

Research collaboration experiences, good and bad: Dispatches from the front lines

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Abstract

The scant literature on individual scientists' collaboration dynamics is used to develop a provisional model of research collaboration effectiveness. It incorporates external, collaborator, and team management factors, forming the basis for our theoretically informed qualitative analysis. We use this provisional model to guide semi-structured interview themes, deriving data from 60 US academic researchers, selected from a range of scientific and engineering disciplines as well as one social sciences discipline (economics). We present our findings in the form of respondent quotations related to the provisional model. We then conduct a further content analysis on the organizing constructs of respondent-assessed good and bad collaboration responses. The results of this second thematic coding of the interview data form the basis for the refinement of our model to include additional indicators, and to discuss some preliminary expectations about the associative relationships among the external, collaborator, and team management factors that contribute to scientist collaboration.

Key words: research collaboration; collaboration team dynamics; collaboration effectiveness.

1. Introduction

Compared to the single investigator research common decades ago, collaborative research in science, technology, engineering and mathematics (STEM) has enhanced the ability of researchers in most fields to contribute to knowledge, economic, and social outcomes (Claxton 2005). Indeed, the demands of theoretical problems and equipment in some fields virtually mandate collaboration (Chompalov et al. 2002; Wagner 2005; van Rijnsvoever and Hessels 2011). Though collaboration is ubiquitous, evidence suggests that collaboration dynamics vary greatly across fields, institutions, purposes and even individual research teams (Katz and Martin 1997; Bozeman et al. 2013; Bozeman and Boardman 2013). Some aspects of variation have a strong bearing not only on the quality of knowledge produced but also on scientific reputation, social control in science and scientific ethics. Recognizing the increasing importance of collaboration, scholars have focused on a variety of collaboration issues including: strategies and motives for collaboration (Bozeman and Corley 2004), effects of collaboration on research productivity (Gaughan and Ponomariov 2008), relation of geographic proximity on collaboration

(Katz 1994; Olson and Olson 2000), effects of new media technology on collaboration (Finholt 2002), and professional guidelines for documenting collaboration contributorship (Madden 1998; Frankel and Bird 2003; Jones 2003; Stenek 2006; Austin et al. 2012).

Our interview-based paper focusing on research collaboration effectiveness relies on 60 US academic faculty researchers' reports of their experiences to provide ideas about what is a 'good' or a 'bad' collaboration and the factors associated with each. While this is a quite different approach than employed in much of the recent work on research collaboration it proves complementary. Many of the related studies employ quantitative measures of publishing productivity (Lee and Bozeman 2005; Gaughan and Ponomariov 2008; Ponomariov and Boardman 2010; Hu et al. 2014). We feel that, in general, these more formal and quantitatively focused studies are quite useful (perhaps an obvious surmise inasmuch as the present authors have conducted some of them). But in the present paper our effectiveness approach is a departure from these studies, not only because it relies on qualitative data, but also because of the more or less subjectivist conception of collaboration effectiveness.

Overall, our study concerns itself with concepts and determinants of research collaboration effectiveness, as expressed in data obtained from interviews with academic researchers who tell us about their collaboration experiences. One contribution of the study is to identify the particular factors researchers view as integral to the research collaborations they perceive as especially good or especially bad ones. A second contribution is to determine the relative incidence of factors related to good and bad collaborations. For example, do crediting problems more often give rise to negative assessments of the collaboration experience, or do differences in work styles more often lead to problems? A third contribution of the paper is to provide indicators of the extent to which research collaboration factors are linked together or co-occur. That is, do some collaboration effectiveness factors occur together while others seem more independent of one another?

The remainder of this paper is organized as follows. First, in Section 2 we discuss the operant concept of collaboration effectiveness employed in this paper, a subject-dependent concept rooted in interviewees' views and experiences. In Section 3 we review the literature on research collaboration determinants to develop and present a provisional model of research effectiveness, which draws from the current literature and prevailing theories of research collaboration effectiveness. In Section 4 we introduce the methodology employed to collect, code, and interpret the results of 60 semi-structured interviews. We then perform a thematic content analysis of the interview data in Section 5, to determine not only whether our findings conform to the model, but also to determine the extent to which there is a need to revise the model to accommodate important research effectiveness themes not included in the provisional model. After the presentation of the interview and content analysis data concludes in Section 6, Section 7 revisits the preliminary model of research effectiveness to fashion a revised model. Section 8 distills our findings about research collaborations and finally, Section 9 presents our conclusions and suggests implications for future research.

2. A subject-dependent concept of research effectiveness

As mentioned briefly above, there are many useful quantitative studies examining the effect of research collaboration on publications and other more or less objectively measured knowledge products such as patents. These quantitative studies (see [Bozeman and Boardman 2014](#) for an overview) have the great advantage of precision but they do not tell the whole story in terms of the impact of experience on subsequent choices, including choices about whether to collaborate, with whom to collaborate, and how (processes, structure) to collaborate. We know from previous research, both quantitative and qualitative ([Melin 2000](#); [Shrum et al. 2001, 2007](#); [Youtie and Bozeman 2014](#)), that collaboration decision-making is sometimes quite complex, multi-faceted, and includes many and diverse considerations. Factors and motivations that may be extremely important to one partner in a collaboration may be much less important to another.

We are not seeking to identify a canonical set of bad or good collaboration types or determinants. Our concepts and indicators are not invariant inasmuch as the interviewees provide form, shape and depth to notions about good and bad collaborations. We feel this approach, while certainly not the only possible useful approach, has the advantage of recognizing that researchers look for different things in collaborations and collaborators ([Bozeman and Corley 2004](#)). What is a good collaboration to one researcher may be

suboptimal to another ([Katz and Martin 1997](#); [Melin 2000](#)). Thus, in this study a 'bad' collaboration is one the respondent thinks is bad and a 'good' collaboration is one that the respondent judges as good.

In short, knowledge of the relationship of collaboration to tangible outputs such as publications and citations, while quite useful, is not enough. Here are some of the reasons why. First, when collaborators make contemporaneous judgments about collaboration effectiveness, publications outcomes are almost never among the 'earliest returns'. We know from evidence we present here that collaborators do not suspend judgment about the effectiveness of collaboration or the value of collaborators while they await acceptance of research for publication or other relevant outcomes such as conference placement. Since early judgments have strong psychological framing effects, these early judgments necessarily affect later decisions, even in the face of new or more telling evidence ([Mandler 1980](#); [Herr 1986](#); [Muchnick et al. 2013](#)). Second, even after a publication is completed, it may take a good deal of time to determine the impact of the publication. Third, and related, the fact of publication does not necessarily give insight into the collaborators' assessment about whether the work achieved its potential (e.g. 'Was the publication in the best possible journal?' 'Was the impact as great as expected?'). Fourth, we know from previous studies that while publication (or patenting) is important for almost all collaborators, it is typically only one among several motives for collaboration. Other motives include: mentoring and developing scientific and technical human capital ([Bozeman and Corley 2004](#)), obtaining a stream of research support ([Bozeman and Gaughan 2011](#)), or contributing to institution building ([Ponomariov and Boardman 2010](#)).

In short, regarding the discrete and observable research outputs such as publication or patenting or citations, all of these are important, but so are the subjective judgments of the collaborators. Moreover, our approach seems to have some validity as evidenced by the fact that our respondents did not have to grasp for straws while telling us about their good and bad collaborations. It was therefore not difficult to identify good and bad collaborations from the evidence provided. Respondents described each with no difficulty whatsoever and, to some extent, with common themes and content. In Section 2.1, we look at the research literature to identify findings pertinent to our study; these findings form the basis for the development of our provisional model of research collaboration effectiveness.

2.1 Field characteristics and interdisciplinary issues: Do disciplines and fields get in one another's way?

It is well-known that a variety of aspects of collaboration are sensitive to differences in scientific fields ([Ennis 1992](#); [Chompalov et al. 2002](#); [Bozeman and Boardman 2013](#)). This is not only due to the nature of the technical work itself but also to such factors as differing work norms, differing styles of graduate education, varied types and degrees of specialization, and whether it is even realistically possible to conduct research as individuals as opposed to teams. It is difficult to sort out direct from indirect effects of field or discipline. In particular, some fields are more likely to have high stakes intellectual property. Thus, if one finds implications for collaboration outcomes, are the effects owing to the field or to the intellectual property in the balance? Likewise, equipment dependence or large funding scale dependence may have more important and independent effects than field. Nonetheless, it is likely that fields and disciplines do have some independent effects inasmuch as fields have unique histories,

distinctive professional norms, and socialization patterns (Austin 2002; Moody 2004).

Some problems that appear to be discipline- or field-related are not so much specific to any given discipline as to the clash of disciplines. As noted above, fields and disciplines vary with respect to their characteristic approach to knowledge production and, perhaps, to research collaboration. When disciplines are brought together on projects the complexities related to these differences are greatly exacerbated (Qin et al. 1997; Katz and Martin 1997). In general, interdisciplinary collaborations are fraught with perils not common to more routine intra-disciplinary collaborations (Jeffrey 2003). Some of these factors are obvious extensions of known differences between and among disciplines, but just as important in many cases is the extent to which team members understand and value other disciplines and or practices. The literature tells us that such status allocation is quite common as is disciplinary parochialism (Becher 1994; Younglove-Webb et al. 1999). We expect these issues to be at the root of some bad collaboration outcomes.

Science across many STEM fields is becoming larger and more international (Wang and Shapira 2011). Although the size of collaboration may reflect underlying field differences such as high-energy physics having larger research teams than mathematics for example, this increase in research team size also crosses disciplinary boundaries. To some extent, this rising scale reflects the use of multi-disciplinary research centers to support research into new emerging areas which tend to involve more investigators from more, geographically distant locations (Boardman and Corley 2008). Large-scale laboratories with multiple research groups headed by a director without day-to-day awareness of the research practices in that laboratory are not uncommon. Likewise, there is the ever-growing segment of international large-scale science (Cronin 2001), where hundreds of authors ('hyperauthorship') are possible and are where supervision and problem solving may be more diffused. Thus, we expect that the size of the collaboration may be a factor in bad collaborations. In summary, differences among disciplines, the emerging norms of interdisciplinary work, and the increasing size of many research collaborations are all likely to be topics addressed by our research subjects as they reflect on their collaboration experiences.

