assistant (ID11). Two other respondents were on parental leave (ID7, ID13) and one respondent was unemployed (ID12). Even though these respondents were not employed or not working in academia at the time of the interview, they were not excluded and were retrospectively interviewed on their postdoc time. Four respondents were working abroad at the time of the interview.

4.2 Interview Procedure and Topics

The interviews had a length of between 30 and 60 minutes. In addition to postdocs' career paths, goals and decisions, the interviews included the topics *collaborating with other scientists* and *career support by the superior professor*. The interviews conducted were standard structured interviews, based on a guideline. The interview guideline consisted of questions on five central topics: Current occupational situation, time investment on different tasks and overtime, scientific collaborations in (multidisciplinary) teams (with focus on benefits and pitfalls of collaborations), career support from the professor, career support from the university, and career aspirations.

4.3 Coding and Analysis of the Interviews

To address our research questions, we only analyzed the related interview sections, encompassing the topics of *1) scientific collaborations* ("Do you also work together with other scientists? Who do you work with and what does the collaborative work look like?", "In what ways can you benefit from working with other scientists?", and "What problems/disadvantages arise while collaborating with others?"), and *2) career support from professors* ("Do you talk to your professor about planning your (academic) career and what support do you receive in this?", and "Do you talk to your professor about opportunities outside academia?").

The interviews were transcribed verbatim and analyzed following Mayring's qualitative content analysis (2000, 2010). Following the interview guideline, we deduc-

4 As there is a shortage of physician scientists in Germany (e.g., Gerst/Hibbeler 2012), it was more difficult to recruit members of this discipline. Accordingly, the subject ratio is not entirely balanced.

tively developed a first draft of the coding scheme that incorporated all main categories but also some subcategories. This coding scheme was supplemented inductively with more subcategories that came up during the first rounds of coding. The relevant main categories were: *1) type of collaboration (internal/external, intensive/less intensive, monodisciplinary/multidisciplinary), 2) benefits of scientific collaboration, 3) pitfalls of scientific collaboration, 4) collaboration with professors, 5) career support from superior professors, 6) no support from superior professors,* and *7) strategies for conflict prevention.*

After the coding scheme was finalized, we coded the interviews independently. We calculated the interrater reliability using Cohens's kappa (Cohen 1968) and had a value of 0.85, thus considered "good" (Lombard et al. 2002). Since the exact location of the codes in the interviews was irrelevant for the interpretation, we calculated Cohen's kappa based on the presence of the code as a measure of agreement (Epstein et al. 2018).

Table 1: Overview of the Interview Study Participants (E-Prom 2)

Interview	Gender	Year of Birth	Field	Occupation at Time of Interview	Career Aspirations
1	male	1985	Medicine and Microbiology	Resident at university hospital and scientist	Completion of specialist medical training, Habilitation (with subsequent application for professorship)
2	male	1975	Biology (Pharmacology)	Scientist	Leaving academic research
3	female	1986	Biology (Environmental Biology)	Scientist	Permanent position as research assistant
4	male	1986	Medicine	Resident at university hospital and scientist	Completion of specialist medical training, Habilitation (with subsequent position as senior physician)
5	male	1986	Medicine (Nuclear Medicine)	Resident at university hospital and scientist	Completion of specialist medical training, Habilitation (with subsequent position as professor or senior physician)
6	female	1977	Medicine (Internal and Rheumatism)	Senior physician (mainly in research)	Extraordinary professorship, or possibly leaving academic research

Interview	Gender	Year of Birth	Field	Occupation at Time of Interview	Career Aspirations
7	female	1984	Medicine (Paediatric Medicine)	Scientist on parental leave	Completion of specialist medical training, Habilitation (if not too time-consuming), clinical and scientific career
8	male	1985	Medicine (Neurology)	Resident at university hospital and scientist	Completion of specialist medical training, Habilitation (if not too time-consuming), clinical and scientific career
9	male	1982	Medicine	Physician and employee in pharmaceutical industry (former postdoc in USA)	No academic career intentions
10	male	1984	Biology	Scientist	Leaving academic research
11	female	1984	Biology	Medical-Technical Assistant	Current position
12	female	1981	Biology	Unemployed	Research assistant or leaving academic research for research position in industry
13	female	1983	Biology	Scientist on parental leave	Permanent position as research assistant or leaving academic research
14	female	1981	Biology (Nutritional Science)	Scientist	No professorship intentions, in general undecided (research assistant or leaving academia)
15	female	missing	Biology	Scientist	Junior professorship (with subsequent application for professorship) or permanent position as research assistant, otherwise leaving academia
16	female	1986	Biology	Scientist (NL)	Junior-group leader (with subsequent application for tenure track program or full professorship)
17	male	1985	Biology	Scientist	Long-term academic career intention, professorship
18	female	missing	Biology	Scientist	Scientific management in public sector
19	male	1982	Biology	Scientist	Position as group leader, permanent position as research assistant

Inter-view	Gender	Year of Birth	Field	Occupation at Time of Interview	Career Aspirations
20	female	1983	Biology	Scientist (USA)	Research assistant or leaving academia
21	male	1982	Biology	Scientist	Research assistant or teaching
22	male	mis-sing	Biology	Scientist (GB)	Research position in industry

5 Results: Scientific Collaboration in the Life Sciences

5.1 Benefits and Pitfalls of Scientific Collaboration

For a better understanding of how the respondents collaborate with other scientists, we were first interested in the *type of collaboration* the postdoctoral life scientists from our study sample engage in. When asked about the location of collaboration partners, respondents reported almost equally on collaborations within their own institution/working group and across institutional boundaries (including international collaborations and collaborations with economic partners). In this context, the interviewees also indicated that internal collaborations were predominantly more intensive than external collaborations. Hence, internal collaborations were rather emphasized as strong ties, and external collaborations as weak ties. As expected, almost all respondents stated that they frequently work with scientists from other disciplines, with multidisciplinary collaborations taking place with both internal and external collaborators. Only three of the interviewees mainly collaborated with scientists from their own discipline (ID15, ID21, ID22).

