Team Roles and Interactions in Academic Research Project Teams and Their Potential Influence on Team Effectiveness

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ABSTRACT

Academic research is increasingly conducted by teams rather than by individual investigators. Researchers show more interest in studying the effectiveness of such teams. Evidence shows that team science leads to publications which have higher impact ratings and more patents. However, teams conducting academic research are facing various difficulties that prevent them from being successful. This thesis examines factors influencing the effectiveness of academic research project teams and explores how team role theory can help. Data collection was conducted in the University of Ottawa in the form of 5 standardized open-ended interviews with two academic research project teams and complemented by a validated questionnaire. Both teams were in the field of health science while team A had 13 – 20 members and team B had 6 members. We adopted a multi-method qualitative-dominant comparative research design and considered each team as a unit of analysis. We inductively generated codes and used the input-process-output (IPO) theory and the team role experience and orientation (TREO) theory as overarching deductive models to analyze data. Findings show that the IPO and TREO theories are helpful in studying the effectiveness of academic research project teams. The findings suggest that further research on academic research project teams using the IPO and the TREO theories is necessary, especially on the topic of team role complementarity. They also suggest that project management training on topics such as project planning and risk management can enhance academic research project teams' effectiveness.

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LIST OF ABBREVIATIONS

CIHR	Canadian Institutes of Health Research
Co-I	Cooperate investigator
HR	Human Resources
IPO	Input-process-output
NSERC	Natural Sciences and Engineering Research Council of Canada
PMBOK	Project Management Body of Knowledge
PI	Principle investigator
RA	Research assistant
RM	Research manager
SciTS	The science of team science
SMTs	Self-managed teams
SSHRC	Social Sciences and Humanities Research Council
TREO	Team role experience and orientation

INTRODUCTION

Academic research refers to scientific activities aiming at acquiring and disseminating knowledge, especially scientific discoveries (Curto & Puang, 1996). It uses systematic investigation methods to collect and analyze data in order to develop a systematically organized body of knowledge on a particular subject (Oxford Dictionaries, 2018). This body of knowledge can focus on, among other things, natural science, which studies the structure and behaviour of the physical and natural world or on social science which studies humanity-related issues (Ledoux, 2002).

In 2017, Canadian agencies such as Natural Sciences and Engineering Research Council of Canada (NSERC), Social Sciences and Humanities Research Council (SSHRC), and Canadian Institutes of Health Research (CIHR) awarded $2.2 billion to Canadian scientists so they can conduct academic research (CIHR, 2018; NSERC, 2017; SSHRC, 2018). Yet, what makes academic research projects successful is understudied (see Stokols, Hall, Taylor, & Moser, 2008 and Börner et al., 2010).

In order to bring out our study objective on exploring how to enhance the effectiveness of academic research project teams, we think it is necessary to start with introducing the concept of academic research. Understanding what makes academic research projects successful is indistinguishable from understanding what makes them complex. Only when figure out the context and content for each barrier can we think of effective solutions to address difficulties in conducting academic research projects. Building on Davis and Sumara (2006)'s view that academic research projects are complex because of the context in which research takes place, competing needs of many stakeholders, and the relationship between stakeholders and context, we will further analyze the complexity through the following three lenses: academic research, project management, and collaboration.

Academic research

There are key overarching interrelated reasons why academic research is complex. First, current academic research occurs as universities' mission is in flux. Universities contribute to knowledge by educating students to become qualified citizens and prepare them to make productive contributions to society (Powers & McDougall, 2005). These processes include qualification (e.g., providing students with

knowledge, skills, and understanding to reach specific tasks), socialization (e.g., transforming students to become a part of a particular social, cultural, or political entity) and subjectification (e.g., helping students build independent self-awareness) (Biesta, 2009). Universities also contribute to knowledge generation. For example, scientists seek answers to fundamental and applied questions. The fundamental research aims at generalizing and formulating a particular theory (Kothari, 2004). Though fundamental research does not generate direct and immediate commercial value, it is likely "to raise the productivity in applied research" and to promote "higher productivity growth" in the society (Poyago‐Theotoky, Beath, & Siegel, 2002, p. 21). Applied research aims at gaining knowledge or understanding in order to meet a specific need (such as vaccine development) (Rosenberg, 2010).

The applied and fundamental perspectives on science result from significant transformations in academia. Etzkowitz and colleagues (1998) explain that universities are in the midst of two "academic revolutions" (p. 1). The first one is turning universities' major task from preserving culture into creating new knowledge. The second one is gradually driving universities' research focus from knowledge-driven discovery to practice-driven application. Robertson (2007) adds that research in universities is "moving away from free inquiry to problem-solving" and is emphasizing more on specific programs which are controlled by their funding providers (p. 542). In today's innovation-valued society, universities are even seen as "the third pillar" supporting modern economy together with government and industry (Jonsson, Baraldi, & Larsson, 2015; Malone, 2010).

Second, in addition to a shift in mission, sources of funding also have a significant influence on the complexity of academic research projects (Braun, 1998). In Canada, the government is an important provider of research funding (Tetroe et al., 2008). There are three major funding agencies: Natural Sciences and Engineering Research Council of Canada (NSERC), Social Sciences and Humanities Research Council (SSHRC), and Canadian Institutes of Health Research (CIHR). The government support universities' research as a strategy to promote the country's innovation capability and build up more competitive advantages in the globalized world (García & Sanz-Menéndez, 2005). In addition to the government, the industry is also an important source of university research funding. Companies fund

university research and even become collaborators to develop new technologies or products since they can be more competitive in the market (Beise & Stahl, 1999). Typical examples are the pharmaceutical industry and biochemical industry. These different sources of funding and universities' shifting priorities impose constraints that contribute to the complexity of academic research projects.

University-driven agency-funded research and private-sector funded research are two ends of a continuum. Research outputs vary along this continuum. On the one hand, the university-driven funded research usually aims at "educating cohorts of graduates, generating scientific knowledge and creating instrumentation infrastructures" (Perkmann & Walsh, 2007, p. 4). Therefore, research outputs are more about training junior scientists and contribution in fundamental knowledge.

On the other hand, private-funded research leads to patenting and licensing of inventions, building spin-outs and creating start-ups (Abreu & Grinevich, 2013; Perkmann et al., 2013). These outputs are a function of what Perkmann and colleagues (2013) call academic engagement. They define academic engagement as "knowledge-related collaboration by academic researchers with non-academic organizations" such as collaborative research and contract research (p. 424). For the industry and the public sector, the close connection with academics via academic engagement is an effective way to benefit from knowledge transfer. However, academic engagement and the need for funding may cause academics to lose autonomy in defining and perusing their research program (Webster & Etzkowitz, 1998). Complex skills are required such as negotiation to protect academic freedom and management skills to improve their research effectiveness as expected by stakeholders.

The nuances along the university-driven agency-funded research and private-sector funded research continuum add complexity to the management of research projects. Interestingly, project management knowledge and skills are not part of researchers' curricula, which adds to the complexity of academic research projects.

The third reason why academic research is complex has to do with the need to use increasingly complicated methodology. Qualitative research evolves as a field and so does quantitative research. Examples of qualitative research evolution include establishing trustworthiness (Lincoln & Guba, 1985),

evaluating interpretive accounts (Packer & Addison, 1989), performing good research practice and enhancing validity by triangulation, participant feedback, and other approaches (Stiles, 1993). Examples of the evolution in quantitative analyses include field experiments, simulation, surveys, correlational study, and multivariate analysis (Queirós, Faria, & Almeida, 2017). Even more, mixed methods are often required now (Alasuutari, Bickman, & Brannen, 2008; Creswell & Creswell, 2017). In addition, there is a trend requiring using data stemming from these two methodological paradigms. Taken together these trends require research to be conducted in a more sophisticated way.

Finally, cross-disciplinary research is necessary to tackle increasingly complex research questions successfully. Cooke and Hilton (2015b), as well as Stokols, Hall, and Taylor (2008), describe a continuum of four increasingly complex types of research. Unidisciplinary research refers to research conducted by academics within a single discipline. Multidisciplinary research is a collaboration among academics in various fields, with individual contributions being added to one another without much cross-pollination for the final result. Interdisciplinary research, where useful elements from two or more disciplines, such as information, theories, and techniques, are integrated by academics across fields to solve problems. Transdisciplinary research where, academics not only integrate knowledge from various disciplines, but also "transcend disciplinary approaches to generate fundamentally new conceptual frameworks, theories, models, and applications" (Cooke & Hilton, 2015b). This trend adds great challenges to the already complex nature of academic research projects. For example, effective collaboration is progressively hard to maintain across the uni-, inter-, multi-, and transdisciplinary continuum. Moreover, it can be even harder because of the need to collaborate virtually with colleagues across countries and cultures (Cooke & Hilton, 2015b).

Project management perspective

While general considerations are contributing to the complexity of academic research projects, two more specific issues need to be addressed. The first one has to do with the management aspect of research projects. The second one is about the way academics interact.

The PMBOK® (Project Management Institute, 2017f) defines a project as "a temporary endeavor undertaken to create a unique product, service, or result.". We propose that research is – by definition – a project-driven activity (see Vom Brocke & Lippe, 2015). Indeed, a research program consists of many research projects. Each of these projects has a limited lifespan and aims at discovering new knowledge, creating new products or services, or applying existing knowledge from one domain into another. Research projects can be planned to some extent but must also adapt progressively as they evolve to account for the inherent uncertainty of scientific discovery. Yet, in spite of the apparent fact that research projects are projects, project management as a discipline has not been put forth explicitly to contribute to research projects' success. As such, a project management perspective can be helpful to address the challenges put forth by the complex nature of academic research[1].

Researchers may learn to conduct a successful research project intuitively and by way of "learning-by-doing" (Vom Brocke & Lippe, 2015). We contend this is not enough to maximize academic research projects' success. Specifically, the lack of formal training in project management hinders the successful completion of research projects. More subtly, the lack of formal training in project management might cause projects to be even more complex to manage. We can think of the lack of risk management knowledge and methods, which might cause avoidable risks to be ignored.

Bodies of knowledge such as the Project Management Institute' PMBOK® are useful to provide a generic basis on which most projects can be managed (Project Management Institute, 2017b). One such basis refers to the life cycle of projects. The PMBOK® (Project Management Institute, 2017c) describes a generic project life cycle into five processes which are initiating, planning, executing, monitoring and controlling, and closing. Research projects may also be conducted using these typical project phases. Perhaps more accurately, a generic model of a research project's life cycle can be considered as consisting of writing and submitting a grant proposal, getting approval from an ethics review board, collecting and analyzing data, and finally disseminating results.

[1] A project by itself can be complex and thus may face one or more of the structural, uncertainty, dynamic, pace, and socio-political complexities (Geraldi, Maylor, & Williams, 2011).