2.2 Commerce: Is academic capitalism a cause of collaboration discord?

There seems little doubt that potential commercial values and goals affect university faculty research collaboration experiences (Perkmann et al. 2013). In some cases experiences may be negative as, for example, when there are clashes between the norms of commerce and those of science (Rai 1999; Rappert et al. 1999; Walsh et al. 2007). Case and historical evidence shows that the clashes can sometimes be highly disruptive (Welsh et al. 2008; Bekkers et al. 2002). In other cases, commercially oriented collaborations can prove particularly positive, especially if they lead to satisfying knowledge objectives and other benefits, including: wealth, differential social capital, and the joys that result from simply doing something outside of routine (Tartari and Breschi 2012). We suspect that the effects of commercial arrangements on collaboration effectiveness will be diverse, with both positive and negative effects.

2.3 Work-style fit

The fit between work styles is important in almost any collaboration effort (Kumar and Van Dissel 1996; Bryson et al. 2006; Huxham and Vangen 2013). Thus, there is every reason to believe it is an

important ingredient in research collaborations. The research literature suggests as much (Kraut, et al. 1988; Hara et al. 2003; Jeffrey 2003; Fox and Mohapatra, 2007). People who work at a steady pace find it difficult to work harmoniously with people who work at a boom or bust pace. Similarly, people who have a very direct or authoritarian style often clash with those who are either indirect or participative in their style. This is essentially the case when there are strong differences in status relationships among team members (De Dreu and Weingart 2003). The work-style-related problems that occur in research collaborations will differ little from the work-style problems one finds in almost any organization, including those not in the business of knowledge or technology production (Kabanoff 1991; Ayoko et al. 2003). The key word here is 'fit'. Previous research suggests that collaborations fail not because of an inherently bad working style but, rather, because the parties to the collaboration have different preferences and these differences give rise to conflict (Fox and Faver 1984; Melin 2000; Brown et al. 2004).

2.4 Career stage: Different stakes, different incentives

In many cases, colleagues recognize that individuals at different career stages have different objectives for the collaboration (Fine and Kurdel 1993). Often it is easy enough to accommodate those differences in objectives. For example, some senior faculty delight in furthering the career motives and objectives of graduate students, postdoctoral fellows, and junior faculty. We know from research that a desire to mentor students and faculty is a major motivation for some senior collaborators (Sands et al. 1991; Green and Bauer 1995; Bozeman and Corley 2004; Bozeman and Gaughan 2011). Nevertheless, in any collaboration where the career motives and the individual's perceptions of the career-related objectives for the collaboration begin to clash, the potential for bad collaborations is greatly exacerbated.

Of particular interest is the role of tenure-seeking in bad collaborations (Hearn and Anderson 2002; Thursby et al. 2007). In some cases individuals are under extreme pressure (real or perceived) and this pressure could have the effect of promoting bad behavior as well as shaping perceptions about others' bad behavior in collaborations (Floyd et al. 1994). There are certainly very good reasons for researchers to work with others who are at a different career stage. Thus, junior researchers may bring drive, knowledge from more recent training and a willingness to work hard at a variety of research roles, including the more thankless ones such as the design of experimental apparatus or data coding. Senior researchers may bring to bear hard-won wisdom, practical knowledge of research strategies, extensive social capital or large-scale research funding. Nevertheless, when the motives of researchers at different career stages fail to mesh, bad collaboration outcomes can occur. When the motives align—or are at least complementary and mutually beneficial—good collaborations are usually the result.

2.5 Gender Issues: Institutional problems, individual problems and attribution errors

Gender issues play out in remarkably different and complicated ways in society, in the workplace and, most relevant for our purposes, in research collaboration. Gender is often intertwined with many of the above issues. For example, there are interactions with career stage: women academics tend on average to be younger because women have only recently entered academic science careers in large numbers. Thus, women team members are often at different career stages, most frequently playing a junior role in teams led by

older persons, usually men. Despite difficulties in sorting out direct effects owing to gender from effects mitigated by or spuriously related to gender (Bozeman and Gaughan 2011), the research literature provides overwhelming evidence that gender matters in research collaboration outcomes (Kyvik and Teigen 1996; Fox 2005; Abramo et al. 2013). Collaboration dynamics stemming from gender are both interpersonal, and embedded in larger institutional structures that transcend micro-level processes.

2.6 Collaboration management strategies

Collaboration management strategies refer to a range of activities such as: developing processes for group decision-making, handling conflict, and establishing crediting procedures. Whether the strategies are formal and systematically applied or informal and *ad hoc*, they guide collaboration activities and coordinate collaborators' pursuits of individual and communal goals and thus have a significant effect on the day-to-day collaboration experience. Empirical research supports the impact of management factors on various aspects of research collaboration including: choosing collaborators (Bozeman and Corley 2004), structuring collaborations (Carayol and Matt 2004; Chompalov et al. 2002; Shrum et al. 2007), and developing trust between collaborative actors (Garrett-Jones et al. 2010).

Negative collaboration experiences may arise when collaborations lack management strategies for particular problems. Bammer (2008) offers case-study based lessons for improving collaboration experiences by developing management strategies for harnessing collaborator differences, establishing collaboration boundaries, and balancing needs for both research support and independence. Additionally, utilizing effective management strategies may offer a pathway for increasing the chances that a collaboration produces the desired outcomes. For instance, some evidence links participative discussions about credit sharing to decreased chances for poor collaboration outcomes (Youtie and Bozeman 2014). This also implies that the potential for bad collaboration experiences may increase when collaboration management strategies are poorly chosen or poorly implemented. Furthermore, if collaboration members have divergent conceptualizations of who has the authority to devise and implement management strategies, negative collaboration experiences may be more likely. In summary, good collaboration experiences are expected to align with the presence and utilization of management strategies that collaborators deem needed and suitable. Bad collaboration experiences can occur when collaborators deem management strategies inadequate or inappropriate.

3. A provisional model of research collaboration effectiveness

As appropriate to a study relying on respondents' experiences and subjective reports to inform conceptualization and theory building, we refrain from developing a formal model or a set of testable hypotheses with explicit test criteria. However, we do begin with expectations fashioned from the literature on research collaboration. By this point, the research findings about research collaboration effectiveness are sufficiently extensive to provide a good and useful set of expectations about factors pertaining to good and bad research collaboration (for overviews see Bozeman and Boardman 2014; Bozeman et al. 2013). The provisional model we employ here is based almost entirely on findings from the research literature. However, there are many different choices in possible emphasis and in linkages among the terms of the model. Thus, the model we present is synoptic, not comprehensive. Moreover, we know from the literature that each of the model's components pertains to collaboration effectiveness. We cannot judge from the literature alone the relative importance or interrelationships among these components. Fig. 1 provides our provisional model of research collaboration effectiveness.

As can be seen in Fig. 1, the model has three major constructs: external factors, collaborator characteristics, and team management. External factors include: disciplinary, interdisciplinary, and commercial factors. Collaborator characteristics include: work-style fit, career stage and motivation, and gender. These lead into team management strategies that ultimately affect collaboration effectiveness. The provisional model presents no interactions among the various components, but we revisit this issue after presenting the data from the thematic content analysis

4. Data and methods

4.1 Study population

This analysis is based on in-person and telephone interviews with 60 academic scientists in 14 STEM disciplines in 13 US states. The STEM disciplines represented include: biology, computer science, mathematics, physics, earth and atmospheric science, chemistry, chemical engineering, economics, civil engineering, electrical engineering, mechanical engineering, materials engineering/materials science, industrial/manufacturing engineering, and biomedical engineering.

In-person interviews were conducted with faculty at geographically distributed research-intensive universities in Arizona, California,

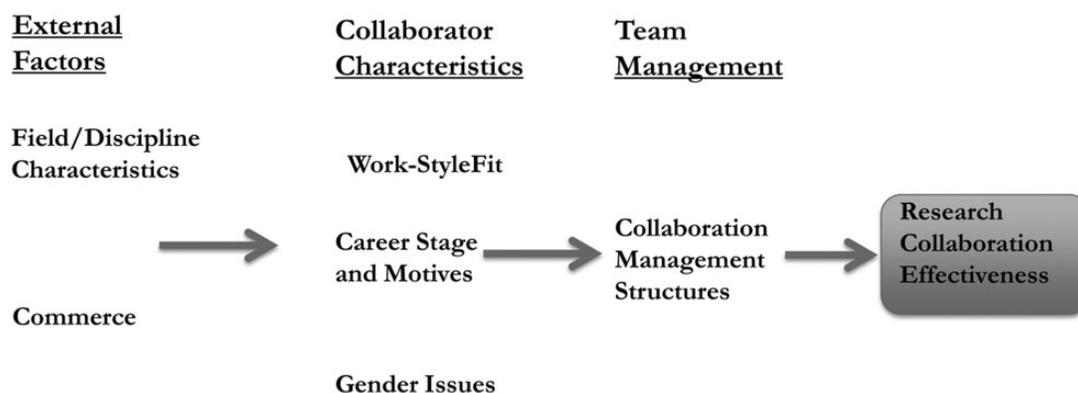


Figure 1. Provisional model of research collaboration effectiveness

Georgia, South Carolina, and Massachusetts. Additional telephone interviews were conducted with faculty at universities in Colorado, Delaware, Georgia, Indiana, Iowa, Kansas, Massachusetts, Mississippi, New Mexico, New York, North Carolina, Pennsylvania, South Carolina, Texas, Utah, Virginia, and Washington. Interview subjects were selected at random based on their affiliation with schools and departments in the 14 STEM disciplines. Senior assistant, associate, and full professors were selected to ensure a sufficient range of research collaboration experience for discussion (although a few non-tenure track researchers were also included). As a result, the results of these interviews can be generalized to the population of academics working in US research-intensive universities. We cannot generalize to the much larger population of professors who work in less research-intensive institutions (which constitute the majority of higher education institutions in the USA). Furthermore, in terms of selection bias, we are not able to study former academic scientists who left the field prior to retirement for any number of reasons, including because of a bad collaboration.