5.1.1 Benefits of Scientific Collaboration

Overall, the interviewees perceive collaborations as indispensable for their professional life:

> *"As a lone wolf, I think you get lost in the life sciences."*[5] (ID1, physician & microbiologist)

Most interviewees highlighted the importance of the **1) experience and knowledge of others/access to human capital**. In this context, the interviewees experience the mutual discussion and the professional exchange with other scientists as particularly beneficial not least for generating creative research approaches and increasing the quality of research:

> *"[Without collaboration] I think something very important would be missing, which is in the area of creativity. Because I believe that input is very important for creativity. I think in modern science we need this exchange. Very little works in the way that, I think about something for years and then come up with a brilliant idea. I think we are also very far away from the universal scholar who can know everything.*

5 All interviews (except interview ID22) were conducted in German. We translated the quoted interview sections into English.

So, we simply need this interaction and this collaboration, and the research I would produce [without collaboration] would simply be much worse." (ID17, biologist)

Interviewees indicated that they benefit from collaborating with colleagues in their own discipline as they can seek expert advice, share experiences, and compare different research approaches. In addition, the respondents stated that they particularly benefit from the knowledge and experience of scientists from other disciplines and with different specializations. Physicians and biologists share this point of view:

"So, on the one hand, you have a very different, different mind-set. So, you approach it very differently. If you assume that we are cell biologists, we always have the cell in mind. And if you then look with these physicians, they always have the implementation in mind. So, these different perspectives are definitely very important." (ID16, biologist)

"I believe that we as physicians have more of an eye for the medically relevant, but that we clearly benefit more from the biochemist when it comes to making any biochemical analyses, which far exceeds our competences." (ID1, physician & microbiologist)

Hence, social networks generally bring in new ideas and foster creativity ("Medici-Effect", see Johansson 2004). They also bring in more human capital. This was specifically emphasized with reference to other disciplines. In contrast to our theoretical assumption that mainly external collaborations/weak ties (Granovetter 1973) bring in new ideas, our study respondents stated that this is the case for both internal and external collaborations. This is probably due to the high number of inter-/multidisciplinary collaborations that are very common in the life sciences in general, also in internal collaborations, and bring in new knowledge, perspectives and ideas.

Directly related to this is the **2) realization of research projects**. Many research projects can only be carried out through collaboration of experts from different fields and with specializations:

"But I would say that the exchange with chemists and biochemists at the beginning is actually essential, without them it wouldn't work at all. You couldn't work at all." (ID16, biologist)

"Well, here in nuclear medicine we would be limited to nuclear medicine questions. And many of the questions we are working on would probably not even be asked, because the input regarding the need for information that this research is supposed to generate in the end does not exist." (ID5, physician)

Furthermore, two interviewees (ID7, ID14) pointed out that collaborations are important for the collection of big datasets that are needed to generate good clinical data and international recognition.

The fact that research projects can often only be realized if scientists collaborate highlights that research projects involving different partners do, generally speaking, establish a state of interdependence, which can be positive, if there are no conflicts of interest and the common goal is equally important to all project partners (Deutsch 2011; Johnson/Johnson 2005).

In addition, the respondents reported that they could **3) expand their own knowledge/human capital** through the aforementioned exchange. The interviewees indi-

cated that they learn from different perspectives and (methodological) approaches, and specifically from scientists with different skills, research specializations or disciplines. Apart from technical and professional knowledge, participants also mentioned social skills, such as learning to lead people, communicate and successfully manage research projects (ID17, ID3):

> *"[…] and on the interaction level, I think you also learn quite a lot when you work with different people. In terms of leading people or maybe understanding why some collaborations didn't work out or something like that."* (ID17, biologist)

In this context, one interviewee also mentioned that the gain of knowledge/human capital can also be useful to prevent errors:

> *"And if you use these techniques several times, of course it becomes easier and you can work together more effectively because you know the problems of both parties and you can address them from the beginning. And maybe also know the difficulties of some techniques directly and avoid problems."* (ID4, physician)

Another benefit of collaborations can be **4) increased productivity** through the division of labor. In this context, the respondents mentioned that collaboration can be more efficient than working alone, as one can save time and work on different projects simultaneously:

> *"And you don't have to learn the methods for yourself and you don't have to learn the expertise to do certain things, so you just save time and you save money and you save nerves."* (ID20, biologist)

Importantly, collaborations are seen as an opportunity for joint publications, i.e. adding to one's publication record as collaboration *"[…] results in publications, which I need for my career"* (ID 15, biologist).

Respondents further benefit from **5) access to technical resources**. Besides profiting from the collaborators' know-how, for instance regarding the implementation of methods, it is mainly technical resources—such as (already established and otherwise costly) technical equipment needed for certain experiments—that are mentioned:

> *"Yes, I can benefit from it in the way that I can carry out analyses or get results that I would not have been able to achieve myself, because you don't have the technical equipment and the technical background to do this analysis."* (ID4, physician)

5.1.2 Pitfalls of Scientific Collaboration

In addition to the benefits of collaboration, the life scientists also reported a variety of potential pitfalls to collaborative work.

Above all, the postdocs mentioned **1) conflicts due to competition** as one negative aspect of collaboration. The interviewees reported that conflicts are predominantly tied to questions of authorship and the order of authors. For example, ID8 (physician) stated *"it's a bit of a question of who stands where on the paper and who benefits more or less. That's always a bit of a point of contention"*. These conflicts were

predominantly mentioned in the context of external collaboration/between working groups, as one interviewee states:

> *"[…] in the end you want to write something about it and publish it and so on. But the other working group that is assigned to us also has this interest. And then it's just a question of who is in charge of writing the article in the end."* (ID5, physician)

One of the interviewees (ID11, biologist) pointed out that sharing knowledge with external collaborators is a *"delicate issue"* since *"you have to trust that they won't publish beforehand"*. Another respondent (ID15, biologist) is even under the impression that collaboration partners in some cases hinder the publication process of other team members to secure their own scientific lead:

> *"[…] there are often competing interests. I don't think that they want us to publish so quickly because they already have their own publication in the pipeline on the topic. And then, they might want to put the brakes on my publication. That's not very nice morally, but it does happen. […]. Sometimes it's just a bad suspicion. But I have the subjective impression that it does happen in individual cases, unfortunately."* (ID15, biologist)

In another case of international collaboration, the interviewee reported that the project partners had applied for a patent in their own name without consultation. While the postdoc herself was the author and inventor of the method in question, the project partners made a profit from their national law, that the first ones who apply for the patent are seen as the patent holders.