Nonetheless, every field of research has its idiosyncrasy. For example, software engineering gives emphasis to post-mortem analyses (Wohlin, Höst, & Henningsson, 2003), research in health will favour randomized controlled trials (Gattellari, Ward, & Solomon, 2001), and historical research in education is different from other forms of historical research in that it tends to compare current paradigms to past historical facts (Rousmaniere, 2003). These various approaches to research are taken at face value from an implicit methodology perspective. That is, each field trains researchers to move along on a sequence of events understood as common or best practices. Such sequences are not seen as intertwined project phases requiring explicit management as project management scholars or project management practitioners would consider them. Two important and specific elements of project management (i.e., project planning and project risk management) are not used explicitly which we contend hinders the successful completion of research projects.

Project planning is a process group which aims at establishing the project's scope, clarifying objectives, and deciding needed actions to complete tasks (Project Management Institute, 2017d). By doing so, project managers can develop a workable schedule and be prepared for predictable difficulties. In spite of thorough planning, all projects carry a fair amount of risks.

Project risk management is a process by which project managers identify risks and prepare preventative and responsive mechanisms (Project Management Institute, 2017e). To our knowledge, project risk management is not explicitly and systematically used by academic research project teams. In addition to hindering the management of projects, this may also impact interactions between team members.

Collaboration perspective

In addition to challenges specific to the management of academic research projects, the way academics interact is also a challenge. As research is increasingly conducted by academic teams rather than by individual investigators, collaborations in research teams add on to its complexity (Börner et al., 2010; Cooke & Hilton, 2015b). In fact, the effort needed to support effective collaborations can be as much as the effort needed to finish critical research tasks. In addition to the uni- to the transdisciplinary

continuum and the training-research dual role of academics addressed above, team composition is a particular challenge adding to the complexity.

A research team can be composed of people from different disciplines and/or with different kinds of expertise (Stokols et al., 2008). Some research project teams may also contain practitioners and/or experts from their sponsors (Meyer, 2003). Their needs and interests are different even though they work in the same research project. These various concerns will guide them taking different actions during the research process and may cause dilemmas. Researchers with different expertise, education background, methodology, and goals can find collaboration and communication are challenging (Bennett, Gadlin, & Levine-Finley, 2010).

In addition to composition, status is also a challenge. An academic research project team can consist of undergraduate students, graduate students, early researchers, and established researchers. There are collaborations among professional researchers to solve difficult research problems and there are collaborations between academics and their students for a publishable paper and students' degree. Neither type of academic research projects is easy in terms of collaboration.

Virtual teams are widely used today, so as in academic research projects (Cooke & Hilton, 2015d). Using virtual teams allows researchers in different locations or even in different countries to work in the same team. However, collaborations in virtual teams are even more challenging. Intimate interactions such as body language, feedback, and richness of communication are important in developing trust within a project team, while virtual teams have fewer opportunities to foster trust under this consideration (Beyerlein, Prasad, Cordas, & Brunese, 2015). This is also true in terms of academic research project teams which are collaborating virtually. The priority reason is that communication is difficult. Face to face communications can not only convey information more effectively but also express emotion signals which are important for developing team commitment. Virtual teams need to make much more effort in terms of effective communication. Time difference and culture difference for cross time zones and cross countries academic research project teams can make collaboration in a virtual team more challenging. Thus, academic research projects are complex because of difficulties in collaboration.

Summary

We have discussed reasons for complexity in academic research projects from a generic perspective and more specifically in terms of project management and collaboration. Taken individually, these three perspectives on complexity underscore significant challenges faced by academic research project teams. Furthermore, these three perspectives interact to add even more complexity. For example, private-funded research which consists of both practitioners and academics from different disciplines together with graduate students can lead to much more complexity in conducting the project.

Overall, we believe that complexity poses a very significant hindrance for academic research project effectiveness. Three needs to be addressed to advance knowledge on academic research project teams.

First, theories and concepts are not developed enough. Specifically, theoretical and conceptual knowledge relative to academic research project management and collaboration in academic research project teams is understudied. Although there is abundant research focusing on project management and teams *in general*, research on managing academic research project teams *in particular* is still scant (Cooke & Hilton, 2015b). Without appropriate theoretical and conceptual footing, knowledge cannot advance effectively.

Second, practical implications are simplistic or absent. The practice of managing projects and the practice of managing the human factor in projects are considered independent from each other. There is a need to address both together rather than independently (Chiocchio & Hobbs, 2014). This is because academic research projects and their teams have unique features and need to respond to specific challenges. For instance, Turner and Cochrane (1993) point out that research projects have neither well-defined methods nor well-defined goals. This unique feature makes academic research projects have greater chances of failure, therefore need a specific and well-developed approach in terms of management. Another example is that research projects typically have many desired outcomes all at once such as advancement of knowledge, training graduate students and policy-related goals (Bennett et al., 2010; Stokols et al., 2008). One consequence of this is that criteria for evaluating the success of academic research project outcomes should be different from the other kinds of projects.

Third, and of particular interest for this thesis, theoretical, conceptual and practical knowledge relative to roles and role complementary is scarce in general and absent in academic research project teams specifically. Team role is an important construct in team management. A team role is defined as a cluster of related and goal-directed behaviours taken on by a person within a specific situation in a team (Stewart & Sims, 1998). Roles have been recognized as necessary for the effective execution of task and team activities (Chiocchio, 2015) and at the heart of both project management and collaboration in the context of academic research project teams. In addition, team role complementary is an important factor for collaboration both in general and academic research project teams. Moreover, extant studies have not yet connected the team role concept with academic research project teams, let alone the concept of team role complementarity. We believe it is important to fill this gap.

In accordance with the above, the objectives of this thesis are twofold:

1. What influences academic research project teams' effectiveness?
2. How can team role theory enhance academic research project teams' effectiveness?

LITERATURE REVIEW

Projects

The project is a human activity with a long history perhaps starting with complex engineering projects such as building the pyramids (Project Management Institute, 2017b). However, it was not seen as a professional discipline until the mid-20th century (Project Management Institute, 2017b). The last two decades saw an increasing trend of using a project structure to conduct activities (Bredin & Söderlund, 2011; Hobbs, Chiocchio, & Kelloway, 2015).

A project can be defined as "a sequence of unique, complex, and connected activities that have one goal or purpose and that must be completed by a specific time, within budget, and according to specification" (Wysocki, 2011, p. 6). A project is usually a highly dynamic process. This feature makes a project ideal in a competitive context. For example, projects play important roles in product and technological innovation as well as introducing change into organizations (Hobbs et al., 2015; Wheelwright & Clark, 1992). Despite explicit features such as task-oriented, temporal and budget limits, projects have implicit yet important features which distinguish them from regular task-based activities. Indeed, projects are "temporary," they create a "unique product, service, or result," and abide to "progressive elaboration" (Hobbs et al., 2015, p. 8; Project Management Institute, 2017f). The endeavor undertaken by a project is designed to be temporary. In contrast to those of a continuous functional structure, a project has a clear and pre-settled beginning and end. A project focusses on a unique product, service, or result which requires a significant effort on intelligence and creativity of individuals working in the project. Also, the process of a project is elaborated progressively because the complexity and difficulty of achieving a goal will be solved gradually with the project unfolding over time (Chiocchio & Essiembre, 2009).

Traditionally, projects are categorized by industry, such as research and development, engineering, construction, and aerospace/defence (Kerzner, 2013). However, projects are becoming widely used in many types of organizations other than these traditional fields (Chiocchio, Grenier, O'Neill, Savaria, & Willms, 2012). Turner (2008a) addressed four kinds of features for describing a

project, including “goal (i.e. unitary or change), features (i.e. unique or novel), pressures (i.e. uncertainty or urgency), and the plan (i.e. flexible or staged)” (p. 4). Wysocki (2011) also mentioned that projects can be classified by several characteristics: “Risk, business value, length, complexity, technology used, and number of departments affected” (p. 17).

Project management

Projects have dynamic processes unfolding over time and following certain patterns. The project life cycle is used as the terminology for describing this process. The life cycle of a project refers to the process by which a project goes through within a finite time frame, and it consists of a number of stages (Turner, 2007). A typical project life cycle consists of initiation, organizing and preparing, monitoring, carrying out the work, and closing the project (Project Management Institute, 2017c). The PMBOK® (Project Management Institute, 2017c) also points out that life cycle stages differ from project to project considering the influence of organization and industry settings, development methods, or technologies employed. Interestingly the project life cycle for academic research projects in particular is still understudied.

Project management is critical for project success. According to the PMBOK® (Project Management Institute, 2017a), “project management is the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements.”. According to Munns and Bjeirmi (1996), project management is “the process of controlling the achievement of the project objectives” and it is oriented towards planning and control (p. 81). Project management needs to balance five inter-related constraints often illustrated using a triangle: scope, quality, cost, time, and resources (Wysocki, 2011). Similarly, Munns and Bjeirmi (1996) also addressed that the function of project management includes “defining the requirement of work, establishing the extent of work, allocating the resources required, planning the execution of the work, monitoring the progress of the work and adjusting deviations from the plan” (p. 82).

Project success

The purpose of project management is to lead to project success. Cooke-Davies (2004) defines project success by considering three dimensions: "project management success, project success, and consistent project success" (p. 106). While the first and second dimensions consider project success in terms of process and, the third one focuses on developing a regulation for achieving sustainable success not only in current projects but also in upcoming projects. Project management success considers criteria such as "cost, time, quality, scope, commercial performance, technical achievements, or safety record" (Cooke-Davies, 2004, p. 113). Project success, the second dimension, focus on a project's outcome and the satisfaction of its stakeholders. In our study, we will focus on two kinds of processes which are (1) technical dimension (i.e., project management) and (2) human dimension (i.e., collaboration).

Determinants of project success, or project success factors, are "elements of the project or its management that can be influenced to increase the chance of achieving a successful outcome" (Turner, 2008b, p. 58). Based on Cooke-Davies's (2004) three-level perspective of project success, determinants need to be considered separately. For the basic level, project management success, possible factors critical for success include clear project goals, well-selected project team members, adequate resourcing, clarity regarding technical performance requirement, effective planning and control, and effective risk management (Cooke-Davies, 2000; Crawford, 2001; Lechler, 1998; Murphy, Baker, & Fisher, 1974; Pinto & Slevin, 1988). The success factors of a project are project strategy, project goals, strategic change, benefits and stakeholders (Crawford, 2001; Lechler, 1998; Miller & Hobbs, 2000; Murphy et al., 1974; Pinto & Slevin, 1988). Consistent project success is a topic which received little attention in the literature (Cooke-Davies, 2004). Existing discussion on this topic considers team is learning from experience, portfolio and program management, and metrics for evaluation and feedback as several examples of determinants for consistent project success (Cooke-Davies, 2001; Egberding & Cooke-Davies, 2002).