4.2 Interview protocol

The interviews were conducted in the spring, summer, and autumn of 2012 and the first two months of 2013, typically in the offices of the faculty member being interviewed. Each interview lasted from 30 minutes to an hour or more. Notes were taken either by hand or computer by a second interview team member. Interview questions covered topics about the faculty member's research characteristics, nature of research collaborations, decision-making processes for determining authorship and author order, the role of policies such as promotion and tenure, and, most important for present purposes, both good and bad research collaboration experiences. The interview protocol allowed for flexibility to adapt to each interview subject's situation. For example, some interview subjects did not initially report ever having any collaboration problems. The interviewer was able to use prompts such as asking about a colleague's problematic experiences or 'urban legends' in the field to obtain such information. Sometimes these accounts of other colleagues would prompt interview subjects to recollect problematic collaborations of their own.

4.3 Initial organization of interview data and thematic content analysis

The researchers used a conceptual framework (here termed the provisional model of research collaboration effectiveness), in both the elicitation of the interview data and in its initial organization for analysis. After the project team developed an initial coding scheme based on the provisional model, two graduate students organized and coded the entire body of interview data, relating specific interview content to particular components of the model as well as to information about the respondent. The coding was then compared for consistency and reliability by the first and third authors. In addition to the guiding components of the provisional model, all coders and users of the qualitative data were alert for emerging and unanticipated themes. These emerging and unanticipated themes become the data we use to revise the provisional model into one better grounded in our qualitative data. As expected (because of the interview protocol), all of the components of the provisional model were to some extent represented in respondents' information about good and bad research collaborations. However, in the initial coding we found that some elements of the conceptual framework were well populated with responses, some were sparsely populated and some of the

responses about good and bad collaboration did not fit into the categories initially posited in the provisional model.

In a next step we submitted all of the responses about good and bad collaboration to a thematic content analysis. Our content analysis approach is quite straightforward, resembling standard approaches to thematic content analysis (Braun and Clarke 2006; Thomas and Harden 2008), as opposed to discrete word- or symbol-based content analysis (Riff et al. 2014). In the interviews, each respondent was asked to discuss an especially 'good collaboration' and an especially 'bad collaboration' experience. Nearly all of the respondents were able to respond easily to these questions. In two instances the responses were so general as to be ambiguous and two of the respondents (junior researchers), indicated plausibly that they had no bad collaboration experiences to report. From the 60 respondents, 56 provided useful and often quite detailed responses, sometimes providing more than one instance of either a good or bad collaboration, and often providing more than one indicator for a good or bad collaboration.

5. Findings: An initial evaluation of the provisional model

We turn now to a consideration of how the semi-structured interviews shed light on the major factors the provisional model posits to affect research collaboration effectiveness: external factors, collaborator characteristics, and team management.

5.1 Disciplinary and interdisciplinary dynamics

It seems to us likely that there could be aspects of certain scientific fields, due to the norms or technical nature of the work, that make them either particularly easy or particularly difficult for effective collaborations. Consider the follow response from an individual whose specialty is techniques for gene expression. The work performed by this individual contributes to many fields of biology but persons working within these other fields seem to have little understanding or appreciation of the difficulties of the work, with the result that our interviewee feels that the people he helps sometimes take advantage of him and do not share credit:

Recently, we did a lot of work with another university, brought in a person from their university as a postdoc, backed up the data with [the specific technique], but we got no credit for it. The reason in part is because this is practical work. People know we do this work and they contact us and say 'hey, can you just set up a gene expression for this [research project]. It will be easy for you to do. We just want you to confirm our results by using another expression approach.' They don't know much about this approach so they just assume it is easy to do even though it isn't. Then they don't give us any credit.

One well-known collaboration issue, related indirectly to fields, is the differential cost of research work. Sometimes there are major differences, by field, in a given discipline. As one interviewee notes, a chemist:

Chemistry is very much driven by resources, sometimes more than actual interest in the science. But my work is very autonomous, driven only by the science, because it is so math oriented and, as you know, math is cheap. We don't need lots of expensive equipment to do mathematics work.

In many cases, the cost issue that affects collaboration experience is the cost of large-scale equipment. Equipment cost sharing can lead

to collaborations that are forced fits. As described by an engineering professor:

It [effective, timely collaboration] is really a mix centering on whether you use a large piece of equipment or not. There is a lot of effort to make us collaborate and sometimes that does not work.

In general, cost issues were not often mentioned in reports of bad collaborations and clashes between disciplines or fields seem to relate more often to a variety of other issues. The chief size or cost issue in bad collaboration outcomes seems more related to the tendency for very large projects to have a profusion of authors and subsequent confusion in sorting out the credits. Many interviewees discussed this problem. An astrophysicist's comments below are illustrative:

Our experiments involve people around the world. That tends to be because sites of experiments are around the world. The size of collaborative groups ranged from a dozen to more than 100 in our NASA–NSF project. In astronomy we try to keep few authors as the number and position of authors are important on a CV. If we can do an observational paper, that is important. In the NASA project we use a random name generator – the big papers vary the first authorship and keep the rest.

Research on interdisciplinary work has shown that while there are often great benefits to bringing together people from diverse disciplines (Holland 2013) the process sometimes leads to disagreements due to differing norms and expectations and perceived statuses (Rossini and Porter 1981; Öberg 2009; Garner et al. 2013). In our interviews there were relatively few reports of disciplinary clashes leading to bad collaborations (indeed, many respondents characterized working with scholars from different disciplines as bringing in ‘complementary capabilities’). Interestingly, almost all such reports incorporated negative experiences working with medical researchers. This is especially telling inasmuch as our interviews specifically excluded medical research and medical researchers (though in retrospect it would have been interesting to hear ‘the other side’ of the collaboration—the experiences of medical researchers working with engineers, chemists and biologists). Here is one of many available examples, this one from a biostatistician:

The collaboration I had, what made it bad was working [with physicians] on more of a consulting basis, working with some medical doctors and doing analysis of their data. It went badly. They were very rigid on what they wanted but then they didn't know. They thought they knew what they wanted and they wanted an analysis done but they didn't really understand the questions that needed to be asked ... The physicians collected the data somehow through their practice or some money that they had through the hospital and then really had no idea how to do any of the analysis of it or set up the study design ... I would end up really having to reorganize the data in a certain way or ask them a lot of questions and then sometimes they get very defensive ... I believe that they just recognized me as providing a service rather than an expert at something. It was always just like, ‘Do this work. We need this done.’ But they had no idea that what they were doing was not really research. It has kind of been a nightmare dealing with the physicians.

The following response is particularly useful because it relates to a problem that is apparently growing: collaboration difficulties owing to affiliation with an interdisciplinary center and multiple

problems associated with by multi-disciplinary work in a multi-disciplinary setting (Boardman and Corley 2008; Ponomariov and Boardman 2010; Su 2014).

I have been in collaborations where I spent a lot of time discussing work with people but there's nonetheless some misunderstanding and for one reason or another the project never really goes anywhere. (...) I do have one collaboration that has not been at all effective but I'm not even sure it's a collaboration. I am a formal member of a [Subfield]Center but I don't really do much of anything with them and my research doesn't go through the Center. They just wanted to have my name on the center. I don't think collaborations dictated from the top are ever very effective. People don't collaborate well just because there's funding available. Good science doesn't come out from those sorts of directed collaborations [involving researchers in different disciplines at different institutions].

While we give quotes about aspects of bad collaboration dynamics related to disciplines, we stress again that the vast majority of respondents saw having collaborators from different disciplines in a positive light. Different disciplines develop different research skills, which encourage scientific complementarity among research collaborators.

5.2 Commercial activity

To some extent, the problems related to disciplines and fields and organizational boundary spanning seem to inter-relate with commercial activities by universities. Sometimes the clashes between ‘the world of physics’ and ‘the world of engineering’ are significant, but when differences between university and industry environments go into the mix the chances of misunderstanding seem even greater (Rasmussen et al. 2014; Cunningham and Link 2014; Boehm and Hogan 2014). We were surprised to find few examples of bad experiences related to commercialization, even though respondents were directly queried about their commercial activities in their collaborations. We can think of several reasons why ‘academic capitalism’ seems less an issue in our data. First, our previous studies of researchers and administrators in university research centers, including centers that closely and routinely engage with industry, have revealed relatively few problems in working with industry, at least at the level of the individual (Bozeman and Boardman 2004, 2013; Bozeman and Gaughan 2007; Dietz and Bozeman 2005; Lin and Bozeman 2006). Second, many academic capitalism disputes seem to occur in medical research and biotechnology, not much represented in our STEM researcher data.

This is not to say we have no evidence of the impacts of commerce on collaboration. Here is an example of a commercially relevant project that could be classified as a ‘bad collaboration’. The respondent is a biotechnology professor who had been active in collaborating with industry. In this first passage, he describes how his group came to work with the industrial firm.

We had a collaboration with a [foreign] company, but we had lots of problems, including intellectual property disputes. This company was originally a gigantic firm that was trying to diversify and go into other areas including biotech. The way we got involved with them is that they wanted to use a patent that we had developed. They first went to court to try to get the ability use the patent. When that didn't work they figured they would license the patent from us and give us money to essentially work as their biotech lab. Once they started working with us they got the

license they wanted in the first place and then they started talking to us about deliverables.