> *"[…]. And that led to difficulties in the patenting process. And that was rather negative, I would say, because we shared our results with them and thereby we cut our own flesh, so to speak."* (ID11, biologist)

As already mentioned, these conflicts primarily took place in the context of external collaborations, hence, rather weak ties with less closure and fewer opportunities for sanctions (Coleman 1988; Granovetter 1973). In contrast, self-chosen collaborations or internal collaborations were mostly described in the light of their benefits. Further, the described situations of conflicts have in common that there are individuals or teams that aspire to an individual goal that is incompatible with team success—being the first and/or only author. Hence, these situations can be characterized as situations of negative interdependence (Deutsch 2011; Johnson/Johnson, 2005). Negative interdependence/competition can lead to oppositional/contrient interactions, i.e., sabotaging others' efforts to reach their goals (Deutsch 2011; Johnson/Johnson 2005). Some of our interviewees' statements show contrient interactions: The interviewees mentioned, e.g., that they withhold information because they are afraid of being scooped by project partners (ID11, biologist) or that they assumed that project partners had thwarted them (ID15, biologist).

There was one interesting case, in which an interviewee described a highly competitive workplace (ID15, biologist), in which there is no real collaboration between employees and everyone "defends his sinecure".

"[…] everyone sits so on their assigned things. One is responsible for the technology; another is more responsible for teaching and defends that very much. Yes, so there is not much exchange among each other, little teamwork takes place" (ID 15, biologist)

She further characterized her chair as a three-tiered society in which the postdocs/research associates with permanent contracts were the "ruling class", then the "regular" postdocs came second and lastly the PhD students. She attributed this state at least in some part to an absent professor and his lack of leadership. In this case, the network structure was present; however, resources could not be (optimally) mobilized due to a highly negative relational dimension (Nahapiet /Ghoshal 1998).

Further, **2) coordination and communication challenges/costs** were mentioned as obstacles to successful collaboration. In this context, the respondents spoke about reduced efficiency due to difficulties in arranging joint project meetings (ID3, biologist), as well as hurdles in joint decision-making (ID6, ID19). These issues were predominately mentioned in relation to external collaborations between institutions:

"[There are already problems] when you are spatially separated, i.e. when there are other institutions. That you can't exchange information so quickly and easily. You always have to arrange these project meetings and then everything has to be discussed there. That is also very inefficient, so you often can't exchange information as well or as deeply as you should." (ID15, biologist).

Coordination challenges were also mentioned with regard to disciplinary discrepancies. For example, ID15 (biologist) described a potential for conflicts if different disciplines work together and team members want to analyze and present the results in a different way, e.g., some of them *"[…] want to look at it more scientifically, but the others are more implementation-oriented".* Moreover, ID2 (biologist) pointed out that there are often problems regarding the distribution of tasks and the roles within the teams especially at the beginning of the collaborative endeavor as *"[…] people don't want to or can't identify with the role*".

Besides these coordination costs, the interviewees reported communication issues, which were often described in connection with multidisciplinary collaboration. These communication challenges were mentioned by both the physicians and the biologists in our study sample:

"You have to move together on one level, which means that as a physician you sometimes lack the technical understanding that biologists have. On the other hand, biologists don't always have a full grasp of these physiological backgrounds or have to familiarize themselves with them." (ID4, physician)

"Well, it's sometimes a bit difficult as a biologist when things get very medical, I'd say. So, when you're sitting in a meeting with all the physicians […] it's sometimes a bit difficult to follow as a biologist. Because you don't know all the abbreviations or idioms or whatever in detail. Because you simply come from a different perspective." (ID13, biologist)

In addition to these disciplinary communication barriers, cultural/linguistic communication challenges were also addressed—especially while working with international partners or collaborators of different nationalities. Here the interviewees

mentioned language-related barriers during meetings, as the following interview excerpt shows:

> *"Cultural problems, I would say. There can be communication problems, where people understand things differently and then don't come out of the discussion with the same conclusions, for example. […] I had an Indian colleague a few years ago, and it took a very long time until communication was clear and we understood each other well. So, I think you often have to adjust to each other more when you come from clearly different cultural backgrounds."* (ID19, biologist)

In general, it shows that coordination and communication costs of collaborations were especially high in reference to external and multi-/interdisciplinary collaborations, hence resulting in rather weak ties with little or no network/group closure (Coleman 1988; Granovetter 1973). Further, referring to the cognitive dimension of social capital (Nahapiet/Ghoshal, 1998) it becomes clear that shared language and codes are important for efficient collaborations.

Following the previous topic, some respondents mentioned **3) prioritization issues and loss of independence** as a negative aspect of collaboration. Prioritization issues can delay projects: Scientists often work on more than one project and *"[…] the prioritization of the projects is not always equally weighted"* (ID4, physician). Usually *"[…] everyone does their own main project first, and if you're involved in something with the others, that always takes a back seat"* (ID1, physician & microbiologist). This difficulty was also mentioned in the context of collaborating with physician scientists, who are often overburdened by multiple scientific and clinical tasks and cannot always fulfill their tasks in the collaborative project in a timely manner:

> *"Of course, with physicians at university hospitals who have a very tight program, you sometimes have to wait a little longer for things to progress. Because everyone is working on many projects and has the clinic at the same time." (ID14, biologist)*

One respondent (ID4, physician), for example, stated that working alone gives more freedom to *"work more independently"* and *"organize things better"* as you are not *"dependent on others"*. Another interviewee described the dependency on (interim) results needed from a project partner in order to advance to further research questions:

> *"The difficult thing about the project was that a lot of industrial partners were involved and some of them did it on the side instead of focusing more on it. That means that in some cases you had to wait for results or interim results before you could continue working yourself."* (ID12, biologist)

This shows that the degree of interdependence (Deutsch, 2011) is higher when collaborating with external partners and that (external) collaboration can entail asymmetries, in the sense that one person may be more dependent on intermediate results or in the advancement of the research project in general. In this case, the postdocs are more dependent on successful project outcomes than their industrial collaboration partners, as they need publications to advance their scientific careers.

Another statement by a respondent (ID15, biologist) points to the problem of 4) **free riding**. The interviewee complained that collaboration with others often does not take the form of a real collaboration *"[…] but you have to put the people on it [on the paper] because they somehow helped a bit at some point"*.