Academic research projects: unique features

Usually, a large-scale and continuous scientific research program consists of many research projects. Each of these projects has a finite lifespan and aims at discovering new knowledge, creating new products or services, or applying existing knowledge from one domain into another. These features of academic research projects conform to all the definitional requirements of a project: temporary, creating unique products, service, or result, and abide to progressive elaboration (Hobbs et al., 2015; Project Management Institute, 2017f). As with any projects, a research project is temporary because it has a beginning and an end. The end can be conclusive such as reaching the goal of a particular study. However, the end can be inconclusive such as when a project needs to be terminated before meeting its objective. The general aim and outcome of a research project are to advance knowledge which is consistent with creating a unique product, service, or result, as advancing knowledge can be achieved by discovering something totally new or using existing knowledge in a new context. Progressive elaboration means that the methods to reach the end result and/or the end result itself are not fully understood at the onset of a project and get to be elaborated as the project moves forward (Chiocchio & Essiembre, 2009). Given the consistency between the definition of a project and the definition of a research project, we believe that knowledge from the project management field will contribute to increasing scientific research effectiveness in academia.

Academic research projects have unique characteristics which are different from those of commonly accepted projects. First, academic research projects are conducted by researchers who belong to postsecondary institutions, government departments, for-profit or not-for-profit organizations, or foundations. These various contexts imply different types of research. Academic research projects can be categorized based on size, organizational complexity, geographic scope (Bennett et al., 2010), research fields, research purposes and the like. For example, an important portion of academic research projects conducted in postsecondary institutions is managed by graduates and Ph.D. candidates who are working on their thesis. Such academic research projects are usually led by their supervisors as part of their research program and are in fact a process of scientific training. Vom Brocke and Lippe (2015) explain that in generic projects, management refers to defining and communicating high-level responsibilities

“while avoiding excessive guidelines on how to undertake sub-level tasks” (p. 1030). However, in academic research projects, great effort is invested in "sub-level" tasks given the requirement to train undergraduate and graduate students. In other contexts, experienced researchers also work on contract-based academic research projects. These projects may have a settled research direction or aim at solving specific problems. What’s more, their scope varies depending on the complexity of tasks such as using interdisciplinary collaboration.

Second, the “products” of research projects are usually very abstract as they are contributions to science and knowledge. This feature makes the result of an academic research project difficult to assess objectively. Although the evaluation of an academic research project is usually done through peer-review - which relies on the judgement of highly experienced researchers in related fields - the exact value created by this project is still difficult to assess, let alone to quantify. In addition, the value of an academic research project may be in its “product” but also its process. For instance, graduate students going through the process of an academic research project end up trained irrespective of what the research “product” is.

Third, academic research projects follow certain project life cycles while they are largely determined by research-related tasks. A typical research project has eight steps which include (1) formulating a research problem, (2) conceptualizing a research design, (3) constructing an instrument for data collection, (4) selecting a sample, (5) writing a research proposal, (6) collecting data, (7) processing and displaying data, and (8) writing a research report (Kumar, 2011).

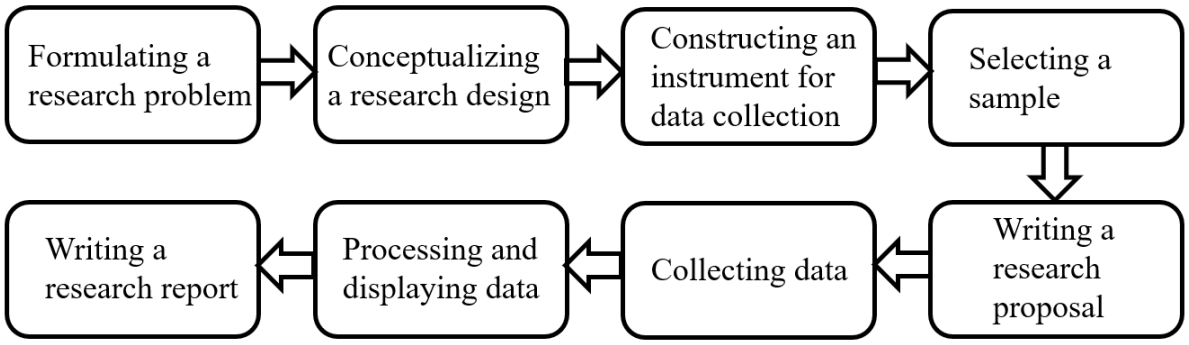

Figure 1. The procedure of a typical research project

The structure of an academic research project is similar to a "typical" project life cycle. Academic research projects and their teams may confront different situations and requirements when they progress from one stage to the next. The project life cycle "provides the basic framework for managing the project" (Project Management Institute, 2017c). From the project management perspective, "researchers must plan and monitor, even if it contradicts their sense of freedom and flexibility" (Vom Brocke & Lippe, 2015, p. 1029). However, academic research projects are different from generic projects in that a proposal does not have the same function or power as a contract. Also, a proposal is also different from a plan of a generic project because there are a larger possibility and higher tolerance for academic research not completely following its design on the proposal. Under this consideration, "typical" life-cycle phases are not necessarily helpful given the particularity of research. However, to the best of our knowledge, no systematic guide is available on managing the project life-cycle in academic research projects.

Fourth, academic research projects face the difficulty on how to properly share recognition and credit in a team. On the one hand, the "product" of an academic research project can "belong" to many people. This is reflected in the many papers that are published and the list and order of authors. This specific feature makes managing authorship complex. For example, there is no settled rule for deciding who should be granted the authorship and who should not. The criteria vary depending on the authors' contribution to the research and manuscript, status, student-supervisor collaboration and other factors (Marušić, Bošnjak, & Jerončić, 2011). On the other hand, the authorship issue is closely connected to the individualistic motive which can create tensions and conflicts. Researchers participate in academic research projects not only for working on certain scientific problems but also for building up their careers as scientists. Authorship credit, in particular, is the "foundation of career advancement, esteem in the scientific community and funding for research" (Marušić et al., 2011, p. 14). However, for decades, the culture in academic field valued scientists' individual accomplishments a lot while didn't pay enough attention to recognize and reward contributions of team players (Bennett et al., 2010). Without careful management on sharing recognition and credit, team members' accomplishments can be overlooked and

lead to negative impacts such as tensions and conflicts. Unfortunately, these specific challenges in academic research projects cannot find proper solutions in extant studies in general projects.

Academic research project management

We have discussed that project success has three levels: project success, project management success, and consist project success (Cooke-Davies, 2004). In academic research projects, it is a frequent situation that the level of project success received much more attention over the other two levels: project management success and consistent project success. For instance, none of the three major research funding agencies - SSHRC, CIHR, and NSERC - uses academic research project management success as criteria for evaluation. The quality of an academic research project is often evaluated based on its proposal and final results, while the process of it is easily being overlooked. As we discussed earlier in this section, plan and management also play important roles in an academic research project and may influence the research quality directly or indirectly. Verschuren and colleagues (2010) point out that unclear planning can be detrimental to the quality of the research project. In addition to project management success, consistent project success is, in fact, a process of experience accumulation and iterative learning. When conducting a large program which consists of numbers of projects, consistent project success becomes more important. Large programs are also applicable to the academic research field as a sophisticated scientific problem may need to be fixed by using multiple academic research projects or even interdisciplinary efforts. Thus, the level of consistent project success should not be completely ignored. However, changing current evaluation criteria on academic research projects is not only a challenge due to the complexity of examining project management and consistent project success but also a challenge towards the culture and tradition in the academic field.

In summary, we propose that on one hand project management perspectives and approaches can also be effective on managing academic research projects; while on the other hand knowledge on project management in general need to be adjusted to adapt to the context and features of academic research projects.

Teams

Teams are widely used by companies in response to competitive challenges in the modern economy and in order to achieve organizational success (Cohen & Bailey, 1997). Considerable discussions on how to define a team can be found in the team literature. Among them, Kozlowski and Bell (2003) give a very comprehensive definition of the "generic" team:

> Work teams and groups: (a) are composed of two or more individuals, (b) who exist to perform organizationally relevant tasks, (c) share one or more common goals, (d) interact socially, (e) exhibit task interdependencies (i.e., workflow, goals, outcomes), (f) maintain and manage boundaries, and (g) are embedded in an organizational context that sets boundaries, constrains the team, and influences exchanges with other units in the broader entity. (Kozlowski & Bell, 2003, p. 6)

In their seminal paper on team performance, Cohen and Bailey (1997) famously stated, "The type of team matters for the determinants of effectiveness" (p. 281). Therefore, efforts to specify types of teams exist. They further identified work teams, parallel teams, project teams, and management teams as four types of teams based on a thorough literature review covering research papers from 1990 to 1996 (Cohen & Bailey, 1997). A more recent typology distinguishes six types of teams: "(1) production, (2) service, (3) management, (4) project, (5) action and performing, and (6) advisory" (Kozlowski & Bell, 2003, p. 8). In addition to general typologies, there are also more specific classifications on teams. For example, researchers have identified crews (Cannon-Bowers, Salas, & Blickensderfer, 1998), top management teams (Hambrick & Mason, 1984; Jackson, 1992), and virtual teams (Bell & Kozlowski, 2002). In our study, we define project teams (and by extension academic research project teams) using Chiocchio's (2015) definition:

> A project team unites people with varied knowledge, expertise, and experience who, within the life span of the project but over long work cycles, must acquire and pool large amounts of information in order to define or clarify their purpose, adapt or create the means to progressively elaborate an incrementally or

> radically new concept, service, product, activity, or more generally, to generate change. (Chiocchio, 2015, p. 54)

This definition proposed a dynamic perspective on project teams; in addition, it emphasizes the need to focus on interactions and task dependency (Chiocchio, 2015; Decostanza, DiROSA, Rogers, Slaughter, & Estrada, 2012).

Team effectiveness: Input-Process-Output Theory

Enhancing team effectiveness is an important purpose for studies on teams. Team effectiveness is a concept based on the input-process-output (IPO) theory which was advanced by McGrath (1964) and its later incarnations (see Ilgen, Hollenbeck, Johnson, & Jundt, 2005). The process-driven approach to team effectiveness is one of the main focal topics within research on teams (Kozlowski & Bell, 2003; Kozlowski & Ilgen, 2006). Specifically, Kozlowski and colleagues (1999) addressed that team effectiveness is "a combination of individual and team-level contributions that unfold over time" to produce outcomes (p. 245). Guzzo and Dickson (1996) also proposed that team effectiveness can be indicated by "(a) group-produced outputs, (b) the consequences a group has for its members, or (c) the enhancement of a team's capability to perform effectively in the future" (p. 309). A similar perspective on team effectiveness simplified the three categories into performance, attitudes, and behaviours (Cohen & Bailey, 1997). Interestingly, while Kozlowski and colleagues (2003) acknowledge that team effectiveness must be defined specifically according to the particular types of teams they did not address this in their line of research.

Although team effectiveness and team performance are unfortunately often used interchangeably, it is important to recognize distinctions between the two. In team performance, the outcome is the main focus while the dynamic process of teamwork is ignored. In contrast, in addition to outcomes, team effectiveness also includes indicators of team members' attitudes (Mathieu, Maynard, Rapp, & Gilson, 2008) and of team performance behaviours which in turn indicates the potential of the team to perform well (Kozlowski et al., 1999). Given the focus of our study, we believe that team effectiveness is the proper construct to warrant our attention. Hence, we consider team effectiveness as a threefold concept

combining the team's performance, team members' affect, and the process of team development which builds team's performance capabilities (Kozlowski et al., 1999; Marks, Mathieu, & Zaccaro, 2001).