The biotechnology professor goes on to relate that it became evident that the industrial partner had put his group into a tournament-like competition with larger firms and other academic competitors.

When we gave them the products and the license, we went to [the country] and had conferences and they asked two or three other [national] groups to come to the conference. We had no idea that these other groups were going to be there. So, we had the conference and then after about six months we found out that they had the [national] groups working on exactly the same things we were working on ... The whole thing was only about \$200,000, and we were competing with multimillion-dollar labs on the same topic.

He goes on to relate, in particular, the difficulty of working with an industrial firm trying to develop independent research capacity. Ultimately, the partnership was not continued.

I think one of the big problems was that they simply had almost no research and development experience they were just a big multimillion-dollar company trying to become a research company. If they had a better understanding of what they wanted then I think things would've worked out much better ... They didn't consider deliverables the same way that we consider deliverables. Sometimes they really didn't even know what they wanted but they wanted us to deliver it anyway. We were supposed to guess what they wanted. After a while things started breaking down and we didn't renew the contract.

The above story seems first and foremost to be a lesson in working with collaborators inexperienced in research, not just a problem with industry collaborators (recall that inexperience also came up in the conflict between the biostatistician and the group of physician s). However, inexperience with basic research is much more likely to occur with industrial firms, and may constitute a cautionary tale to academic researchers considering becoming involved in such a venture.

A more conventional problem, at least one more common in the literature, pertains to the respective time frames and goals of industry and university researchers (Bruneel et al. 2010; Bodas Freitas and Marques 2013). Consider the two examples below. As one respondent noted:

I have not been able to collaborate [effectively] with people in industry. They say things like 'show me the business value' and that narrows the conversation to the instrumental. When that happens the conversation is over.

Another respondent acknowledged that standard commercial management decisions concerning market size and mergers and acquisitions limited the ability of an academic scholar to collaborate with the private sector on medium- and long-term research activities:

I got approached by [a company] that builds equipment for [a subfield]. They were thinking about building a next generation amplifier that could do the [specific technique]. They wanted me to be a consultant and they started sending me the first drafts as a user to give feedback. And this went on for half a year, then they got bought by [another company] which decided that the market wasn't big enough and it was scrapped.

One of our respondents spent most of his career in industry before joining a university faculty as a senior professor and center director. His ideas about good and bad collaboration experiences with

industry seem particularly thoughtful and perhaps more clear-eyed than most.

Collaborations in industry are more targeted, and have clear metrics. You work with industry because you want to produce something. Industrial collaborations can be much more effective than in academia, but can be less intellectually engaged than those in academia. Academia is less effective in terms of producing intellectual output. The good thing in industry is you know what you are supposed to do, and there are metrics to evaluate it. In industry, if you do not produce research output, the consequences can be brutal. In academia, it is much fuzzier—and that can become cover for intellectual masturbation. I am amazed how little meaningful thought comes out of academia, given the amount of effort that goes into it. The publication thing is ridiculous—little pieces here, little pieces there. You cannot help but think there is research produced that did not need to get done.

The research literature is rife with good ideas for avoiding friction between university and industry research collaborators (Davenport et al. 1998; Santoro 2000; Siegel et al. 2003; Sherwood and Covin 2008; for an overview see Bruneel et al. 2010). However, some excellent first-hand ideas came from one of our respondents, an individual who has worked successfully with industry suggested that it is easy enough to avoid friction, at least if academics have clear expectations and understand the motives of industry collaborators:

I have gotten some money from private industry ... Private industry doesn't publish. They put strings on the collaboration; for example, you have to give them a six months period to review the publication. You know that private industry's goal is to make money and get as much as possible for free. That is the rule of their game. The problem is when academicians cry because they think the rules are the same for private industry as academia and then private industry doesn't behave that way.

In this section, we have given examples of how macro-level external factors associated with field effects and commercial applications can have an impact on research collaboration effectiveness. In Section 5.3, we take a more micro perspective to see how interpersonal dynamics may affect collaborations.

5.3 Work-style fit

We begin our consideration of interpersonal dynamics with a description of a highly effective, long-term collaboration for which the work-style seems to fit well. We then consider various bad collaborations where work-style fit is a major problem. We offer several examples of work-style fit that appear to have resulted in bad collaborations. It would be easy enough to quadruple the examples: work-style fit problems were the category most often cited in our interview data.

We begin with a testimonial to the positive effects of a good work-style fit, this from a senior female chemical engineering professor:

My rule is that I collaborate with people I like. People who collaborate need to know about what I know about without knowing the same thing. We have to be able to communicate in general terms without actually learning someone else's field. My most successful collaborations have been with [gives name] and [gives name] and those collaborations have been very good indeed. The writing is really the key. If you both take the time to express well and articulate that is a key factor. Also if you like sitting around in a room and bouncing around ideas and doing 'what if's' then I like to collaborate with you.

By contrast, consider this proposed collaboration between two senior academics, one that was actually a non-collaboration because it ended before it really began.

Last year I was asked by my department chair to collaborate with a big-name person [at the same university as the respondent]. I said, if he wants to collaborate with me then he should ask me, he should talk to me, and he should send me a copy of the proposal. There is no reason for him to ask you to communicate for him. Finally he [the ‘big-name’ professor] got back to me and sent me a copy of his ideas for a proposal and it was clear that what he wanted me to do was to work on [a subfield]. I told him that I don’t do anything in [this subfield], and that I don’t have any interest in working on a proposal that relates to [it]. But he has such a big group in such a big bureaucracy that my response wasn’t enough. I still kept getting emails from his research staff asking me when I was going to contribute my CV and when I am going to write up this or that. Somehow it has not gotten through to them that I declined to work on the proposal. I wouldn’t want to work with this guy under any circumstance. Why are you asking my chair to recruit me for your project, why not talk to me? That’s just total disrespect. I don’t want to work with some jack-ass that I don’t even know and then work from a distance and communicate only through other people.

Here is a more typical instance of what seems clearly a work fit collaboration problem, one exemplifying what we mean by a ‘routinely bad’ research collaboration owing to poor work-style fit:

I had a problem working with someone whose timing was way off compared to mine. We were doing the experiments and someone at University X was doing a small part of the experiments. They were so incredibly slow with doing the experiments and editing the paper. It was like pulling teeth getting anything out of them. I was hammering on the lead PI to get it done, get it done. She became very frustrated with me, just as I was very frustrated with her. We had very different ideas about work pace. She liked to do many things at once and I liked to do one thing quickly and then go to the next.

Research shows that many difficulties in collaboration are owing to the need of one individual to control others (Fiske 1993; Keltner et al. 2003), even when those others are peers (Freidson and Rhea 1963; Raelin 1989; Dickson et al. 1991). Many collaborations are undermined by collaboration participants’ need to control everything. Here are a few examples from our data:

I was working with a collaborator. He had the data but he did not want to share the data unless all ideas were first channeled through him. I said I couldn’t work that way so I dropped it.

Another also related to control:

[Names person] was appointed director of [gives name of NSF Science and Technology Center]. As soon as he was appointed, he had a personality change. His idea of being director was to control everyone that had anything to do with the center. A lot of us just went back to our faculty homes and quit working there.

In most cases it is not easy to disentangle three types of inter-related problems: first, personality problems and personal psychopathologies; second, problems related to personality clashes with no clear ‘bad guy’; and third, problems related to the compatibility of work styles. There seems considerable wisdom in the comments of an electrical engineering professor:

I think the most successful people are the ones who are most adaptable, who can say, okay I have talent here, but I need to

adjust my expectations. I have a student who is not a morning person but who is brilliant. He just cannot get in before ten A.M. When he has to show up for an early morning meeting, you can see it in his eyes that he is not awake yet. I think the real skill in being productive when you are working with people you have to ask, ‘What drives this person? What are they bringing to the table? What’s their baggage? How do I adjust my expectations?’

We found some evidence of personality clashes. Far more common, however, were accounts of how approaches to time management and productivity differed between collaborators, leading to conflict in the work. While work-style differences between collaborators occur irrespective of status, another important component of collaboration dynamics is related to the respective career stages of the collaborators.

5.4 Career stage

American academic science is nothing if not hierarchically structured. Even when scientists have worked through the earlier levels of the hierarchy through formal education, postdoctoral fellowships, and non-academic appointments, the profession of being a professor is itself hierarchical. In the US system, professors undergo a longer probationary period than those in other science systems—on average, six years of productivity is required before tenure is conferred. After tenure (which is by no means ‘guaranteed’), academics can spend the rest of their careers at the ‘associate’ professor rank. Those who are promoted to the rank of full professor typically spend an additional five years in the rank of associate before promotion. After this milestone is achieved, there are additional rank-related honors that can be accrued in the form of named and endowed professorships. In short, not all professors are equal in the US system, which translates into very different career management and collaboration strategies. Consider the following reflections of a senior faculty member about her early career—we see quite a change in motives:

When I was an assistant professor I was much more instrumental and focused on what a person could do for me than whether we could work together easily. Now I am less interested in who can get me ahead or even who can do great science: I want to collaborate with people I like.

A very similar life course pattern is given by a tenured computer science professor:

When I was younger, I focused more on substance and the needs of a particular project. I thought about how people could help me do a project, make up for my own weaknesses. I was interested in people being complementary to me. It was much more instrumental than it is now. Later in my career, I am moving away from instrumental and more toward enjoyable collaborations. I think this shift is true in general later in one’s career: you do things that are enjoyable. Now, what I look for in collaborations: Is the person worth working with? How much will I learn from this collaboration?

This sentiment brings into relief findings from research on collaboration strategies that emphasize enjoyment as a motivation (Bozeman and Corley 2004; Bozeman and Gaughan 2011; Bozeman et al. 2013).

Whether or not strategies and motives change during the life course, it seems likely that bad outcomes are especially likely in early-career collaborations:

When I was first starting out as an assistant professor about half of my collaborations were bad ones. I was very flattered to work

with people who are well-known but then I would get into the collaboration and think oh my God what have I done? But I haven't been in a really awful collaboration in a very long time.