5.2 Collaboration with Professors and Career Support from Superior Professors

This section describes the postdocs' experiences of working with professors within projects—this comprises the superior professors but also other professors. In addition, we analyze the career support that postdocs receive from their superior professors.

The interviewees reported **1) collaboration with professors** such as professional advice and joint work on publications or proposals:

> *"Yes, that's definitely the case. He is also very much involved in the whole publication process. So, it's also the case that with every publication we really sit at the computer again at the end and fine-tune the text."* (ID3, biologist)

> *"When I write proposals—but unfortunately this has not been successful so far—because he is very encouraging and helps and has ideas and says we'll try again. He also reads through it and so on, in that respect."* (ID17, biologist)

Another positive aspect of collaborating with professors is their experience of navigating within academia, e.g., how to talk about delicate subjects with projects partners. In this respect, postdocs can acquire a form of "Habitus" through observing their superior professors:

> *"And I also experience that it is the case that you have to be careful and diplomatic, and then maybe you don't ask or do certain things directly for strategic-political reasons. But the more experienced you become—and I can see that above all in my boss, who has many years more experience—the better you can deal with it, I think, and then you can also use it positively for yourself."* (ID5, biologist)

One interviewee (ID15) described that she is obliged to list the professor as co-author and that he slows down the publication process:

> *"No. He just says that I should publish as much as possible, or he actually always says that we all have to publish more. But if I then write a publication where he has to be co-author, that's simply the requirement from him, and put it on his desk to be corrected, then it stays there for at least a year. No matter how often I ask and put pressure on him. He tends to put the brakes on me when it comes to things like that. He says he wants us all to do it, but then he actually slows us all down."* (ID15, biologist)

This shows that collaborating with professors not only entails benefits through access to professors' human capital, but that postdocs are also highly dependent on them. Here, asymmetries in the degree of dependency (Deutsch 2011) become visible.

In a similar direction, another postdoc reported, that professors insisted on their "right" to first and last author positions in a project, not because of their contribution, but because of their reputation. While the postdoc needed the authorship for his publication record and his professor instantly supported him, the professor

gave in to the demands of the other professors and also to the sponsors of the study and their right to have a say:

> *"Two or three days ago I had a discussion with my professor, hey, that wasn't the agreement, publication strategy or not. But he said, what can you do, of course the sponsor also has a say, and of course there are other authors, important authors, who also want their rights, blah, blah. And now there's a bit of arguing and negotiating. But I, as a small fish, will probably get the short end of the stick"* (ID2, biologist)

This example highlights the potential pitfalls of collaborating with professors due to the power asymmetry between postdoc and professor but also the discrepancy in dependency (Deutsch 2011): The authorship is more important for the postdoc's than the professor's career.

Half of the respondents stated that they received advice and **2) support for their career from their superior professors**. ID19 (biologist), for example, stressed that his career development is a *"very important topic"* for the professor and that he feels *"quite well advised"*. Others reported that career planning is *"an important part of our regular meetings"* (ID17, biologist) or that there is *"kind of a performance talk once a semester"* in which questions regarding career development could also be addressed (ID20, biologist). In terms of content, these discussions mainly relate to general recommendations on the Habilitation, publication goals and strategies, implementation of projects and recommendations about networking:

> *„So, in the end, it is agreed that it should lead to a Habilitation. And in this respect, you are also supported in the implementation of these academic projects. And there have already been consultations about whether you are on schedule or whether you should possibly initiate other projects, [...] and the goal is to sit down with your supervisor and set priorities. So, I can already see that there is support there."* (ID4, physician)

> *"And we also discuss the concept together beforehand and sit down together strategically more often and think about what projects we have, what could be published and what would be most effective for whom in our team as small research packages."* (ID3, biologist)

> *"Yes, that's true. It's more in the direction of who you meet, at which conferences you might talk to whom. In that direction, yes."* (ID20, biologist)

Another example of career support is provided by one interviewee, who was nominated for an award by her professor to enhance her CV:

> *"[...] and he is always on the lookout, for example. So right now, he suggested me for a water monitoring prize and I didn't have to come and say, hey, can you suggest me or something. To be honest, I didn't even notice that the prize existed and he saw it somewhere and thought of me and said, see if we shouldn't put you forward, because that would be great for your CV and so on. And he's definitely on board with that. So, I can't complain at all."* (ID3, biologist)

This example illustrates that professors occupy central positions within networks and have information that postdocs may not have, and therefore can act as brokers (Burt 2001).

One interviewee stated that the professor had also previously helped postdocs to find positions outside academia, making use of his networks. The interviewee also stated that the professor would support him in this direction too, if he asked for it:

> *"I could imagine something like the State Office for the Environment or the Ministry of the Environment or something like that, to somehow try to get a job there. But he would definitely support me there, [...] then I would definitely approach him and say that I would like to be placed in such and such a direction, and whether he can support me there. And I know from other colleagues, from several colleagues for whom this has already worked, this support, that he would definitely do that."* (ID3, biologist)

This example shows that professors—presumably depending on the discipline—not only have access to networks within academia, but can also assert their position and influence and can use other networks outside of academia to accommodate their postdocs.

Some respondents also suggest that their professors provide support for continued employment. The respondents indicate that their professors discuss employment options with HR and try to get contract extensions for their postdocs (ID3, ID10). ID14 (biologist), e.g., pointed out that her professor *"would go to great lengths to accommodate us well"* and *"to open opportunities for us or to use her contacts to find another door for us"*. Again, this shows that professors can use their influence and central network positions to open career opportunities for their postdoc.

Three respondents (ID2, ID8, ID15) answered that they currently receive 3)**no support from superior professors**. ID8 (physician) pointed out that *"[…] there is no such thing [as career support], no, and I hardly know anyone who really has such conversations here"*. ID2 (biologist) even assumes that professors are generally not interested in supporting their scientific employees, because *"it's not in the nature of a professor to stand up for the individual staff members in that respect. No, you can forget that"*. Also, ID15 (biologist) feels that the professor is *"not interested at all"* in advising or promoting research assistants.

5.3 Strategies for Conflict Prevention

In addition, some interviewees mentioned strategies they use to avoid conflicts in collaborative settings, which usually included different institutions.