Extant research shows that team effectiveness is closely related to three types of indicators which are cognitive, motivational, and behavioural processes within teams (Kozlowski & Ilgen, 2006). Kozlowski and Ilgen (2006) further specified that cognitive processes include indicators of "unit-team climate, team mental models, and transactive memory," the motivational process includes "team cohesion, team efficacy, and potency," and the behavioural process includes "team competencies, functions, and regulatory mechanisms" (p. 116). In addition to these indicators, group composition, leadership, motivation, and group goals can also perform as leverages for influencing team effectiveness (Guzzo & Dickson, 1996).

The science of team science

In recent years, experts in teams expressed concerns regarding teams in academia. Research teams received attention under the label of "science teams," a new focus which builds on the team literature (i.e., the science of team science (Cooke & Hilton, 2015a)). Team experts also coined the term "science of team science (SciTS)" as the management and coordinated effort professionals undertake to focus on a common scientific problem to achieve collaboration (Cooke & Hilton, 2015b; Falk‐Krzesinski et al., 2010; Hinrichs, Seager, Tracy, & Hannah, 2017). "Team science has been described as a collaborative and often cross-disciplinary approach to scientific inquiry" (Bennett et al., 2010, p. 1). Stokols and colleagues (2008) defined team science as "large research and training initiatives implemented by public agencies and nonpublic organizations," and it also covers research projects conducted by multiple scholars (p. 77). It is still a relatively recent and unfolding research area (Börner et al., 2010; Stokols et al., 2008). However, it is of great need to build up knowledge in this field. First of all, scientific research is more frequently conducted by teams (Börner et al., 2010; Cooke & Hilton, 2015b), and collaborations are believed to be necessary for researchers who want to make a breakthrough (Macrina, 1995). And it was identified that team science leads to publications which have higher impact ratings and yield more patents (Fiore, 2008). What's more, team science faces particular challenges due to

its features such as high diversity of membership, large size, geographic dispersion (Cooke & Hilton, 2015b), and permeable team boundaries (Cash et al., 2003), which can lead to difficulties in enhancing effective collaboration. Because scientific inquiry itself is a complex activity, team science also has challenges in terms of the complexity of research tasks, the requirement of deep knowledge integration and high task interdependence, and facilitating goal alignment with other academic research teams (Cooke & Hilton, 2015b).

Thus, developing knowledge on SciTS is necessary. SciTS aims at studying the unique features of teams involved in academic research from the perspective of a long tradition of research on teams in organizational psychology. Interestingly, this tradition has not integrated advances in project management that can impact effectiveness (Chiocchio & Hobbs, 2014). And thus, in addition to the potential for improving SciTS by adapting knowledge gained from research on teams in general, there are additional gains to be made by adding the project management perspective, which is one of our focus.

The definition of team science is consistent with Chiocchio's (2015) definition of project teams. In terms of functions, academic research project teams can also be referred to as "science teams". A science team usually consists of 2 to 10 individuals who work on a scientific research task while those have more than 10 individuals are called larger groups (Cooke & Hilton, 2015b). Such a team usually has a principal investigator (PI) who is in charge of the whole research project, cooperate investigators (Co-I), research associates, as well as students (Ph.D. students, graduate students, and undergraduate students). Tasks of academic research teams can be pure scientific goals such as scientific discovery; they can be translational to adapt recent research findings into practice such as clinical translation; and they can also be more practical issues like training, public health, and health policy (Bennett et al., 2010; Cooke & Hilton, 2015a; Stokols et al., 2008).

In the previous section discussing the concept of "project," we have proposed and explained that the academic research project is a type of project with unique features as explained by the "science team" perspective. In accordance with the definition of project teams, an academic research project team consists of members with varied knowledge, expertise, and experience. The team members work closely

together to make scientific contributions based on limited time and resources. Therefore, we further propose that teams working on academic research projects can also be seen as a special type of project teams.

The effectiveness of academic research project teams can also be evaluated under three indicators same as in teams in general: the team's performance, team members' affect, and the process of team development. Börner and colleagues (2010) proposed a multi-level perspective to study the functioning of academic research teams. First, the organizational context and culture in scientific research are summarized into the macro-level; Second, factors related to research team composition and collaboration are considered belonging to the meso-level; Finally, the micro-level focuses on individuals in a research team, such as their education, training, characteristics and other features which can have influence on team science (Börner et al., 2010; Cooke & Hilton, 2015a; Fiore, 2008). In addition to the challenge caused by the complexity and difficulty of scientific research itself, other challenges faced by research teams can also be summarized into these three levels.

In spite of the obvious overlap between project teams and their more specific academic research kind, academic research project teams likely have other features. An academic research project team is usually supervised by a tenured or tenure-track professor (as a principal investigator), and consists of "contractual junior scientist trainees (students) who require coaching" (Riol & Thuillier, 2015, p. 254). This implicit professor-student relationship differs from colleagues' relationships or leader-follower relationships seen in more typical organizational settings.

In line with this discussion on teams, team effectiveness, and the science of science teams, our first research question is: **What influences academic research project teams' effectiveness?**

Roles in teams

One aspect of teamwork is the work roles team members play. Murphy and Jackson (1999) define the work role as "the total set of performance responsibilities associated with one's employment" (p. 325). Roles are defined as a cluster of related and goal-directed behaviours taken on by a person within a specific situation in a team (Stewart & Sims, 1998). Team roles have been recognized as necessary for the

effective execution of a task and social team activities (Chiocchio, 2015). Mathieu and colleagues (2015) proposed that team roles are "a critical part of effective teaming," and also an essential feature of work teams (p. 7). However, three points need to be made. First, roles are understudied in general. Second, when they are studied, that are studied from the perspective of a generic team. Finally, to our knowledge roles have not been studied from the specific perspective of academic research projects teams. We believe that studying team roles can provide us further understanding on the topic of academic research project team effectiveness.

Typologies and definitions of team role have evolved over time, and there is still no consensus to this day. The approaches to classifying team roles over time can be seen from Table 1.

Table 1. ***Evolution of Team Role Typologies and Team Effectiveness***

Author	Typology	Comment
Benne and Sheats (1948)	Group Task Roles: initiator-contributor; information seeker; opinion seeker; information giver; opinion giver; elaborator; coordinator; orienter; evaluator-critic; energizer; procedural technician; recorder; Group Building and Maintenance Roles: encourager; harmonizer; compromiser; gate-keeper and expediter; standard setter or ego ideal; group-observer and commentator; follower	No explicit discussion on team roles and team effectiveness.
Bales (1950) cited in Mathieu et al. (2015)	Gives and asks for orientation opinion, suggestion, disagrees, shows solidarity, tension release, agrees	--
Belbin (1981, 1993, 2010)	Plants; resource investigators; coordinator; shaper; monitor evaluator; teamworker; implementer; completer finisher; specialist	Team effectiveness will be enhanced by raising awareness of team roles and by keeping good team role balance.
McCann and Margerison (1985)	Creator-innovators; explorer-promoters; assessor-developers; thruster-organizers; concluder-producers; controller-inspectors; upholder-maintainers; reporter-advisers;	High-performing management teams have well-balanced team roles.
Ancona and Caldwell (1988)	Scout, ambassador, sentry, guard, immigrants, captives, and emigrants	No empirical study on the relationship between these activities/roles and team performance.
Barry (1991)	Organizing leadership roles, envisioning leadership roles, social leadership roles, spanning leadership roles;	The author illustrated these "team roles" as "leadership roles". The four clusters of "leadership roles" are all required for proper self-managed teams (SMTs) functioning.
DuBrin (1995), Cited in Mathieu et al. (2015)	Collaborator, summarizer, challenger, knowledge contributor, people supporter, listener;	--
Parker (1996, 2008)	Collaborator, contributor, challenger, innovator Contributors, collaborators, communicators, challengers	The author referred to the "team role" as the "team-player styles". A good balance of team-player styles makes the most effective team.
Mumford et al. (2008)	Contractor, creator, contributor, completer, critic, cooperator, communicator, calibrator, consul, coordinator;	The authors proposed a new typology of team roles based on a review on prior literature and illustrated that team role knowledge is related to team role performance.
Mathieu et al. (2015)	Organizer, doer, challenger, innovator, team builder, connector.	There is no explicit discussion on team roles and team effectiveness.

One aspect of team effectiveness that has not received much attention in the literature is team member role complementarity. Team role complementarity is a novel area of research and refers to the particular mix of roles played by team members that impact team effectiveness. Although some studies focusing on team roles discussed team member configurations (see Mathieu et al., 2015) and team role

balance (see Belbin, 2010), more specific research on team role complementary is scant. While understudied, this perspective is in line with theoretical foundations in the team literature. For example, as we discussed earlier in this section, team effectiveness is "a combination of individual and team-level contributions that unfold over time" (Kozlowski et al., 1999, p. 245). As such, team effectiveness is not only a team-level outcome produced by tasks and interactions but also the product of individual factors. These include factors on the individual level such as knowledge, skill, capability, and personality, as well as factors on team level such as team member interaction, team commitment, task assignment, and cohesion can all influence team effectiveness. We view team role complementarity as a key factor because of its pivotal place at the frontier of team-level phenomena and individual-level phenomena.

Stemming from these considerations and lacking in research despite their importance is the impact of team roles and team role complementarity in academic research project teams. We will use Mathieu et al.'s (2015) typology of team roles in this study for the reason that it is the most recent and all-encompassing. It is therefore applicable to a variety of types of teams such as academic research project teams. Mathieu et al. (2015) concluded that there are six types of team roles which are the organizer, doer, challenger, innovator, team builder, and connector. Description and explanation for each type of team role are showed in Table 2.

Table 2. ***Team role* (*TREO) theory: Team Role Definitions***

Role	Definition
Organizer	Someone who acts to structure what the team is doing. An Organizer also keeps track of accomplishments and how the team is progressing relative to goals and timelines.
Doer	Someone who willingly takes on work and gets things done. A "Doer" can be counted on to complete work, meet deadlines, and take on tasks to ensure the team's success.
Challenger	Someone who will push the team to explore all aspects of a situation and to consider alternative assumptions, explanations, and solutions. A Challenger often asks "why" and is comfortable debating and critiquing.
Innovator	Someone who regularly generates new and creative ideas, strategies, and approaches for how the team can handle various situations and challenges. An Innovator often offers original and imaginative suggestions.
Team Builder	Someone who helps establish norms, supports decisions, and maintains a positive work atmosphere within the team. A Team Builder calms members when they are stressed, and motivates them when they are down.
Connector	Someone who helps bridge and connect the team with people, groups, or other stakeholders outside of the team. Connectors ensure good working relationships between the team and "outsiders," whereas Team Builders work to ensure good relationship within the team.