Often, students are among the most vulnerable, as related by one of our senior respondents:

[I know of] a student who worked in a colleague's lab a few years ago. He really wanted to get a master's and she wanted him to get a Ph.D. She talked him into getting a Ph.D. In his third or fourth year he said, 'I don't want to do this anymore. I want to leave.' It started really going downhill from there. She was coming up for tenure and needed to have both a certain number of students as well as publications. She was pushing him to finish multiple papers at that point. She was refusing to allow him to graduate until he finished the papers.

This last anecdote makes us wonder where the other professors were in advocating for the student. In general, we found that collaboration dynamics that were related to rank differences had to be sorted out by the collaborators themselves, and often by the most junior collaborator. These experiences do lead to the development of career-stage heuristics, but it does beg the question of whether people leave the field as junior researchers because of power dynamics related to career stage. While an interesting question, our study population does not allow us to answer this question.

5.5 Gender issues

Nearly all of the women we interviewed, and at least a few of the men, reported that gender issues negatively affected research collaborations. In some cases these issues played out exactly as reported in the feminist literature on occupations and workplace dynamics, with nothing specific to STEM careers. In other cases the issues were more distinctive to academic science. In some cases, problems go directly to biology, especially child bearing. This respondent recounted the negative feedback she received from some of the faculty members in her department who assumed she would not complete her PhD when she had her first child. She goes on, however, to recount how in the matter of collaboration, her primary advisor supported her academic research as well as her need to attend to the needs of her family.

I had two children when I was in graduate school, and so I had two maternity leaves. Science is very competitive, and the project I was working on was very competitive. There were others outside our group working on it, so it is not unheard of for an investigator—if someone is on maternity leave—to take that project and give it to someone else. And then if you have done all the legwork to get it working, you lose credit for that in the publication process. To her credit, my advisor did not give my project away, despite the fact that she was then going up for tenure [and needed quick results]. I felt that she was really being supportive, that she was willing to wait, that she was willing for me to do a decent maternity leave. I was literally gone for three months the first time and six months the second time—I had some complications. I came back and my notebooks were there.

The above story at least seems like a happy one, and at one level it is, but it also underscores two problems. First, it seems, at least from the evidence provided, that one's treatment in such a case is not a matter of routinized policy but the 'luck of the draw' in supervisors. Our respondent had a lucky draw. Second, the case shows one of the reasons why people who are having babies (or who are facing similar life transitions) sometimes have unfortunate

collaboration outcomes. If junior faculty or students are working for faculty whose very careers may depend on the result produced by the person being supervised, not everyone will be self-sacrificing. This implies, perhaps, that such situations beg for institutional solutions, not individual ones.

In some cases, there are institutional and public policy protections already in place and they are still not sufficient to the task. Moreover, some of the most troublesome gender problems encountered in the academic workplace have much in common with those found in any work setting. One such problem is sexual harassment, a focus of much attention by policy-makers but a problem that has not been eradicated. Obviously, effective collaboration requires some level of confidence in one's personal security. Consider the following case with a highly troublesome collaboration outcome:

During my geophysics post-doc, my direct supervisor decided he was in love with me and began to stalk me. This caused a lot of anxiety and I began to have health problems (shortness of breath, heart palpitations, and stomach problems). When I reported the man to a senior manager, somehow the problem became public. I had to leave the research group, and then was denied access to work I'd done before, and my name removed from papers resulting from our collaborations.

The respondent's attempt to address the sexual harassment problem resulted in punitive action that had a direct impact on her academic research productivity and reputation. This led to a series of unfortunate institutional responses that led to significantly altering the trajectory of this scientist's career:

I was never able to integrate myself into the research group I was placed in. At that point, I left my Ph.D. field and took a student position in [gives name of new work group] at the same institution. It was a wonderful group and I enjoyed my time there. However, I had to start over again when my husband and I came to our current institution. I did yet another post-doc in [gives new field] and am now a senior researcher [in a non-tenure track position]. Things have been somewhat better in this field, but far from perfect. Again, there are few women, and non-professorial research staff (mostly female) tends to get the short end of the deal, irrespective of the scale of their contributions. I suppose I am a little bitter about it, after trying so hard for so many years to gain respect and acceptance. Occasionally I wonder if I should have left research and gone to medical school years ago—at least I would have some job security and a little respect.

Sometimes discrimination-related collaboration problems interact with one another. Nevertheless, some people have managed successful careers and harmonious collaborations despite dual minority status. A senior female researcher, who is also a member of an ethnic minority group, noted that it is possible to manage others' biases and expectations but that it is not easy to do so:

There are few females in life sciences that are in [indicates her own highly specialized area]. So people aren't accustomed to working with women in my subfield. I have encountered many gender issues, not so many race issues, which is good since I could get the double whammy. A lot of it is this sort of a 'respect your elders' thing and you could see the differences in expectations between young males and young females. It is okay to be an aggressive young male but not an aggressive young female. A young female can't just say to a senior scientist 'I think you are wrong.' Even if you say it in a very nice way you can still be sure that everything just goes to hell. I did find when I was a young scientist that I could work well with men, even very senior and

aggressive men, but only if they perceived me as a sort of daughter and not as a competitor. Maybe it helps if they have daughters themselves. I don't know.

Perhaps related to different competition dynamics, one of the most common collaboration problems identified by women pertains to credit sharing, and not just for co-authorship. A senior female researcher reported:

Women generally don't get credit for what they do. They can make teams a lot better, but that doesn't mean they get credit. There are always problems in open meetings where women have an idea, nobody responds to the idea, and then the man says pretty much the same thing and everybody thinks it's his idea and wonders why women don't make a contribution.

We found few instances of gender attribution we thought were in error. Indeed, our respondents were reluctant to attribute collaboration dynamics to gender unless there was overwhelming evidence that this was the case. We have presented evidence of external factors and collaborator characteristics affecting research collaborations. In Section 5.6, we present evidence about some of the ways in which academic scientists have developed collaboration management strategies to mitigate problems.

5.6 Collaboration management strategies

Organizational theorists have known for a long time that group dynamics and the informal organization can provide powerful and useful ancillary support to the policies and rules of institutions (Selznick 1943; Conrath 1968; Sonnenfeld 1985). In other parts of this project, we have found that the informal management structures of collaborative groups are extremely important in preventing bad collaboration outcomes. It does not take much. Thus, for example, teams that routinely have early, frequent and participative discussions of credit sharing and other strategic choices seem less likely to have bad outcomes (Youtie and Bozeman 2014). However, surprisingly few collaborations systematically incorporate such processes. In a large number of cases, the principal investigator seems to assume that all parties have similar perceptions about work rules and credits and there is no need to discuss them because it is so obvious. Here is an instance, not uncommon, of a principal investigator who simply mandates the author order. When asked about author decisions, the respondent told us:

I pick the author list for all the papers I am on.

The conflict resolution approach was, similarly, not participative and not routinized. For example:

I pick the author list for all the papers I am on. I had a disagreement with one of the authors as to whether a student should be on a paper. I convinced her that my student should be on the paper. She thought he hadn't done enough work. But what is enough? We didn't agree on that. He was closer to putting in 50 hours, which was remarkable enough. When we were writing the paper, she wrote the first draft and the first thing I did was add my student and sent my revision back to her and we talked about the author lists not being the same. She is a good friend. So we went to lunch and discussed it and once she understood my viewpoint, she was fine with it.

This commentary and the general practice is not at all atypical but does raise questions, such as: 'What is the likelihood that there will be obvious consensus about author crediting, so much so that

one person can make the decision with little expectation of rancor?' and 'What if the party to the dispute had not been 'a good friend' but a new collaborator?' and 'Where was the student as others were determining outcomes without apparently having direct representation of his views?'

When the respondent was queried directly as to whether some problems could be headed off by considering author order in advance, the response was:

Perhaps it would be good to sort the collaboration in advance . . . When I was a younger professor I was advised to do that. I didn't do this [in this case] because I knew everybody I worked with. Also [at the beginning of a project] the collaborators aren't set in stone until the work is finished. [For example] a grad student may join in the middle of the project. My primary instinct is to put the person who did the most work in the first spot and the idea person—the person who came up with the idea is usually the professor—who goes in the last spot. [Otherwise] I just base it on the hours.

Certainly these heuristics are defensible and not at all uncommon. Moreover, sometimes science proceeds in unexpected directions with 'Friday night discoveries' happening without the ability to designate in advance who should and should not be included as an author on the papers resulting from these unanticipated findings. However, it remains the case that those who make decisions without transparent routines and without consultation may experience more bad collaborations. Perhaps the chief self-deception—one voiced by many respondents—is the adequacy of the rule 'whoever does the most work is the first author (or in the preferred author position)'. Many of our reports of bad collaboration provide direct evidence that in some cases there is little agreement about who has done the most work. One easy resolution is for participants, even if not asked, to take the lead:

I address that stuff right up front. Something comes up and someone asks for samples or analyses. I will say what is the authorship related to it? Based on what you ask I think it is appropriate that I am the 5th or 4th author. Or I will say what are your expectations? I have learned that it is far better to be upfront about it.

However, not everyone, especially junior faculty or students, feels comfortable being so direct. Indeed, by far the most common strategy employed by our respondents to deal with collaboration management problems was simply to avoid them by not working with that person or people again.

5.7 Evaluating the provisional model of collaboration

Table 1 includes the collaboration factors derived from the provisional model. It gives the number of times each collaboration factor was mentioned by our respondents, as well as new examples not presented in the preceding analysis.

It should be noted that the body of data as a whole lends good support to the provisional model, although issues related to disciplinary are clearly the most common theme. Indeed, of the 39 instances of disciplinary/interdisciplinarity affecting the research collaboration, 30 of them were viewed as clearly positive by the respondents. As already noted, commercial experiences are relatively few, and when gender attributions are made, they are almost always negative examples. We expand on the implications of the various factors in the model as exhibited in the content analysis in Section 6.