The postdocs stated that it is important to clearly communicate and define the individual contribution of the project partners and the individual and common goals within the joint project from the outset:

> *"That's why whenever I do something with someone, I always try to discuss clearly in advance with all the people involved what the distribution should be, what the effort is for each person and what everyone has to gain from it."* (ID8, physician)

Problems usually arise at the end of collaborative projects if the expectations were not set clearly from the beginning. In relation to this, one respondent stated that the negotiation over authors' positions is "*[…] mostly [conducted by] the hierarchical*

levels above the postdocs" (ID5, physician). However, another interviewee mentioned that in spite of agreements made at the start of the project, problems can still occur. Conflicts would then arise between professors who want to "push" their own postdocs/scientific staff:

> *"That's usually at the end, when everything has already been done and then someone wants to push someone else in some way and then somehow thinks about changing everything. And these are often professors who somehow don't agree."* (ID8, physician)

6 Discussion and Conclusion

The aim of this study, set in the German academic career context, was to explore postdocs' collaboration experiences drawing on the concept of social capital (Coleman 1988, 1990; Granovetter 1973; Nahapiet/Ghoshal 1998) and the theory of social interdependence (Deutsch 2011; Johnson/Johnson 2005). Hereby, our aims were 1) to explore whether postdocs perceive positive or negative aspects of scientific collaborations to be predominant, 2) to specify the situations, in which conflicts occur and competition prevails, and 3) to specifically investigate postdocs' collaboration experiences with professors in general and the career support they receive from their superior professors in particular.

In terms of the benefits and pitfalls of collaborations, the benefits, overall, outweighed the pitfalls. The interview partners hereby highlighted the access to resources that were made possible through their collaborative network: human capital/cognitive resources and technical resources. Access to these cognitive and technical resources was described as indispensable for realizing certain projects, specifically multi-/interdisciplinary projects. Furthermore, and consistent with previous research (e.g., Freeman et al. 2015), learning from collaborative partners, within collaborations, was mentioned as a positive aspect—specifically in projects including multiple disciplines. This not only included professional/technical knowledge, but also social and project management skills. This shows that social networks generally bring in new ideas and foster creativity ("Medici-Effect", see Johansson 2004), not only in external but also internal collaborations, due to the strong multidisciplinary work environment. In addition, scientific collaborations can increase the productivity of individual scientists, as they have the opportunity to work on different projects simultaneously and act as co-authors, which increases their publication record (e.g., Wieczorek et al. 2020). The number of publications is crucial for an academic career, and studies suggest this is the most important factor of attaining tenure (e.g., Jungbauer-Gans/Gross 2013; Lutter/Schröder 2016).

Despite the positive aspects mentioned, our study supports the assumption that collaboration can be linked with, for instance, problems of coordination and communication (e.g., Bikard et al. 2015; Freeman et al. 2015), which are especially common in the context of external and multi-/interdisciplinary collaborations, characterized by rather weak ties with reduced network/group closure (Coleman

1988; Granovetter 1973). Coordination issues can arise, e.g., due to difficulties in arranging joint project meetings and prolonged joint decision-making on the basis of different disciplinary- and cultural/linguistic backgrounds. This shows that the cognitive dimension of social capital (Nahapiet/Ghoshal 1998), i.e., shared language and codes, is important for efficient collaboration. Also, some interviewees described prioritization issues and the loss of independence as negative aspects of collaboration. In summary, projects including multiple disciplines might be more innovative at the cost of a reduced efficiency—which is in line with the results of Leahey et al. (2016).

Furthermore, respondents' statements implied aspects of partner opportunism. Leahey (2016) describes free riding as a form of partner opportunism that occurs when team members are credited as co-authors, even though they did not make an adequate contribution. Consistent with this theoretical assumption, one interviewee complains that she has to include other scientists as authors even if they have only made a small contribution. Beyond that, partner opportunism/free riding seems to appear in situations of power imbalance; as one interview partner describes, the professors involved claimed their "right" to authorship based on their position and reputation.

Above all, the interviewees perceived competition as a major pitfall to scientific collaboration. Postdocs report conflicts especially regarding the order of authors and (fears of) being scooped by project partners. Interestingly, conflicts were mentioned almost exclusively in reference to external project partners that are probably characterized by weaker ties, less closure and fewer possible sanctions for misconduct (Coleman 1988; Granovetter 1973).

Further, as described by the theory of interdependence (Deutsch 2011; Johnson/Johnson 2005) the competitive situations described by postdocs have in common that one team member can only reach their goal if the others do not, e.g., being first or last author. Negative interdependence/competition can lead to oppositional/contrient interactions, i.e., sabotaging others' efforts to reach their goals (ibid.). Some of our interviewees' statements show contrient interactions: The interviewees mentioned that they withhold information because they are afraid of being scooped by project partners or that they suspected that collaboration partners tried to impede team members' publications in order to publish beforehand. Tendencies towards secrecy and unethical behavior in a competitive research environment have also been highlighted in a few previous studies by, e.g., Hong and Walsh (2009) and Blumenthal et al. (2006). In one case, an interviewee described a competitive internal working environment with very little teamwork. Her descriptions imply that the insecure career perspectives in academic research can lead to a general competitive mindset that hinders the emergence of collaboration from the outset.

In order to prevent conflicts in scientific collaborations with (external) project partners, the respondents mentioned some strategies they use: It is important to clearly

define and communicate from the beginning the individual contribution and the position of the authors for joint project publications, as well as the individual and common goals. Conflicts often arise at the end of collaborative projects when expectations were not clearly formulated from the beginning or are changed (by professors) at the last minute after the project has ended.

In line with Müller (2012) our study shows that agreeing on the author sequence in particular is often fraught with conflict and perceived as burdensome and obstructive to collaborative work. This can lead to scientists preferring to work alone. However, scientific collaborations are not only important for individual careers, but serve a greater purpose: To generate novel and important research ideas and results that advance our society in various domains. As postdocs have to accumulate a certain number of publications as first, co- or last authors[6] in order to achieve their postdoctoral lecturer qualification but also to attain professorship, postdocs may often focus more on their number of publications and on their position on papers than on other research goals. This may lead to less innovative and less risky research. To counteract this "competition for reputation", we should think about possibilities for adjusting the current incentive systems in academia to encourage collaboration and the advancement of scientific knowledge (e.g., Ellemers 2021; Freeman et al. 2015; Müller 2012).