Note.
Reprinted from Mathieu et al. (2015).

We believe studying team roles and team role complementarity will contribute to both project management and managing academic research project teams. As the academic research project is a highly dynamic process, the function of team roles is vital for project success. Team role complementarity is likely to create an important effect on team member interactions and further influencing collaboration effectiveness in academic research project teams.

To date, there are no studies on team role complementarity in academic research project teams. In fact, to the best of our knowledge, no study has been conducted on this topic in any kind of team. None address team role complementary, and none consider project management issues. Thus, conducting studies on this topic will provide valuable knowledge for improving our understanding of the effectiveness of academic research teams.

As a natural extension to our first research question, on the effectiveness of academic research project teams, our second research question will examine issues relevant to roles: **How can team role theory enhance academic research project teams' effectiveness?**

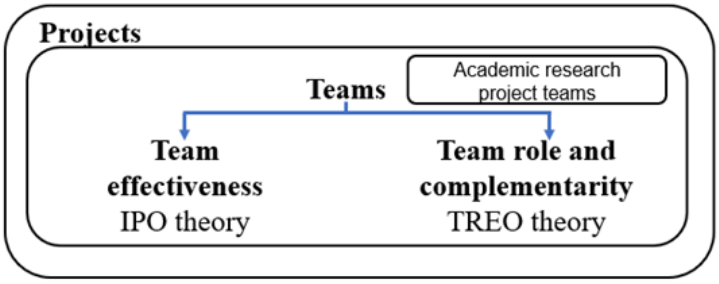

Figure 2. The structure of the literature review

Figure 2 sketches the structure of the literature review. As it illustrates, we focus on the study of academic research project teams. Because we are interested in team effectiveness and team roles in particular, we introduced the IPO theory and the TREO theory.

METHOD

Design and unit of analysis

This study adopted a multi-method qualitative-dominant comparative research design (Bryman, 2006) at both data collection and data analysis stages. The unit of analysis is the academic research project team. A multi-method research design provides "richer/more meaningful/more useful answers to research questions," and helps synthesize and integrate theories (Johnson, Onwuegbuzie, & Turner, 2007, p. 115). Combining quantitative and qualitative approaches contributes to enhancing complementarity (Greene, Caracelli, & Graham, 1989). We collected data from both interviews and surveys. Interviews were the major source providing the data; while surveys provided complementary information to enhance the richness of the data. What's more, analysis results derived from data of one side to some extent can be verified by data from the other side.

In order to answer the research questions, we adopt a multiple-case study (Yin, 2018c). A case study is a qualitative empirical research method that conducts in-depth investigations on a contemporary phenomenon in its real-world context (Yin, 2018c). This research method adds confidence to findings because a more in-depth understanding can be developed via studying a range of similar and contrasting cases (Miles, Huberman, & Saldana, 2014c). By using a multiple-case study, we will be able to enhance the richness of evidence and draw cross-case conclusions (Yin, 2018c).

The unit of analysis used in this study is the academic research project team. This is consistent with our focus on team-level factors such as team effectiveness, and team member roles. We use Bennett, Gadlin, and Levine-Finley's (2010) definition of a science team (see p.19) which fits under Chiocchio's (2015) definition of a project team (see p.17).

Sample

This study's sample consisted of researchers (i.e., academics, research professionals and assistants, graduate students) at the University of Ottawa who are currently involved in a team working on an academic research project. A convenient sampling method was conducted and based on a "first come

first serve" rule. Once the University of Ottawa's Social Sciences and Humanities Research Ethics Board issued an Ethics certificate (see Appendix 1), recruitment proceeded in the following steps.

First, the principal investigator obtained the permission to send all University of Ottawa's professors an email with a brief introduction to the research topic, purpose, ways of participation, and potential contributions. Interested professors contacted the principal investigator and were instructed to contact the rest of their team to invite them to participate. Once names and email addresses were communicated back to this candidate, an email with a link to a secure electronic consent form was sent. Participants who consented (see consent form in Appendix 2) to answer the survey were directed to a secure online electronic questionnaire. Those who consented to both the survey and the interview answered the questionnaire and took part in a forty-minute interview. Interviews were conducted whether face-to-face or by phone according to participants' preferences. The interviews were recorded, and then transcribed in order to provide a more accurate rendition for analysis (Yin, 2018b). In total, the five interviews provided nine stories for further analysis.

Given teams must consist of at least two members that interact over time (Brannick & Prince, 1997; Kozlowski & Bell, 2003), it is necessary to set inclusion (or exclusion) criteria for each of these factors. First, the number of team members refers to the complexity of the task. While there is some overlap, project team members contribute to the project success in distinct ways; this is what is meant by cross-functional or inter-professional teams (Chiocchio, 2015). Consequently, the size of the project team is a response to the complexity of the project. Hollenbeck et al., (1997) suggest that when complexity is a factor - and we believe research projects are complex projects - a team must consist of a minimum of 3 members. Therefore, teams of three or more members are included in our study.

Second, project team members interact over time to successfully deliver their expected output. The question that arises when conducting studies on team member interactions is how much time must pass before team members can provide reliable information on the quality of their interactions. This issue of team familiarity is a complex one in part because it depends on the frequency with which team members must interact (Huckman, Staats, & Upton, 2009). In the case of measures of cohesion, for

example, a minimum of four weeks is a good threshold (Chiocchio & Essiembre, 2009). For academic research project teams, we believe that while the task is complex teams typically do not constantly work with each other (e.g., every day all day long). As such we reckon that team members must have been working on a particular project for a minimum of six months to be included in our study.

Interested participants that adhered to these criteria were included in the study. Specifically, five participants from two academic research project teams provided data for both questionnaire and interview. In order to keep their identities anonymous, as we promised, alphabetic codes are used to represent the two teams (team A and team B), and numeric codes are used to represent each participant (such as 1001 and 1301).

Data acquisition

Two data acquisition techniques were used: interviews for qualitative data and a survey on team roles.

Qualitative

Interviews are appropriate to access participants' relativist perspectives and understand their perception of key events (Yin, 2018b). Our specific interview protocol was a standardized open-ended interview (Quinn-Patton, 2002) that followed Flanagan's (1954) critical incidents technique (see Figure 3 and Appendix 3).

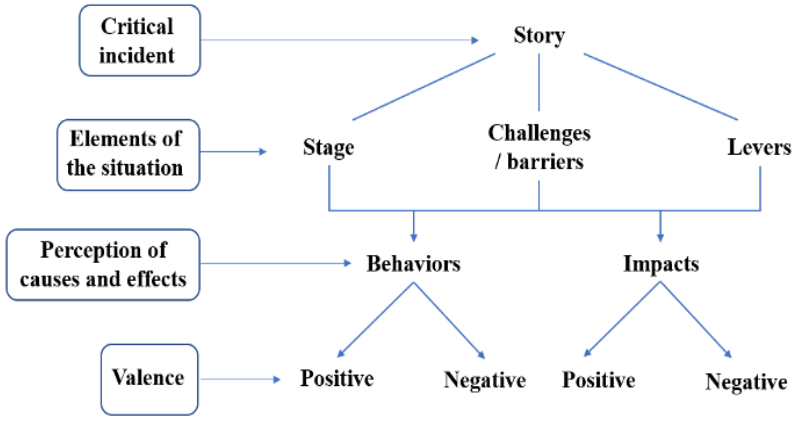

Figure 3. *Graphical representation of the interview protocol's structure and data collection*

Participants were asked to recall events involving team member interactions in their academic research project. Each participant was encouraged to recall important events, one with a positive outcome and one with a negative outcome. Furthermore, the protocol included a series of probing questions to

ensure that each "story" was described regarding the situation, actions (or lack of action), justifications for these actions (or lack of action), and outcomes. Probing is usually necessary because people often overlook several parts of their "story" which hinders the understanding and causal chain of events. As such, the critical incidents technique provides highly contextualized information. Specifically, we asked each participant to share two stories that demonstrated team members' behaviours leading to positive or negative impacts on the functioning of their academic research project teams. This technique is called critical incident. Critical incidents are important events that consist of five elements which are the stage, challenges/barriers, levers, behaviours, and impacts. The first three elements (stage, challenges/barriers, and levers) illustrate the situation of the story. "Stage" refers to when the event occurred, in particular at which stage of the project. "Challenges/barriers" refers to the potential difficulties and existing problems that the team faced during the event. "Levers," on the contrary, are potentially helpful factors that the team has during the event. Behaviours and impacts show participants' perception of causes and effects in the story. "Behaviours" are the actions team members took that influenced the event. "Impacts" shows the direct and indirect results of the event in terms of the research project as well as the academic research project team. Based on the information they shared, we further gave valence to each behaviour and impact and labelled them as positive or negative. Figure 3 shows a schematic description of how the critical incident interview technique structures the information participants provide. In addition to the themes demonstrated in this figure, we also asked questions such as "Could you summarize your role in this situation?"

The critical incidents technique is consistent with our goal to understand the interplay of team roles and team effectiveness embedded in specific contexts. Participants' perspective in explaining behavioural events (Yin, 2018b) is critical to gain insights based on experience.

Survey

The survey on team roles is based on Mathieu et al., 's (2015) role typology as described earlier (see p.24). The survey proceeded in two steps. First, participants were exposed to the six roles presented

randomly. They were asked to pick from 0 to 6 roles. Second, they were asked to rank order the roles according to their importance (see Appendix 4)

Quantitative data is often helpful in identifying relevant or innovative concepts by offering extra clues (Yin, 2018a). By using this theory-driven survey, we can know more about how participants think of their roles in the team. Therefore, the data collected by the questionnaire survey was used as an important complement to data collected from the interviews.

The validity of our process

This study's validity was strengthened by abiding to criteria suggested by Miles, Huberman, and Saldana (2014a) which are (1) objectivity, (2) reliability, (3) internal validity, (4) external validity, and (5) utilization. Indeed, we developed complete study procedures, and carefully chose research methods in the preparation stage to avoid researcher biases, and thus improve objectivity. We used a standardized interview protocol and a validated questionnaire in data collection and therefore increased reliability. Internal validity of this study is ensured by using triangulation among complementary methods and data sources to reach converging conclusions. We used the cross-case analysis to increase the external validity of this study. In terms of utilization, this study shows application value as it addresses real-world challenges of academic research project teams and aims at exploring solutions by adapting theories from other fields such as project management and the team role theory. A detailed interpretation will be provided in the discussion section.

Case methodology

We used a case-oriented approach (Miles, Huberman, & Saldana, 2014b) in data analysis. This particular approach is very effective in finding specific and concrete patterns within a specified context (Miles et al., 2014b). Specifically, we used both within- and cross-case analysis to develop in-depth understanding and explanation to the cases (Miles et al., 2014b).