Table 1. Collaboration factors and incidence: Constructs from provisional model*

Collaboration factor	Number of respondents mentioning	Illustrative quote
Disciplinary and interdisciplinary: Responses pertain to the impacts of disciplines professional norms and dynamics and to issues related to collaboration among persons from different disciplines	39	In computer science we care about efficiency. We care about using resources, kind of optimizing resources a lot. So we care about the time being short and that you need to have answers quickly, if possible, and that you need to be able to use relatively limited resources to get those answers, so you don't need huge, supercomputers, that is if possible. So, sometimes we spend months and months and months trying to cut down on say the writing time by a factor of ten, and for some people who are not a computer scientist, that's not a big deal. [Biologists] speak a different language, and you know it's English but a whole different language. ... You know the neat thing about that collaboration was that all three of us brought different things to the collaboration. The senior person was mechanism design; I was virtual reality and my focus was mechanism design and the other person had some more practical skills. So our expertise didn't overlap but complemented each other.
Commercial relationships: Responses pertain to issues related to different norms, expectations and incentives among industrial and academic participants in collaborations	3	With industrial people there are issues with what you can and cannot publish. Once we agree on that then the norms are like academia. I have one industrial collaborator who says ok we're not going to be able to publish anything useful (laughs), and then we can go from there.
Work-style fit: Responses pertain to compatibility of approaches to work, including such issues as work timing and scheduling	8	I visited a professor a couple of years back and started a collaboration with him. His attitude was that I was to do all the work and he would micromanage it. He would say 'you need a picture' and I would say, 'ok draw it.' It also was annoying because we had different ideas about how the paper should be written. That collaboration didn't work out well and I wouldn't work with him again. ... You want to work with people who are team players. I have had mostly successful collaborations. The few unsuccessful ones have been with people with large egos and they let that get in the way of the science.
Differing career needs: Responses pertain to collaborator issues related to different career stages, such as employment needs and impending tenure or promotion decisions	6	When I was a postdoc my two advisors were well established and they didn't have publishing pressure and they also had big groups. It was easy for your papers to get buried in the pile and that doesn't go away when you no longer work with them. It can be very difficult to get papers out with a senior faculty member. It is usually easier to get junior faculty to let go of a paper.
Negative gender dynamics: Responses pertain to not only conflicts between men and women but also to conflicts related to the construction of gender roles and expectations	7	One example [of undesirable gender dynamics] I can give you of a student I had two years ago. He was from [gives national origin] and I had a class with people from lots of different departments. For a bunch of assignments I assigned them to small groups. After every assignment I would have someone come and complain about him. It was always female graduate students and I would move him to a different group. I thought hmm... I wonder what is going on with this. The last time it happened the student [said she] felt physically intimidated. Then, he came to my office for something and I understood what they meant. He got verbally abusive and I ended up kicking him out[.]

* Categories in Tables 1–3 are only provided if there are three or more mentions by respondents

6. Findings: Content analysis of good and bad collaborations, additional themes

We know from evaluating our data systematically based on the literature-derived themes, that each of the factors suggested in the provisional model of research collaboration effectiveness has a least some resonance with our interview data. Here we provide the results of a second systematic content analysis focused specifically on 'good' versus 'bad' research collaborations in order to identify themes that were not originally part of the provisional model. Procedures were as follows: first, the first and second authors for this study did separate careful readings of all the interviews, identifying comments and themes relating to collaboration quality. Second, in each case put the comment on the 'good' or 'bad' ledger

(not difficult since most responses were from direct questions about this topic). Third, we identified key additional factors¹ mentioned as respectively good or bad aspects of collaboration. Finally, we ultimately developed a category set and a tally for each category. The coders' identification of 'good' and 'bad' collaboration instances approached near perfect agreement. The extent of agreement in the categorization of the good and bad factors mentioned was only moderately lower but well above generally accepted standards. We use Cohen's kappa² (Cohen 1968) as a measure of agreement and the coefficient for the classification of 'good' versus 'bad' is 0.945 whereas the coefficient for the classification of factors is 0.848.

The main purpose of this second systematic analysis was to explore additional constructs that were not included in the original

Table 2. Bad collaboration factors and incidence: Additional constructs from revised model

Bad collaboration factor	Number of respondents mentioning	Illustrative quote
Not meet work commitments: Problems related to perceptions that agreed upon work is not delivered on time or up to expectations	18	I had one coauthor who ended up stopping work and wouldn't respond to emails. I tried to contact him many times. I had to redo all his work because he didn't send me anything. I saw him once at a conference and was mad at him and he apologized and said he was very busy. Too busy to send an email?
Crediting disputes: Problems related to disagreements about who should receive credit or about the apportionment of credit	16	Had a postdoc who sat in lab meetings and claimed work as his own. We had full faith in him and when it came to surface it resulted in unpleasant exchange. Ultimate resolution was retracted paper and internal investigation and at the end was clear that nothing was win-win for anyone and the postdoc left.
Personality clash: Problems related to friction owing to diverse personality types	10	There was one guy I knew that I involved in a collaboration. He was too negative. He didn't like things that he didn't come up with. Math is a lot of work. You are in isolation. It is a little depressing. I like to have a group of people who are enthusiastic. I am extremely positive because I want to be encouraging – even if I privately feel that it might not work out – because I want these guys to be having fun and working hard. This one guy, I got sick of his attitude.
Selfish: Problems related to perceptions that individuals act only in their own interests without consideration of others	10	I came up with an idea with my first PhD student. It was a great idea, which became his thesis. We worked it out and talked about it at a conference. Two other people heard my presentation and read my paper. They began to work on this same problem after they read my paper . . . I was trying to be the first author but everybody wanted the authorship to be alphabetical. Then someone from Spain came up with another proof. I felt that my original idea was taken away from me(.).
Ghost author: Problems related to an individual insisting on authorship but having made no contribution	7	A faculty member read a paper of mine. [I asked him to make suggestions] but instead of making suggestions he said that he knew about something that I did not know about that would make the paper better, but he would not tell me because he was going to write a different paper. I wanted the paper to be the best it could be and we collaborated but he was basically blackmailing me. [He then did almost nothing on the collaboration].
Exploitation: Problems related to the exploitation by the powerful of the relatively less powerful	6	There was a student who worked in a colleague's lab a few years ago. He really wanted to get a masters and she wanted him to get a PhD. She talked him into getting a PhD. In his third or fourth year he was like 'I don't want to do this anymore. I want to leave.' It started really going downhill from there. She was coming up for tenure and needed to have both a certain number of students as well as publications. She was pushing him to finish multiple papers at that point. She was refusing to allow him to graduate until he finished the papers.
Asymmetric investment: Problems related to conflicts arising from differential levels of investment in the collaboration	5	I was working as a postdoc with a PhD student. I was doing more of the work than he did but he was counting on that for his PhD dissertation since dissertations are a combination of papers. It bugged me but I understood later on that his need was more than mine.
Organizational or institutional clash: Problems related to conflicting norms, rules, and expectations of the participants' respective organizations	5	I have collaborated with someone at the USDA. The USDA has less flexibility in what they do. I don't have a boss – nobody is telling me what research to do. Most people in a government facility will have a boss who tells them that they can or cannot address particular questions.
Cultural/national origins differences: Problems related to conflicting norms and expectation of persons from different nations or cultures	5	Language issues are a bit of an issue and some cultural issues arise in the way we critique each other's work. There is a pair of people, one from [gives nation of origin] and one from [gives a different nation of origin] in the [gives name of project] project. The one person is very upfront and the other person takes it hard. That tends to alienate people fast. I have to take responsibility for this, the human relationship problems.
Controlling collaborator: Problems related to one or more collaborators seeking undue and unhelpful levels of control of the collaboration or collaborators	3	He doesn't understand the idea of collaboration. He wants to be the boss. He doesn't want anybody else to think but he doesn't know what to do or how to move a project forward. He wanted our project to be a success, but he felt threatened if somebody else tried to move it along.

provisional model. Table 2 characterizes 'bad' collaborations and Table 3 provides incidences of new constructs characterizing 'good' collaborations.

In Table 2, we see that two factors lead the list of complaints: failure to meet work commitments and crediting disputes. However, there are many other factors that are often mentioned including: personality clashes, selfishness and unreliability, exploitation, and conflicts related to cultural origins and inter-organizational dynamics. Because so much of the collaboration literature presumes its positive

benefit, one of the important contributions of this paper is to explore in more depth the ways in which collaborations can be disrupted.

The new 'good factors' list provided in Table 3 is led by personality factors, communication, productivity, and interpersonal trust. It should be noted that personality plays a dual role in research collaborations: good personalities, and good personality fit can be a boon to collaborative productivity and happiness, while bad personalities and poor personality fit can seriously disrupt collaborations.

Table 3. Good collaboration factors and incidence: Constructs from revised model

Good collaboration factor	Number of respondents mentioning	Illustrative quote
Personality: Success pertaining to the meshing of collaborators' personalities	13	They have got to have mature egos and a nice firm sense of themselves so that we don't feel threatened by each other, and that we've got some common passion and problems that we work. Personality, personality, personality. You can't work with egomaniacs. I'm too old but you shouldn't have to do that.
Effective communication: Success pertaining to the ability to communicate effectively and in the manner preferred by team members	10	People who talk regularly. I like to talk regularly. I work by standing at a board and playing with ideas.
Productive: Success related to the high levels of collaborators' work productivity	9	All of that [long list of desirable collaborator characteristics] is of course is predicated on them being people who do high quality work to begin with. (...) They should be very good at what they do.
Meets commitments: Success related to delivering work when agreed and as agreed	6	People who do their professional work on time and aren't tardy in meeting deadlines. All those sort of good professional activities you would want.
Trust: Success related to the belief that collaborators can be trusted to work effectively and ethically	4	There are different types of collaboration in the field [biology]. You have a joint grant where you are required to work together. There are other collaborations that are less structured, so if those aren't going well, people can just leave. A shared grant means people have to work it out and people have to trust each other more. So they lead to different conditions in which you suggest to collaborate with one another.