Referring to the structural dimension of social capital (Nahapiet/Ghoshal 1998), professors hold central network positions and may thus have access to more resources, which they can use to positively influence postdocs' career development. For this reason, we were particularly interested in postdocs' collaboration experiences with (superior) professors. Postdocs reported that professors collaborate with them by, e.g., working together on proposals and publications. Their superior professors also help them to find employment as they discuss options with HR and use their contacts to find new positions for their postdocs. Postdocs can further learn from professors' experiences with navigating academia, e.g., how to discuss delicate issues with project partners. In this respect, postdocs can acquire a form of "Habitus" (Bourdieu 1983) through the collaboration with their professors. In our study, we focused on the benefits and pitfalls of scientific collaborations for postdocs. However, it is also conceivable that professors' careers are influenced by collaborations with postdocs, in a positive sense, for instance, through increased visibility and reputation through joint publications.

Recently, the imbalance of power between established professors and their postdocs has been discussed in Germany. This discussion is part of a broader discourse on the working conditions of untenured scientists (e.g., Haug 2018; N² 2019). Even though empirical evidence on frequency, conditions, causes and consequences of

6 The position as last author is (besides the first author position) a key position in the life sciences, since the last author receives most credit for the initial conception and supervision of the research project (Wren et al. 2007).

power abuse is still sparse (e.g., Heckmann et al. 2019; Schraudner et al. 2020; Striebing et al. 2021), there seems to be potential for conflict in German academia. Our data shows that collaborating with professors is not only beneficial for postdocs: One interviewee described that she is obliged to list the professor as co-author even though he even slows down the publication process. This shows that postdocs are highly dependent on their professors and asymmetries in the dependency (Deutsch 2011) become visible. While in our sample only two respondents made statements about professors claiming authorships, regardless of their contribution, the issue of honorary authorships in the life sciences has been addressed by other studies. Al-Herz et al. (2014) find that it is common to include scientists as authors who did not deserve authorship credit, in order to avoid conflicts or facilitate the acceptance of the article.

Moreover, half of the respondents stated that professors advised them on their (scientific) career, e.g., suggesting them for scientific prices or using their ties for their postdocs to getting employed also outside of academia. The arbitrariness of the professorial support (Richter/Reul 2016) becomes clear by the fact that three respondents did not receive any support or career advice at all from their professors.

7 Limitations and Outlook

Our study focused on the life sciences, which differ from other disciplines in several respects. In comparison to other disciplines, for instance, the humanities, but also social sciences, they are multidisciplinary and collaborative by nature. Hence, a strong interdependence of the sub-disciplines/specializations may be not as relevant in these disciplines. For various disciplines within the social sciences with similar quantitative and qualitative research methods, the cost in time and money of acquiring new theories and methods is lower when compared to the life sciences, in which technical equipment is also usually much more expensive. Since we use qualitative data and our study sample does not cover a wide range of sub-disciplines, our results cannot be transferred to all sub-disciplines of the life sciences or to other disciplines. Further research should address the benefits and pitfalls of scientific collaborations—especially settings that lead to competitive behavior—in other scientific fields. Since our qualitative results cannot be generalized, it would be interesting to examine internal vs. external collaborations quantitatively, not only in terms of their level of competitiveness, but also in terms of innovative research. Future studies may examine whether a competitive atmosphere/mindset hinders collaborative projects or the results of such projects.

In our study, we specifically focused on postdocs' collaboration experiences with (superior) professors and the benefits and pitfalls for postdocs' career development. It would therefore also be interesting to explore the perceptions of professors and investigate their collaboration experiences with their postdocs/early career researchers. In what ways are they also dependent on fruitful collaboration with post-

docs/early career researchers? In what ways can they profit from these collaborations career wise, despite already holding a professorship? In our sample there was no evidence that status differences were relevant in the conflicts in external collaborations, however we cannot rule out that such status differences were present. Future studies should consider status as a potential source of conflict—this could concern rivalries between researchers on the same status level or abuse of power in the case of status differences.

References

Abramo, Giovanni, D'Angelo, Ciriaco Andrea & Murgia, Gianluca (2014). Variation in research collaboration patterns across academic ranks. *Scientometrics*, *98*(3), 2275–2294. https://doi.org/10.1007/s11192-013-1185-3

Acedo, Francisco José, Barroso, Carmen, Casanueva, Cristóbal & Galan, José Luis (2006). Co-authorship in management and organizational studies: An empirical and network analysis. *Journal of Management Studies*, *43*(5), 957–983. https://doi.org/10.1111/j.1467-6486.2006.00625.x

Afonso, Alexandre (2015): Varieties of academic labor markets in Europe. *Forthcoming in Political Science and Politics*.

Aldrich, Howard E. & Al-Turk, Akram (2018). Crouching authors, hidden pitfalls: Collaboration in research. *Studi di Sociologia*, *56*(4), 351–368.

Al-Herz, Waleed, Haider, Hani, Al-Bahhar, Mahmoud & Sadeq, Adnan (2014). Honorary authorship in biomedical journals: How common is it and why does it exist? *Journal of Medical Ethics*, *40*(5), 346–348. https://doi.org/10.1136/medethics-2012-101311

Anderson, Melissa S., Ronning, Emily A., De Vries, Raymond & Martinson, Brian C. (2007). The perverse effects of competition on scientists' work and relationships. *Science and Engineering Ethics*, *13*(4), 437–461. https://doi.org/10.1007/s11948-007-9042-5

Bikard, Michaël, Murray, Fiona & Gans, Joshua S. (2015). Exploring trade-offs in the organization of scientific work: Collaboration and scientific reward. *Management Science*, *61*(7), 1473–1495. https://doi.org/10.1287/mnsc.2014.2052

Blumenthal, D., Campbell, E. G., Gokhale, M., Yucel, R., Clarridge, B., Hilgartner, S. & Holtzman, N. A. (2006). Data withholding in genetics and the other life sciences: Prevalences and predictors. *Academic Medicine*, *81*(2), 137–145.

Bourdieu, Pierre (1983). Ökonomisches Kapital, kulturelles Kapital, soziales Kapital. In Reinhard Kreckel (Ed.), *Soziale Ungleichheiten* (pp. 183–198).

Burt, Roland S. (2001). Structural Holes versus Network Closure as Social Capital. In Nan Lin, Karen S. Cook, & Ronald S. Burt (Eds.), *Social capital: Theory and research* (pp. 31–56). Transaction Publishers.