The two teams in our study were considered as two separate cases. Each case in our study is first treated as a whole entity and then explored to find patterns which are common or unique to them. We use the technique of multiple exemplars (Denzin, 2001): each case is deciphered first, then the comparison of

patterns is made between two cases, and finally, we rebuild them under suitable conceptual structures with considering their social context (Miles et al., 2014b). By using a cross-case analysis, our understanding and explanation on the two cases can get deepened and the generalizability of this study is hopefully to be enhanced (Miles et al., 2014b).

Table 3 shows the summary of data collection results. In total, two academic research project teams participated in this study. We conducted interviews with five participants separately, and the five interviews provided nine events or stories for further analysis. The average length of interviews is 24 minutes. Every participant also completed an online survey which provided five survey results.

Table 3. ***Summary of data collection results***

The number of teams:	2
The number of participants:	5
The number of interviews:	5
The average length of interviews:	24 minutes
The number of events collected:	9
The number of surveys completed:	5

The basic information of the two academic research project teams is presented in Table 4. The two academic research project teams participated in our study both conducting research project in health science. In this case study, team A consists of 13 – 20 members which is called a large group while team B has six members[2] which is called a science team defined by Cooke and Hilton (2015b). Team A's project happened in four different locations but within the same province while members of team B worked in the same location. Three people from team A participated in our study who are the principal investigator, an investigator, and a research assistant. We have two people from team B participated in the study, and they are the principal investigator and a post-doctoral fellow. The numeric code of each participant is also presented in Table 4. Team A was built to complete a single academic research project. All members of team A are working on the same project, and the project is "about halfway"[3] in terms of

[2] Technically, the six people in team B are its core team while the full team has "at least 40 investigators" (quoted from participant 1301). The experience shared by participants from team B only occurred in the 6-member core team. Therefore, we identified team B here as the core team.

[3] Quoted from participant 1001.

project stages. Team B continuously works on different academic research projects, and there are overlapped stages between two projects.

Table 4. ***General Information on team A and B***

	Team A	Team B
Research field	Health science	Health science
Team size	13 - 20 people (large group)	6 people (science team)
Location	4 different locations	Same location
Number of participants	3	2
Participant's position and reference code	1001: Principal investigator 1002: Investigator 1003: Research assistant	1301: Principal investigator 1303: Post-doctoral fellow
Project feature	Working on a single project	Working on multiple projects
Project stage	"About halfway"	N/A

Inductive and deductive processes

Interview transcripts were analyzed in three steps. First, codes were developed inductively from interview transcripts. Second, the input-process-output (IPO) theoretical framework was used deductively onto the list of codes. This process was done to see if and to what extent what emerges from the interview can be explained by existing theory. The third step is a similarly deductive process but uses the TREO theory; that is, the team roles typology from Mathieu at al. (2015) (see page.24). We adopted the technique of pattern matching (Yin, 2018a) to analysis our codes. In order to avoid making a comparison on different dimensions, we use the same format of displaying codes as suggested by Miles & Huberman (2014b). The next section will present our results according to these three steps.

RESULTS

This section covers the data analysis process as well as the results. It consists of four parts. First, we will introduce how codes were generated from interview transcripts. Also, we will explain the analysis process using the IPO theory and its results. Following that, a similar analysis process using the TREO theory and results will be described. In the end, we will show the comparison between our analysis results and survey results on team roles played by participants.

Inductively generated codes

The interviews provided with a wealth of data to inductively generate codes. Participants recalled a total of 9 events (see Appendix 5 for a detailed description of all events).

These events address two major topics which are task related and relationship related. Task-related events appear in a higher frequency and include a team-based critical literature review, difficulties in the project and team management, inclusiveness of team activity, teleconference, communication and coordination of a large team, team meeting, and hiring. The relationship related event is about a new member's work that was not valued by the team. In between, there is an event addressing hiring someone who cannot fit in the team and another event about receiving help from a team member. Challenges/barriers and levers in these events are mostly created from team level factors such as geographical dispersion and having regular meetings. A barrier coming from the organizational level is a human resource policy. Behaviours mentioned in the nine events have a lot to do with communication. For example, there are formal meetings or one-on-one talks, visual meetings or face-to-face, effective or ineffective communication. In terms of impacts, a frequently mentioned topic is the publishing of final reports. Another typical impact is about the effect of a particular event on the team and its members. Overall 46 codes emerged from the data as can be seen in Table 5.

Table 5. ***Codenames and definitions***

Codename	Sub-code	Definition
Policy	N/A	Policies that made on the organizational level and that the academic research project teams need to follow. In team A's case, the policy was made by a grant institution; in team B's case, the policy was made by the organization that team B embedded in.
Composition	N/A	Team members' positions in the team. The record is not exhausted but only counted positions mentioned by participants. Positions in team A include the principal investigator, investigator, and research assistant. Positions in team B include the principal investigator, post-doc fellow, and research manager.
Funds	N/A	This code covers principle investigators' attitudes and concerns in terms of using funds.
Geography	N/A	Whether the location of each academic research project team was sperate or not.
Hierarchy	N/A	Situations within academic research project teams that resulted from the difference of team members' status.
History	N/A	Team members knew other members or had experiences working with them in the past.
Member change	N/A	Three situations are included in this code: hiring, drop out, and concerns on having new members.
Mismatch	N/A	The mismatch of a team member's ability and the task assigned to that person.
Project composition	N/A	Features of the project. For example, whether the project was multidisciplinary, having multiple investigators, and consisting of multiple projects.
Size	N/A	Size measured by the number of team members.
Authorship	N/A	Issues and concerns about sharing the credit of authorship.
Autonomy	N/A	To what extent team members can make decisions when doing their tasks.
Busy	N/A	Members of academic research project teams had limited time and energy to do all kinds of tasks. Moreover, the research project happened at a fast pace.
Collaboration	Blur function	Some team members' responsibility was not clear to others or to the whole team.
	Concrete work	The team finished certain tasks and this progress was recognized by the whole team.
	Connection	Had the chance to get access to and/or be involved with other team members.
	Distract	The difficulty of keeping focusing on some tasks.
	Involve	Team members were able to know the most recent progress of the project and they were included in team activities (i.e. team meetings).
	Plan	The team made plans as a whole.
	Provide help	Team members willing to offer help to the team or to other members to finish tasks.
	Social loafing	The concern on some team members did not make any progress or complete their tasks on purpose.
Communication	General	Circulated project related information within the team.
	Face to face	Team members met in real person to discuss issues, which is distinct from discussions on email, telephone call, or other approaches.
	Feedbacks	The comments and reactions provided by other team members on certain tasks or behaviours.
	One on one	The chance to have discussions with a team member, especially the team leader, in a private way.

	Reflection	The team behaviour of reviewing previous events and learning lessons from them.
	Team meeting	All or some of the team members met together physically or virtually to have discussions on project related topics.
	Virtual	The approach of using facilities like the Internet or phones to allow team members in different locations working together.
Problem and solution	Problem	The negative situations arose during the progress of the project due to ineffective behaviours such as wrong decisions.
	Solution	The efforts made by the team or could have been made by the team to reduce the negative impact of problems.
States	Commitment	Team members' awareness of being a team player and their behaviours which showed they care about the team.
	Confidence	Principle investigators' concern on whether they did specific tasks or made decisions in an ideal way.
	Interpersonal	The atmosphere regarding relationships among team members. This factor can have an influence on team members' decisions, such as whether reach out for help.
	Passion	The degree of willingness that team members showed on doing tasks for the project.
	Pressure	The feeling of stressfulness which resulted from a heavy workload, existing problems, and other factors.
	Trust	A belief that other team members can be helpful in the project progress.
Team effectiveness	Publish	Research results of academic research project teams can be published.
	Research contribution	Research results of academic research projects can contribute to knowledge and/or practice.
Viability	Future project	The same academic research project team have a chance to work together again on the next research project.
	Grow	Team members received new knowledge and/or sharpened their skills during the process of the research project.

Deductive process using Input-Process-Output Theory

Inductively generated codes set the stage for examining whether the extant theory can explain critical incidents. By comparing the input-process-output theory with our data, we found that all our codes could be classified into the IPO theory (see Table 7 for a summary and see Appendix 6 for a full account of the analysis). Table 6 listed key quotes that were used in this process. Table 7 presents a summary of the result on overlaying the IPO theory to the codes. The first column lists stages and categories in the IPO theory, and the second and third column shows codes and subcodes which can be classified into those stages and categories. For example, in terms of inputs, the codes can be sorted into the organizational level (code: policy) and the team level (codes: composition, funds, geography, hierarchy, history, member change, mismatch, project composition, and size). In terms of the mediator category, the codes fit into processes sub-category (codes: authorship, autonomy, busy, collaboration, communication,

interpersonal state, and relationships) as well as states sub-category (codes: commitment, confidence, passion, pressure, and trust). Finally, in terms of the output, our codes support the sub-category of team effectiveness (codes: publish and research contribution) and the sub-category of viability (codes: future project and grow of team members). Table 7 also displays what is common to team A and B, what is unique to team A, and what is unique to team B under the lenses of the IPO theory. Our data showed neither new categories complement to the IPO model nor conflicts to the model. The good fit of our data to the IPO model implies that this theory can be used in the academic research project team context. However, this theory is too general to provide suggestions to enhance academic research project teams' effectiveness. Nor does it help in understanding team roles and team role complementarity; which brings us to the next set of results.

Table 6. ***Key quotes related to deductive process using the IPO theory***

Team	Participant #	Key quotes
Team A	1001	• "[…] There was trust already and we could build on that."
	1002	• "I think it was important that I had access to her, one on one."
	1003	• "I kind of do all the groundwork and […] keep things on track, keep things moving."
Team B	1301	• "We're so constrained by human resource policies, […] that human resource burden can prevent us actually from doing well as a group."
	1303	• "I don't get a lot of feedback on how I'm doing."