In each of the two tables we see that the respondents, all of whom were asked to identify both bad and good collaboration experiences, identified twice as many new bad collaboration factors categories (10) than good ones (5) and more aggregate instances for the bad collaboration factors than good ones. Perhaps there is a 'Tolstoy principle' of research collaboration: namely, that 'all happy collaborations are alike; each unhappy collaboration is unhappy in its own way'.³ The cliché has at least as much veracity for research collaborations as for families, but probably just as many shortcomings as well. It may be that good collaborations are more alike than bad ones, but it may also be the case that bad collaborations are more readily recalled. In so many realms, including ones far removed from research collaboration perceptions and experience, negative experiences have higher salience than positive ones. Generally, negative experiences are especially memorable and likely to influence future choices (Rook 1984; McFarland and Buehler 1997; Moberly and Watkins 2008). As expressed in the title of one of the best-known studies (Baumeister et al., 2001) of the effect of bad experiences, 'bad is stronger than good'. Particularly in a collaborative context, one can learn much from negative experiences (Scindler and Eppler 2003). For whatever reasons, we observe both in counts and in detailed content analysis that reports of bad collaborations are more numerous, more variegated and often more detailed.

One interesting feature of the factors appearing in the analysis is that some of the factors viewed as 'good' seem to be the opposite pole of factors mentioned as 'bad', whereas other factors seem to be uniquely associated with one 'valence' (i.e. either positive or negative and orthogonal to the other). In some cases, the polarities are virtually indisputable such as in 'good communication' and 'bad communication' or 'meets commitments', 'does not meet commitments', and in others the polarities are suggested, even if they are not utterly clear-cut, such as in 'personality clash' and 'good personal relations' (in this case good personal relations seems a broader category in that it likely involves personalities but also other factors). Indeed almost all the factors mentioned could be viewed as dimensional. Only a couple of factors, 'negative gender dynamics' and

'exploitation' seemed not to have a counterpart as a good collaboration factor. Perhaps this is because the absence of noticeable gender dynamics or of exploitation is a success. Moreover, none of the respondents said precisely that 'this collaboration was effective because of positive gender dynamics', or 'that collaboration was effective because no graduate students were exploited'. The failure to mention a positive case may not be evidence of a lack of dimensionality but a means of reporting. Thus, many candidates mentioned explicitly that effective groups were made up entirely of women who had worked together for years (at least suggestive of a positive gender dynamic) and others indicated that mentors and collaborators were especially helpful to students.

Taking the results of the interview content analysis as a whole, we find support for the initial provisional model that stemmed from the extant research literature. In addition, we identified a number of factors that should be included in a revised model of research collaboration effectiveness, to which we now turn.

7. A revised research collaboration effectiveness model

Our results show that the components of the provisional research collaboration effectiveness model have some considerable veracity, and also that they are insufficient. The structure of Fig. 2 resembles the provisional model presented in Fig. 1, but the Fig. 2 model includes the additional factors identified in this research, indicating that some important factors have perhaps received insufficient attention in the research literature. We do not show linkages among the components of Fig. 2 because, although we know from our interviews that certain factors are especially important to the success or failure of research collaboration, we do not know, and cannot know from these data, the causal sequence involved or the intensity of impacts of particular factors.

We can see from Fig. 2 that our interview results lead us to distinguish team characteristics from the characteristics of individual team members. Much of the research treats these as essentially the same.

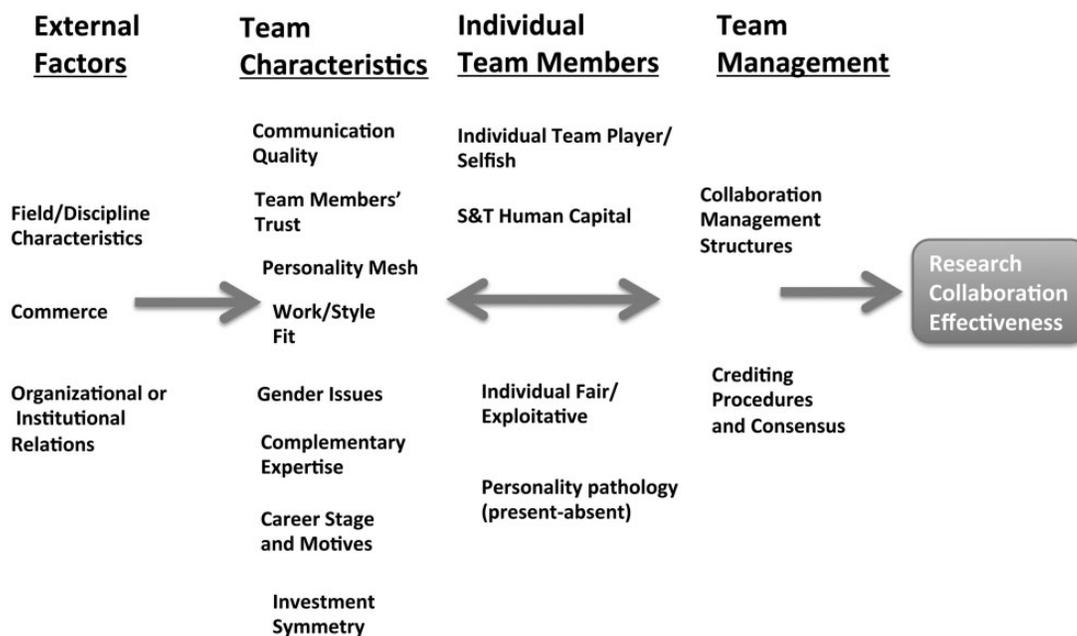


Figure 2. Revised model of research collaboration effectiveness

Clearly, the two are intimately related inasmuch as team characteristics flow from those of the individuals. But often in teams it is the fit of the particular skills and preferences and values that are most important. In any team, effectiveness is a matter not only of the components of the team but the unique relationships among those components and, thus, team characteristics flow from this fit, not just from aggregated attributes. While we are not profligate in signaling causality (due to the limitations of the data), in this case we at least show a two-way causal arrow between characteristics of teams and team members owing to the dynamic relation between the two.

The only other respect in which the revised model in Fig. 2 differs from the literature-based model in Fig. 1 is in the depiction of a variety of factors that receive limited attention in the literature but seem, at least according to our interviews, to have some considerable import for the effectiveness of research collaboration. We discuss the factors above and give examples in tables but, in general, personality issues do not receive much play in the literature, perhaps understandably since the mesh of personalities is idiosyncratic. Even if one knows that they are important, it is quite difficult to use this knowledge to construct more effective collaborative teams. Even if difficult to predict, it is nonetheless the case that personality problems, rampant egomania, and selfishness are all inter-collaborator factors that can lead to poor collaborations. Most interesting perhaps is the finding that crediting norms and procedures are often important to research collaboration effectiveness. This is a set of factors that has received attention in the literature on research ethics but rarely in studies of research collaboration effectiveness. Moreover, much of the research ethics literature understandably focuses on the most egregious violations, but we find that even relatively minor differences, even ones that are not communicated directly, can easily undercut the effectiveness of collaborations.

In general, we expect that the most promising avenue for future research is likely to be focused on the management and decision-making structures related to collaboration. In the first place, as teams continue to grow in size, diversity, and dispersion it is no longer the case that most research is 'among friends'. When people are

not close to one another, either socially or geographically, good management can sometimes help forestall problems. Our data indicate that 'good management' is not remarkably complicated in research collaboration. The basics include: frequent and effective collaboration, respects for others' ideas and needs, and, perhaps most important, recognizing diverse disciplinary, field, and organizational norms is often paramount and a factor in good management. In short, much more attention needs to be given to crediting issues and, the related issue of collaboration management procedures for dealing with them.

We have, at best, presented preliminary evidence in support of this revised model, but certainly more research is warranted, particularly using a research design that would allow the testing of the different causal structures implied by our revised model presentation.

8. Distilling lessons about improving research collaboration

This paper is chiefly about identifying collaboration problems, not solving them. We are working on solutions research but it is in process. Nevertheless, some preliminary lessons are apparent from our interviews and the thematic content analysis. In the light of our results, three approaches to increasing collaboration effectiveness occur to us. First, researchers can choose collaborators they trust and to continue to work with them, generally increasing levels of trust. Second, individuals who are collaborating can devise informal practices and rules that work for them, including well-specified crediting and collaboration management procedures. Third, institutions such as professional associations, universities and research centers can do the same and then implement them successfully.

Previous research tells us that researchers often have strong preferences to focus most of their collaborative work on those with whom they have had previous collaborative successes rather than developing the broadest possible collaborative network (Bozeman and Corley 2004). This may be especially the case with female

researchers (Fox and Ferri 1992; Corley and Gaughan 2005). We do not expect that a procedure will be a magic bullet for avoiding bad outcomes or a necessary requirement. In some cases collaborators, through long working experience, have such a close reading of one another's values that direct and explicit collaboration management procedures may be unimportant. A related issue is that most researchers feel that interpersonal trust is a strong factor in effective collaboration (Melin 2000; Davenport et al., 1998). The role of experience in collaborations is closely intertwined with trust. The relationship is reciprocal. When asked about their most positive research collaborations, many of our respondents mentioned trust and experience, often in tandem.