Clark, Benjamin Y. & Llorens, Jared J. (2012). Investments in scientific research: Examining the funding threshold effects on scientific collaboration and variation by academic discipline. *Policy Studies Journal*, *40*(4), 698–729. https://doi.org/10.1111/j.1541-0072.2012.00470.x

Cohen, Jacob (1968). Weighted kappa: nominal scale agreement with provision for scaled disagreement or partial credit. *Psychological Bulletin*, *70*(4), 213–220. https://doi.org/10.1037/h0026256

Coleman, James S. (1988). Social capital in the creation of human capital. *The American Journal of Sociology*, *Vol. 94*, 95–120.

Coleman, James S. (1990). *Foundation of Social Theory.*

Cummings, Jonathon N. & Kiesler, Sara (2016). Collaborative research across disciplinary and organizational coundaries. *Social Studies of Science*, *35*(5), 703–722. https://doi.org/10.1177/030631270505535

Deutsch, Morton (2011). Cooperation and Competition. In Peter T. Coleman (Ed.), *Conflict, Interdependence, and Justice* (pp. 23–40). New York, NY: Springer New York.

Deutsche Forschungsgemeinschaft (DFG) (2015). *Etablierung eines integrierten Forschungs- und Weiterbildungs-Programms für „Clinician Scientists" parallel zur Facharztweiterbildung. Empfehlungen der Ständigen Senatskommission für Grundsatzfragen in der Klinischen Forschung der Deutschen Forschungsgemeinschaft.*

Ellemers, Naomi (2021). Science as collaborative knowledge generation. *The British Journal of Social Psychology*, *60*(1), 1–28. https://doi.org/10.1111/bjso.12430

Epstein, Nurith & Fischer, Martin R. (2017). Academic career intentions in the life sciences: Can research self-efficacy beliefs explain low numbers of aspiring physician and female scientists? *PloS One*, *12*(9), e0184543. https://doi.org/10.1371/journal.pone.0184543

Epstein, Nurith, Heuser, Sonja, & Fischer, Martin R. (2020). *Einflussfaktoren auf die Karriere Promovierter in den Lebenswissenschaften (E-Prom 2): Teilprojekt Klinikum der Universität München, Institut für Didaktik und Ausbildungsforschung in der Medizin*. (project report).

Epstein, Nurith, Huber, Johanna, Gartmeier, Martin, Berberat, Pascal O., Reimer, Maike & Fischer, Martin R. (2018). Investigation on the acquisition of scientific competences during medical studies and the medical doctoral thesis. *GMS Journal for Medical Education*, *35*(2), Doc20.

Freeman, Richard B., Ganguli, Ina & Raviv, Murciano-Goroff (2015). 1. Why and Wherefore of Increased Scientific Collaboration. In Adam B. Jaffe, Benjamin F. Jones (Ed.), *The Changing Frontier* (pp. 17–48). Chicago: University of Chicago Press.

Gallas, Alexander (2018). Precarious academic labor in Germany: Termed contracts and new Berufsverbot. *Academic Labor: Research and Artistry*, *2*(8).

Gerst, Thomas & Hibbeler, Birgit (2012). Klinische Forschung: Ärztemangel im Labor. *Deutsches Ärzteblatt*, *109*(37), A1804-A1808.

Gläser, Jochen & Laudel, Grit (2015). The three careers of an academic. Discussion Paper.

Granovetter, Mark (1973). The strength of weak ties. *American Journal of Sociology*, *78*(6), 1360–1380.

Greene, Mott (2007). The demise of the lone author. *Nature*, *450*(7173), 1165. https://doi.org/10.1038/4501165a

Haug, Kristin (2018). Machtmissbrauch an Hochschulen: Junge Professoren fordern Abschaffung der Lehrstühle. Retrieved from https://www.spiegel.de/karriere/machtmissbrauch-an-unis-professoren-fordern-abschaffung-der-lehrstuehle-a-1197805.html

Heckmann, Lea, Young, Sarah, Liu, Hang & Bultema, Lindsey (2019). Beurteilt die akademische Welt das Verhalten weiblicher Führungskräfte strenger? Retrieved from https://www.phdnet.mpg.de/186798/2_Statement_GenderBias_Reporting_DE.pdf

Hendriks, Barbara, Simons, Arno & Reinhart, Martin (2019). What are clinician scientists expected to do? The undefined space for professionalizable work in translational biomedicine. *Minerva*, *57*(2), 219–237.

Hong, Wei & Walsh, John P. (2009). For money or glory? Commercialization, competition, and secrecy in the entrepreneurial University. *The Sociological Quarterly*, *50*(1), 145–171. https://doi.org/10.1111/j.1533-8525.2008.01136.x

Johansson, Frans (2004). *The Medici effect: Breakthrough insights at the intersection of ideas, concepts, and cultures*. Boston, Mass: Harvard Business School Press. Retrieved from http://www.loc.gov/catdir/enhancements/fy1311/2004003850-d.html

Johnson, David W. & Johnson, Roger T. (2005). New developments in social interdependence theory. *Genetic, Social, and General Psychology Monographs*, *131*(4), 285–358. https://doi.org/10.3200/MONO.131.4.285-358

Jungbauer-Gans, Monika & Gross, Christiane (2013). Determinants of success in university careers: Findings from the German academic labor market. *Zeitschrift für Soziologie*. (42, 1), 74–92.

Kreckel, Reinhard (2016). Zur Lage des wissenschaftlichen Nachwuchses an Universitäten: Deutschland im Vergleich mit Frankreich, England, den USA und Österreich. *Beiträge zur Hochschulforschung*. (38, 1–2), 12–40.

Kreckel, Reinhard (2017). University career models and international staff mobility. Germany, France, Great Britain, USA and Russia compared. *SSRN Electronic Journal*, *19*(1), 727. https://doi.org/10.2139/ssrn.2924590

Leahey, Erin (2016). From sole Investigator to team scientist: Trends in the practice and study of research collaboration. *Annual Review of Sociology*, *42*(1), 81–100. https://doi.org/10.1146/annurev-soc-081715-074219

Leahey, Erin, Beckman, Christine M. & Stanko, Taryn L. (2016). Prominent but less productive. *Administrative Science Quarterly*, *62*(1), 105–139. https://doi.org/10.1177/0001839216665364

Lee, Sooho & Bozeman, Barry (2005). The impact of research collaboration on scientific productivity. *Social Studies of Science*, *35*(5), 673–702. https://doi.org/10.1177/0306312705052359

Lin, Nan (1999). Building a network theory of social capital. *Connections*, *22*(1), 28–51.