Table 7. ***Comparison of team A and B using IPO theory***

IPO theory		Codes	Sub-codes	Common to A and B	Unique to A	Unique to B
Inputs	Organization level	Policy	--	--	Funding agencies	Human resource
	Team level	Composition	PI	"Hands-on"	Accessible	Overlook
			Post-doc fellow	--	N/A	Blurred role
			RA	--	Groundwork	N/A
			RM	--	N/A	Duel-role
		Funds	--	--	Avoided wasting money	Accepted risks
		Geography	--	Dispersion	Four locations	The core team stays together
		Hierarchy	--	--	Between institutions	Supervisor-student
		History	--	Built trust	Knew each other before	Tend to recruit acquaintances
		Member change	Hiring	--	Decided by investigators	Decided by the core team
			Drop out	Moved on to new jobs	Neutral reasons	Negative reasons
			New members	New to the project	Lack of communication	Made contribution
		Mismatch	--	--	Self-evaluation	Lack of skills
		Project composition	Multidisciplinary	--	Cross-discipline	N/A
			Multiple investigators	--	Four main investigators	N/A
			Multiple projects	Worked in all stages	Different paces and speeds	Multiple projects
		Size	--	--	13 - 20 people	6 members
Mediators	Processes	Authorship	--	--	Sharing credit	N/A
		Autonomy	--	Asked opinions	Team lead roles	Certain tasks
		Busy	--	Busy	Busy	Stressed
		Collaboration	Blur function	--	N/A	Unclear responsibility
			Concrete work	--	Could make a difference	Have difficulties
			Connections	--	Involvement	N/A

			Distract	--	N/A	Multiple projects
			Involve	--	Everyone was included	--
			Plan	--	N/A	Made plans together
			Provide help	People are helpful	Ethics procedure	Provide different perspective
			Social loafing	--	A possibility	N/A
		Communication	General	Good	Great experience	Could be clearer
			Face to face	Important	Met most of the people face to face"	Shared feelings
			Feedbacks	--	Asked for opinion	Lack of feedback
			One-on-one	Important	Access to PI	No chance
			Reflection	--	Needed somebody to reflect with	Needed reflection on events
			Team meeting	Regular meetings	Difficult telephone meetings	Introduced task scope
			Virtual	--	Phone, teleconference, and email,	N/A
		Interpersonal	--	Respectful	Respected everybody else's views	Frustrated
		Relationships	Problems	Relationships	Healthy relationships	Didn't aware
			Solve the problem	--	N/A	Didn't handle it the best way
	States	Commitment	--	Commitment	Worked together	Offered help
		Confidence	--	Led a team	Nervous	Took a chance
		Passion	--	N/A	Active	Passive
		Pressure	--	Felt a lot of pressure.	Need someone to talk to	Have to keep moving
		Trust	--	N/A	There was trust already	Difficult to speak up
Outputs	Team effectiveness	Publish	--	Publish	--	--
		Research contribution	--	--	Suggested a new way	N/A
	Viability	Future project	--	New projects	A related project	A new project
		Grow	--	--	N/A	Everyone has grown

Deductive process using TREO Theory

Inductively generated codes were also used to examine whether the TREO theory can explain critical incidents. Results point in two directions. First, our codes fit very well but provide more nuance to the theory (see Table 9 for a summary and see Appendix 7 for a full account of the analysis). Table 8

listed key quotes that were used in this process. Table 9 shows the summary of the result on overlaying the TREO theory to the codes. The first column shows the six original team roles in the TREO theory, and the second column lists the codes which can provide evidence for each of the team roles. For example, the role of the organizer can be identified in the code of "team meeting". The PI, research assistant, research manager are three positions in academic research project teams that behaved as an organizer. The role of the doer is identified in the code of "concrete work". This role is usually taken by every member, no matter what their status is in a team. For example, "The principal researcher with two other people […] crafted a major paper together, and […] asked the rest of the team […] to comment".[4] The challenger role appears in two codes: "concrete work" and "new members". This role has meanings on two facets: (1) task-related (i.e. challenging existing knowledge to answer research questions) and (2) management-related (i.e. bringing in new members to provide different opinions). The innovator role is shown in the codes of "provide help" as well as "new members". Both codes describe a situation that a team member suggested a new way to solve a problem. For example, "[a team member] really helped us figure out what the ethics procedure we need to go through."[5] The role of team builder is identified in the code "involve," and this role is mostly demonstrated in PIs' behaviours. For example, "The project leader […] was really good about being very inclusive."[6] The connector role can be found in the role of "policy" and "hierarchy." Examples in both codes address team members (often the PI) which made connections to an outside institution (i.e. the funding agency, ethics board, policy maker). Table 9 also demonstrates what is common to team A and B, what is unique to team A, and what is unique to team B from the perspective of the TREO theory. The comparison result of team A and B shows much more differences than similarities. This result is not surprising given the two teams have more distinctions than similarities in terms of their features (see table 4 on page.33)

[4] Quoted from participant 1002.

[5] Quoted from participant 1001.

[6] Quoted from participant 1002.

Table 8. ***Key quotes related to deductive process using the TREO theory***

Team	Participant #	Key quotes
Team A	1001	• "I'm the one that has asked [to have meetings]. I have a wonderful research assistant […] who organizes it all."
	1002	• "The project leader […] was really good about being very inclusive."
	1003	• "If it's one of the professionals […] they are often able to get a quicker response (e.g. from an ethics board) […]."
Team B	1301	• "There was one team member in particular who helped to really make us clear on what skills we needed to meet those tasks […]"
	1303	• "I thought that was very nice of him to offer like that, as a team member, to be a real team member."

Table 9. ***Comparison of team A and B using TREO theory***

TREO theory	Codes	Common to A and B	Unique to A	Unique to B
Organizer	Team meeting	--	Organized meetings	Identified required skills
Doer	Concrete work	Made progress	Wrote paper	Outputs dissemination
Challenger	Concrete work New members	--	Challenge current practice	Different perspective
Innovator	Provide help New members	--	Ethics procedure	Had a new member
Team builder	Involve	--	Inclusive	Got to know problems
Connector	Hierarchy Policy	--	Professionals got a quicker response	Constrained by HR policy

The second aspect of our results is that in addition to the six existing roles in the TREO theory, we also identified three new roles in academic research project team context in particular. The first one is the mentor which is a role that guides the team in scientific learning, skills development, collaboration, and policy understanding (see Bennett et al., 2010). For example, when sharing experience in the academic research project team, one of our participants mentioned that when hand in a write-up to the PI "she doesn't just comment, […] she actually changes sentences […] so you can really learn from that."[7] The implicit relationship of supervisor and students has a greater chance existing in academic research project teams as junior scientists (i.e. graduate students) work in those teams. However, the role of a mentor is not restricted to help scientific learning and skills development. Other positions within a team

[7] Quoted from participant 1303.

such as the research manager can become the mentor of policy understanding who helps the team be aware of important policies.

The second role that we suggest is the network builder. This role is a complement to the role of team builder. The network builder aims to foster a long-lasting connection among researchers who work in the same academic research project. This need is already a concern of researchers who are participating in a large scope academic research project having limited opportunities to get to know every team member. In fact, strong networks of researchers can be helpful to bring out greater research accomplishment (Bennett et al., 2010). Therefore, the role of network builder can add value to academic research project teams.

The third new role that we suggest is the problem solver. This role can be seen as an upgraded version of team builder but focusing more on clearly identifying a problem and making live actions to solve it. The situation exists that a problem in its initial stage is not identified or identified but being ignored on purpose. However, greater trouble can happen due to the initial problem is not solved in a timely manner, which will lead to negative impacts on the team. Not everyone in a team is comfortable with pinpointing a problem and tackling it directly. Moreover, this situation is more likely to happen in an academic research project team (Bennett et al., 2010). Therefore, a role of problem solver can be helpful to the function of academic research project teams.

Summary of inductive and deductive results

We inductively generated 46 codes from five interviews recalling nine critical incidents (i.e., events). After deductively overlaying the IPO theory on our codes we see that the theory explained all critical incidents. After deductively overlaying the TREO theory on our codes we found two things. First, our data provide more nuance to the original six roles. Second, three new roles emerge as important in the context of academic research project teams. An additional aspect needs to be examined: survey results.

The complementary impact of the roles survey data

As we introduced earlier in the research design section, we use survey data as a complement to qualitative data. Table 10 presents the results of the self-evaluation of the team role ranking by each

participant in our study. The first column shows which team participants belong to, and the second column shows the numeric code of each participant. The following columns are perceived team roles ranked by order of importance by respondents. Table 11 shows the team roles identification based on qualitative data. The first column shows the teams and participants. The second column displays the team roles identified by us based on the data from interviews. The last column shows the evidence for each of the identified team roles.

Table 10. ***Survey results for roles and their ranking***

Team	Participant #	1st role	2nd role	3rd role	4th role	5th role	6th role
Team A	1001	Organizer	Doer	Connector	Team builder	Innovator	Challenger
	1002	--	--	--	--	--	--
	1003	Doer	Organizer	--	--	--	--
Team B	1301	Connector	Team builder	Doer	--	--	--
	1303	Doer	Innovator	--	--	--	--

Table 11. ***Team role identification based on qualitative data***

	Participant #	Team role	Evidence
Team A	1001	Organizer	The PI asked for group meetings and RA organized them.
		Doer	The PI and two other people drafted the paper and then get the comment from the rest of the team.
		Challenger	Reviewed and critiqued the literature in a small group and gave feedback.
		Team builder	Met most team members face to face individually or in a small group.
	1002	Doer	Had extensive input in the paper.
	1003	Organizer	Watched and led the logistics in ethics applications and recruitment.
		Doer	Did all the groundwork and kept things on track and moving.
		Team builder	Made sure other team leads feel appreciated and their time is valued.
Team B	1301	Organizer	Had a meeting on "the scope of all the work" need to do
		Doer	Changed sentences and made real edits.
		Team builder	Tried to solve the problem by having a three-way discussion.
		Connector	We have our own projects and then we have projects that we lead for the broader team.
	1303	Doer	Made a poster demonstrating project results.
		Team builder	Talked with a new member for debriefing

Overall, this result is in line with the qualitative data (i.e. codes developed from interview transcripts). What's more, this result provides a complement to qualitative data. Starting with team A, we identified four team roles demonstrated by participant 1001 (the PI of team A) based on the two critical events that she shared. The four team roles are the organizer, doer, challenger, and team builder. However, according to her self-evaluation, two more team roles (innovator and connector) were added and listed as the third (connector) and fifth (innovator) important ones. By conducting a review on the

transcripts, we found that evidence for the two team roles exists but somewhat implicit compared with other roles. Participant 1002 is an investigator in team A. We identified the role of doer according to the event she shared. However, in the self-evaluation, no team role was picked. We discerned three team roles of participant 1003 based on the event provided which include the organizer, doer, and team builder. A slight difference is shown in their self-evaluation result which only listed two roles (doer and organizer).

In team B, we recognized four team roles played by participant 1301 (the PI) including the organizer, doer, team builder, and connector. However, only three roles were listed in her self-evaluation and missed the organizer role which we thought was important. A possible explanation for this particular case is that participant 1301 once mentioned "it's a bit of a shared leadership role"[8] in the interview. We identified two team roles for participant 1303: the doer and team builder. However, her self-ranking of the team roles listed the doer and innovator as the two most important roles in the team.

This situation that some disagreements happened in comparison has two possible reasons. First, critical incidents shared by participants provided incomplete information on their team roles. Second, the perceived team roles identified by self-evaluation have errors in terms of the importance level. The second reason also reveals a situation that researchers working in academic research project teams do not have a clear recognition of their roles in a team. Though some team roles appeared in the survey data, they neither support or contradict the evidence provided by the qualitative data.

Summary of comparing qualitative and survey data

We compared the analysis result (based on qualitative data) and self-evaluation result (based on the survey data) regarding team roles of all 5 participants. In most cases, perceived team toles picked by participants can find evidence in qualitative data. However, though having no against evidence, some disagreements exist between our analysis and participants' self-evaluation. We discussed two possible reasons: incomplete information collected in interviews and unclear recognition of team roles of participants. Overall, the survey data is a useful complement to the qualitative data.

[8] Quoted from participant 1301.