Most collaborations have a range of issues flowing naturally from the collaboration, including: deciding publication timing and outlets, determining publication objectives, choosing fora for public presentation, and, especially important, assigning credit. Typically, institutions do not have rules pertaining to these choices. There are, of course, a few instances in which these choices are constrained by institutions. For example, university-business research contracts sometimes have specifications about when and where findings can be released. In the vast majority of cases universities and other research institutions do not have hard and fast rules about these research collaboration choices and the decision to leave discretion to the researchers themselves seems wise. However, in the absence of clear rules of the game, the routine choices made during collaborations can often give rise to disappointment, disagreement and conflict.

Why is it the case that such a small percentage of extremely bright, often highly experienced, and generally well-intentioned professionals have not learned that a modest amount of participative group decision-making and a few simple but transparent decision heuristics can make their collaborations run more smoothly? On the basis of the evidence we have thus far collected we cannot give a confidence-inspiring answer to this question. But here are some possibilities. First, the fact that an individual is a brilliant physicist or biologist seems to relate not at all to either management skills or human relations ability. However, highly accomplished individuals may have a false confidence or limited ability to empathize with those in less powerful positions. For example, authoritative requests given to students concerning authorship inclusion and order do not take into account the asymmetric power relationship between director/advisor and student. It should be noted that some senior scholars we interviewed said they decided to manage in a more participatory fashion because of a bad experience they had with their advisors when they were a student. Second, we are dealing with a set of extremely busy people who understandably have limited patience for management, even at its simplest level, and may view process work on collaborations as an undesirable transaction cost to be avoided. Third, if collaborative groups directly confront decisions about allocating credit, author order, selection of journals, timing of release of results, and all of the other small and large decisions that must be made during collaborations, there is clearly a potential for conflict. It is certainly the case that many people prefer to keep any conflict *sub rosa* so as to avoid direct confrontation. Fourth, academic scientists, much as the rest of humanity, are not necessarily eager to share power. This does not always mean that those who are in power and preemptive in their collaborations have bad intentions. In some cases, there is simply the assumption that they are experienced and they know best. Indeed, there is some defense to that point since inexperienced people participating in collaboration decisions may have difficulties. For example, many

graduate students seem to feel that the most important determinant of crediting is number of hours on the project, an idea that they often lose quickly when discovering how challenging it may be to conceive and construct a project. Despite the fact that we can understand reasons why collaborators wish to avoid processes, transparency, and participative decision-making, we nonetheless hold that doing so is one of the easiest means of avoiding bad collaboration outcomes.

While 'bottom-up' collaboration heuristics and management practices can be in many instances enormously effective, there are at least a few commonplace problems with relying on good will and the operation of informal organization in research collaborations. First, the fact that there is a self-conscious approach to managing research collaborations does not imply that it is necessarily an effective approach. In some instances people simply perpetuate bad management and increase the likelihood of bad outcomes (though, to be sure, most problems we observed owed more to non-management or *ad hoc* approaches than to poor systematic management). Second, not everyone contributes equally to informal management frameworks and heuristics. The less powerful and those with less status often have little or no role in establishing the collaboration management framework they work in. To some extent this is understandable: junior people and students often do not have the experience helpful in developing systematic approaches to collaboration. But this does not mean they should necessarily go unprotected, subject chiefly to the whims of persons who are generally, but not always, well-intentioned and who generally, but not always, develop a collaboration management framework that has mutual benefit.

Despite the many advantages of the bottom-up approach to collaboration management, there is something to be said for an institutional and more formal role (Landry and Amara 1998). Some professional journals have led the way, specifying requirements for contributorship. Some professional associations have begun to develop ethical codes, or at least explicit expectations, about the conduct of collaborations, especially as they pertain to coauthor credit.

Our results suggest that extending research on contributorship to other STEM fields beyond the medical domain is important for addressing these ethical, practical, individual, and institutional issues. Moreover, from a policy perspective, journals in the medical field have developed mechanisms such as journal contributorship guidelines (Rennie et al. 2000; Steneck 2006), these mechanisms are less prevalent but developing outside of the medical domain (Osborne and Holland 2009), even though our study shows that these problems are evident throughout STEM disciplines. Discourse on ethics in science research is not new. Specific contributorship, authorship and collaboration guidelines are being developed by STEM journals (COPE 2002; Anonymous 2004; Greene 2007; CSE 2012; IJABE 2012). Federal research funding agencies recognize the variation in collaboration and contributorship practices and lack of universal standards among disciplines that threaten the quality of research. Furthermore, a number of science societies are exploring increased discussion of, training on, and standard development for research collaboration (DCSD 1998; Frankel and Bird 2003; Weltzin et al. 2006; Duke and Porter 2013; Lynch et al. 2013; ACS 2014). Nevertheless, we see little empirical research, and in particular interpretations of specific situations, about ethical concerns in research collaborations outside of the biomedical fields.

The institutional innovations are still very much the exception. Is further expansion of institutional formalization a good idea? This is a topic ripe for debate. Many argue that the 'free market of ideas' is likely to prosper with as little formalization and bureaucratization

as possible. At the same time, ethical breaches do occur. We expect that more formal approaches could be useful in lessening the likelihood of nightmare collaborations but, perhaps, routinely bad collaborations will be less sensitive to formal rules.

9. Conclusions

Although this paper represents only one of many aspects of a large-scale, multi-year project and employs only interview data, we nonetheless feel that we have been able to learn some worthwhile lessons about good and bad collaboration factors and their associated constructs. When reflecting on their worst collaborations, even the most senior respondents typically mentioned problems related to short-term personal acrimony, conflicts about crediting on a single paper, or, most common, the failure of individuals to come through with promised work. One caveat is that our interview subjects were still in academia, so we may be under-estimating the extent of nightmare collaborations by not having talked to former academicians who left for other professions. Within this limitation, we nevertheless conclude that the vast majority of collaborations are good collaborations.

With respect to routinely bad collaborations, it seems to us that the most common factor is a lack of fit among work styles and, related, autocratic management of collaborations. We are not surprised that commerce plays a small role. We feel that there is always a strong potential for commerce-based, university–industry collaborations to have bad outcomes and that they are particularly prone to nightmare outcomes. However, while many researchers have some interaction with industry, the proportion having more than casual (paper exchanges, seminars, technical assistance) work with industry, collaborating directly on research and patents, is a very small percentage (Lin and Bozeman 2006). Moreover, those who do work extensively with industry rarely do it as a ‘one off’ and develop experience that helps them across the organizational culture chasm one often finds.

We are not really sure how what we refer to as egomania fits in. Certainly it is a major problem but one not in any way unique to academic research or collaboration. Sometimes people simply behave badly, treating others unfairly, exploiting the weak, and making the workplace a site for exorcising their personal demons. There does not seem to be one approach to collaboration management that has much potential to remedy this. Our respondents do have a relatively effective strategy. When mentioning someone who could fit into the egomaniac category, they almost all say the same thing—they will never work with that person again. However, if that person is one’s postdoctoral supervisor or dissertation advisor that remedy may be less effective.

Perhaps the most significant limitation of our paper is that it is based on 60 interviews. While the number of interviews compares favorably to other recently published interview-based studies on collaboration (Amabile et al. 2001; Jeffrey 2003; He et al. 2009; McCable et al. 2015), it is nonetheless the case that one must take great care in generalizing from such a small and possibly unrepresentative number of respondents. Our only consolation is that our present findings can perhaps be set beside related studies using survey data and curriculum vitae data (Bozeman and Corley 2004; Bozeman and Gaughan 2007; Youtie and Bozeman 2014), studies having data from a much larger number of researchers. Perhaps our current limited number of in-depth interviews will complement findings from studies with more respondents but based on less detailed and nuanced findings.

Another significant limitation of our study is that we are getting obtaining one person’s perspective about a ‘bad collaboration’. What if it is the *de facto* egomaniac that is doing the reporting? What if one person views a collaboration as ‘bad’ whereas all others view it as ‘routine’ and productive? Our concern here was to cast a wide net but it would be useful as a next step to study collaborations as a unit rather than collaborators. We caution, though, that this will be challenging. The ‘Rashomon’ aspect of research collaborations is only one of many questions the present research has set for us. To elaborate on our future research agenda on collaboration: first, we are interested in tracing systemically the life cycle of collaborative groups and the quality of outcomes from sets of collaborations. Second, we wish to firm up the idea of good and bad collaboration factors, developing indicators and testing them more thoroughly. Third, we wish to understand the long-term career effects of bad collaborations, and especially how good or bad early-career collaboration experiences affect student and junior researchers. Fourth, we wish to understand the impact that guidelines developed by (or under development by) science societies, journals, and funding agencies are having on collaborations in general and reducing bad collaborations in particular. Finally, after we expand our grasp of the determinants of collaboration outcomes we hope to develop some viable prescriptions. Perhaps certain steps can be taken to remedy some of the predictable problems encountered in bad collaborations and to increase the likelihood of good ones, or even dream ones.

Notes

1. We use the term ‘factors’ rather than ‘causes’ because it is inordinately difficult (and perhaps not imperative) to separate a cause of a bad collaboration from a type of bad collaboration. The respondents were not prepared to make precise analytical distinctions on this point and in some cases they seemed to differ in their conceptualization with some, for example, implying that unfair crediting is a cause of bad collaborations and others implying that it is a type of bad collaboration. Since our chief focus is on the individual respondent’s construction of ‘bad collaboration’, rather than an analytically precise definition, we feel that difficulty in providing a discrete separation of types of putative causes from types of collaboration outcome phenomena does not greatly hinder understanding. It certainly does not seem to do so from the standpoint of the respondents’ understanding of their own experience.
2. Cohen’s kappa is a standard measure of agreement between raters classifying items into categories. The equation is:

$$k = \frac{Pr(a) - Pr(e)}{1 - Pr(e)}$$

Where $Pr(a)$ is the relative observed agreement between raters and $Pr(e)$ is the random chance of agreement. With complete agreement, $k=1$ and with no agreement beyond random chance $k=0$.

3. The equivalence with Tolstoy’s pithy epigram is, however, not perfect. Our results indicate that the vast majority of research collaborations are happy, perhaps not true of family relations.

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