Lombard, Matthew, Snyder-Duch, Jennifer & Bracken, Cheryl C. (2002). Content analysis in mass communication: Assessment and reporting of intercoder reliability. *Human Communication Research*, *28*(4), 587–604. https://doi.org/10.1111/j.1468-2958.2002.tb00826.x

Lutter, Mark, & Schröder, Martin (2016). Who becomes a tenured professor, and why? Panel data evidence from German sociology, 1980–2013. *Research Policy*, *45*(5), 999–1013.

Mayring, Philipp (2000). Qualitative content analysis. *Forum: Qualitative Social Research*, *1*(2), Art. 20.

Mayring, Philipp (2010). Qualitative Inhaltsanalyse. In G. Mey & K. Mruck (Eds.), *Handbuch Qualitative Forschung in der Psychologie* (pp. 601–613). Wiesbaden: VS Verlag für Sozialwissenschaften. https://doi.org/10.1007/978-3-531-92052-8_42

Moosa, Imad A. (2018). *Publish or perish: Perceived benefits versus unintended consequences*. Cheltenham, UK, Northampton, MA: Edward Elgar Publishing.

Mukherjee, Satyam, Uzzi, Brian, Jones, Benjamin F. & Stringer, Michael (2017). How atypical combinations of scientific ideas are related to impact: The general case and the case of the field of geography. In Johannes Glückler, Emmanuel Lazega, & Ingmar Hammer (Eds.), *Knowledge and Networks* (Vol. 11, pp. 243–268). Cham: Springer International Publishing.

Müller, Ruth (2012). Collaborating in life science research groups: The question of authorship. *Higher Education Policy*, *25*(3), 289–311. https://doi.org/10.1057/hep.2012.11

N² (2019). Machtmissbrauch und Konfliktlösung. Retrieved from https://www.phdnet.mpg.de/n2/publications-and-press/N2_PowerAbuseStatement_German

Nahapiet, Janine & Ghoshal, Sumantra (1998). Social capital, intellectual capital, and the organizational advantage. *Academy of Management Review*, *23*(2), 242. https://doi.org/10.2307/259373

Parker, John N., Penders, Bart & Vermeulen, Niki (Eds.) (2010). *Collaboration in the new life sciences*. Farnham, Surrey, England, Burlington, VT: Ashgate.

Plümper, Thomas & Schimmelfennig, Frank (2007). Wer wird Prof – und wann? Berufungsdeterminanten in der deutschen Politikwissenschaft. *Politische Vierteljahresschrift*, *48*(1), 97–117.

Richter, Carolin & Reul, Christina (2016). Nicht mit- und nicht ohneeinander: Professor_innen, Spezialist_innen und die institutionalisierte Ambiguität der Nachwuchsförderung. In Julia Reuter, Oliver Berli, & Manuela Tischler (Eds.), *Wissenschaftliche Karrieren als Hasard: Eine Sondierung* (pp. 313–336). Frankfurt/New York: Campus Verlag.

Scaffidi, Amelia K., & Berman, Judith E. (2011). A positive postdoctoral experience is related to quality supervision and career mentoring, collaborations, networking and a nurturing research environment. *Higher Education*, *62*(6), 685–698. https://doi.org/10.1007/s10734-011-9407-1

Schmidt, Martin, Fecher, Benedikt & Kobsda, Christian (2017). How many authors does it really need to write a paper? Retrieved from http://elephantinthelab.org/factory-science/

Schraudner, Martina, Striebing, Clemens & Hochfeld, Katharina (2020). Arbeitskultur und Arbeitsatmosphäre in der Max-Planck-Gesellschaft: Ergebnisbericht. Retrieved from https://www.mpg.de/14275312/MPG-Arbeitskultur_Ergebnisbericht_deutsch.pdf

Striebing, Clemens, Schneider, Sascha & Schraudner, Martina (2021). Die Verbreitung und Meldung nichtwissenschaftlichen Fehlverhaltens in Forschungsorganisationen: Die größten Herausforderungen am Beispiel der Max-Planck-Gesellschaft. *Beiträge zur Hochschulforschung*, *43*(1–2), 14–47.

Ullrich, Peter (2019). In Itself But Not Yet For Itself – Organising The New Academic Precariat. In Walter Baier, Eric Canepa, & Harris Golemis (Eds.), *The radical left in Europe: Rediscovering hope*. London: The Merlin Press.

Uzzi, Brian, Mukherjee, Satyam, Stringer, Michael & Jones, Ben (2013). Atypical combinations and scientific impact. *Science (New York, N.Y.)*, *342*(6157), 468–472. https://doi.org/10.1126/science.1240474

Vermeulen, Niki & Penders, Bart (2010). Collecting Collaborations: Understanding Life Together. In John N. Parker, Bart Penders, & Niki Vermeulen (Eds.), *Collaboration in the new life sciences* (pp. 3–14). Farnham, Surrey, England, Burlington, VT: Ashgate.

Vignola-Gagne, Etienne (2014). Argumentative practices in science, technology and innovation policy: The case of clinician-scientists and translational research. *Science and Public Policy*, *41*(1), 94–106. https://doi.org/10.1093/scipol/sct039

Wieczorek, Oliver, Wittek, Mark & Heiberger, Raphael H. (2020). Being published successfully or getting arXived? The importance of social capital and interdisciplinary collaboration for getting printed in a high impact journal in Physics. *arXiv preprint*. (2006.02148).

Wren, Jonathan D., Kozak, Katarzyna Z., Johnson, Kathryn R., Deakyne, Sara J., Schilling, Lisa M. & Dellavalle, Robert P. (2007). The write position. A survey of perceived contributions to papers based on byline position and number of authors. *EMBO Reports*, *8*(11), 988–991. https://doi.org/10.1038/sj.embor.7401095

Wuchty, Stefan, Jones, Benjamin F., & Uzzi, Brian (2007). The increasing dominance of teams in production of knowledge. *Science (New York, N.Y.)*, *316*(5827), 1036–1039. https://doi.org/10.1126/science.1136099