DISCUSSION

Summary

This study shows that factors influencing academic research project teams' effectiveness can be deciphered using the IPO theory. Our codes could be classified into the IPO model and provided a good fit. However, factors covered in the IPO theory are not fully demonstrated in our cases.

Our study also shows that the TREO theory can be used to explain critical incidents in academic research project teams. In addition to providing evidence of the original six roles, we identified three new roles (mentor, network builder, and problem solver) which are important in the context of academic research project teams. However, our data is not sufficient enough to draw a conclusion on team role complementarity.

Interpretation

Unique features of academic research project teams

We have discussed four unique features of academic research project teams in the previous section. These features are focusing on the context, product, life cycle, and sharing the credit of an academic research project team. Our study results provide insights towards these topics.

First, academic research projects often take place in postsecondary institutions and conducted by a leading researcher together with graduates and Ph.D. candidates. The supervisor-student relationship makes such a project has not only collaboration activities, but also teaching and learning. From the perspective of the IPO theory, efforts can be made from all three stages to help the academic research project teams succeed. In the inputs stage, factors on the individual level should be considered such as learning capacity, interest, research skills and the like. On the team level, if the composition of an academic research project team is identified as a mix of researchers and students, the team should be prepared to have certain activities in the mediator stage like providing instruction, giving regular feedback, and having debrief meetings. From the TREO theory's perspective, however, an academic research project team with supervisor-student relationship requires the organizer to become a mentor which is a new team role suggested by us and who can help other team members in scientific learning,

skills development, and other tasks. However, the practice of teaching and learning within an academic research project team can be different depending on which scientific discipline the team embedded in. Specific instruction to each discipline cannot be answered by a single study.

Second, the "product" of academic research projects is a combination of knowledge contribution and scientific training, which makes its true value difficult to evaluate. Overlaying the IPO model onto our data, we identified four specific outputs of an academic research project team, including "publish" and "research contribution" in the team effectiveness sub-category, as well as "future project" and "grow" in the viability sub-category. These four kinds of outputs can be suggested as prototype criteria evaluating academic research projects, and the value of such teams can be better recognized. What's more, our results show that the "product" of academic research project teams can be fully interpreted by the IPO model. Therefore, the "team effectiveness - viability" structure can be used by academic research project teams to decipher their specific aims and make goals clear. From the perspective of the TREO theory, the organizer should make it clear what are the purposes of the academic research project and monitor the completion of each goal in progress. The connector, when reaching out for resources or help, needs also consider the multiple goals and make the best decision. We suggested four potential criteria of better evaluating the "project" of an academic research project, but there are two important questions still unanswered: (1) Whether there are criteria that can fit academic research projects in all discipline, and (2) Whether it is workable to quantify the evaluation data.

The third unique feature of academic research project teams is that their project has a life cycle which closely related to research tasks, while there is no systematic guide available on how to manage it. In our analysis using the IPO theory, we identified the "plan" as a collaboration factor under the processes sub-category. Planning is leverage to the functioning of an academic research project team because it allows the team to identify upcoming tasks and/or potential difficulties and make preparation. From the TREO theory's perspective, the organizer is the one in the team who decides which stage should the project go to; and the doer makes an effort to push the project to unfold. These two roles are critical to an academic research project team to move forward following its project life cycle. However, the remaining

question is that what a typical project life cycle should be like in terms of academic research project teams.

The last unique feature is that the academic research project has the difficulty on how to properly share recognition and credit in a team. The "product" of an academic research project is a collaborative contribution, while a researcher's individual accomplishment is better recognized in the current system. Therefore, the opportunity of taking authorship credit is closely connected to the individualistic motive and may lead to conflicts in a team. From the perspective of the IPO theory, sharing recognition and credit should be considered as a factor in the processes sub-category. The authorship credit can be decided according to the contribution made by team members in the entire process of the project. Therefore, it is reasonable to treat it as a mission in the processes. Considering the authorship credit issue under the TREO theory, we found that although doers all contribute to the academic research project, it does not mean all of them can be listed as authors and share the credit. In fact, the decision of granting authorship can be made by the PI only, or it can be made under a group discussion. However, widely accepted criteria of sharing recognition and credit are yet to be developed (see Marušić et al., 2011).

Potential challenges faced by academic research project teams

In addition to the four unique features, experts in the science of team science (SciTS) also listed seven reasons that lead to challenges faced by academic research project teams (see Cooke & Hilton, 2015). We further condensed them into four categories: (1) feature of team composition; (2) team size and geographic dispersion; (3) feature of tasks; (4) team boundaries.

First, academic research project teams often have a high diversity of membership which adds difficulty to effective collaboration. Team composition is a sub-category in the input stage of the IPO model. The "diversity" is based on expertise, status, disciplines, experience, and other criteria. On the one hand, such "diversity" allows the team to integrate abundant knowledge from its members. On the other hand, it can lead to problems in collaboration such as difficulty in involvement and scientific communication. To solve these problems, the team builder as a role in the TREO theory could help to encourage involvement and communication. In addition, the network builder can make further effort to

develop interpersonal relationships and maintain long-lasting connections among team members. As the membership diversity can bring both positive and negative effects to an academic research project team, where is the balance point of the level of diversity remains a question.

Second, team size and geographic dispersion can create challenges in academic research project teams. Size and geography are both team level input factors. More team members usually need more efforts in terms of management. Also, a larger team is more likely to face geographical dispersion. Our result shows team meeting, as an approach to communication in the mediator category, provide great help to build connections between members and the team. Regular team meetings are also an effective tool to communicate progress and keep team members "on the same page." In terms of geographic dispersion, meeting virtually is a popular choice. Having virtual meetings could save time and energy of travelling; however, there are arguments on whether virtual teams are as effective as teams which physically work together (see O'Leary & Cummings, 2007). From the perspective of the TREO theory, large team size requires the organizer being more efficient in coordinating tasks and team members. The team builder can create more opportunities to involve team members in group activities. Our data shows the team with both effective organizer and team builder successfully created commitment of team members to the team, despite the fact that it is large in size and disperse in geography. However, systematic instruction on managing large and virtual academic research project teams is still needed.

The third category which can lead to challenges in academic research project teams is the feature of project tasks. An academic research project usually requires deep knowledge integration and therefore needs high task interdependence. These features make collaboration complicated and challenging in academic research project teams. What's more, there is a risk of goal misalignment within the team or with other teams (as in a larger research program). Using the IPO theory, we captured such a risk as "mismatch" on the team level of the input category. A lesson learned from our data is that "mismatch" needs to be identified and solved as early as possible. "Mismatch" cannot be solved simply waiting for the unfolding of a project. From the TREO theory's perspective, the innovator and challenger are two important roles which fit the requirement of deep knowledge integration and high tasks interdependence.

When it comes to the issue of goal misalignment, the problem solver, which is one of the new roles suggested by us, is expected to identify such a problem and solve it in a timely manner. However, considering that an academic research project is also progress of learning, it can be difficult to make it clear whether a member and a task are mismatched for sure.

The last category is the feature of team boundaries. Academic research project teams have permeable boundaries as researchers may work in multiple research projects at the same time. Another explanation for this issue is that some academic research projects contain the collaboration between researchers and practitioners (i.e. a research project in agriculture has farmers involved). From the perspective of the IPO theory, this feature is related to a category which we named "member change" as a team level sub-category of inputs. Within this sub-category, three issues need to be managed properly are hiring, dealing with member drop out, and helping new members fit in the team. In terms of the TREO theory, permeable boundaries of academic research project teams require the organizer be clear about who is available and who is not. This feature also needs the team builder and network builder to create proper connections between team members and the team. A question still needs to be answered is that how academic research project teams should decide their boundaries.

Implications

Theory

The IPO theory and the TREO theory are adopted in our study. Our data can be adequately interpreted by the IPO theory, which shows that the effectiveness of academic research project teams is to some extent similar to that of generic teams. What's more, some factors have been proved important in the IPO theory but are not mentioned in our cases of academic research project teams. For example, fault lines in a team and the personality of an individual as two factors in the input category cannot be found in the data. Therefore, we think that research on academic research project teams needs to develop a deeper understanding of the IPO theory.

In terms of the TREO theory, we identified all original six roles in the data and further suggested three new roles in the context of academic research project teams (i.e. mentor, network builder, and, problem solver). However, whether the new roles apply to other teams is beyond the task of this study. Another question remains unanswered is about team role complementarity. We believe future studies addressing these two topics can contribute to knowledge on academic research project teams.

Practice

Back into the previous sections of this paper, we identified a number of practical issues that lead to the complexity which hinders academic research project teams' success. In terms of the characteristic of projects and project management, these issues include (1) lack of formal training in project management, (2) need of project planning, and (3) need of project risk management.

Evidence of lacking formal training in project management was found in our data. Organizing and hosting larger teleconference, managing relationships, and dealing with human resource policy are three examples of such an issue. Training in project management can be classified into the individual level in the input category. However, this particular input was not shown in the data. Compared with other team members, the PI, research assistant, and research manager are more experienced in managing research projects which provide great help in the effective functioning of the team. Therefore, we confirmed that knowledge on project management is important to academic research project teams' success and formal training in project management can be helpful.

Project planning is already frequently used in academic research projects. In our cases, project planning is not only a step of managing upcoming tasks but also a group activity that involves team members and encourages them to share information. These approach for sure will help an academic research project become a success. But project planning is not a typical behaviour identified as important as we imagined. This situation shows that academic research project teams need to be more aware of the importance of project planning.

Project risk management is also a useful tool originated from project management. In our data, we found examples of lack of project risk management and its negative effects on the academic research

project team. Therefore, we came up with a new team role - problem solver - to take responsibility for identifying risks as well as problems and act positively to solve these issues. However, more efforts should be taken on applying project risk management in academic research project teams.

The validity of our process: detailed interpretation

This study shows validity through reaching five criteria suggested by Miles, Huberman, and Saldana (2014a) which are (1) objectivity, (2) reliability, (3) internal validity, (4) external validity, and (5) utilization.

We developed complete study procedures and carefully chose research methods in the preparation stage to avoid researcher biases, and thus improve objectivity. As suggested by Lincoln and Guba (1985) a detailed record of our study's methods and procedures can be found in the method section (Miles et al., 2014a). By doing so, outsiders can examine critical procedures and audit our study. We also archived all the data collected in this study, and thus make it possible for other researchers to reanalyze them. The possible biases due to researchers' personal assumptions, values, and affective states are avoided through regular and in-depth debrief meetings with the research supervisor. Data are analyzed using multiple lenses (i.e. IPO theory and TREO theory) to consider possible competing hypotheses and rival conclusions.

We used a standardized interview protocol and a validated questionnaire in data collection and therefore increased reliability. We raised clear research questions as shown in the introduction section, and the study design was congruent with them. For example, we conducted interviews to explore factors that influence academic research project teams' effectiveness. The interview is an effective qualitative technique to access participants' relativist perspectives and understand their perception of key events (Yin, 2018b). Another example is that we used the TREO theory to develop deductive codes and made a comparison between two cases. This procedure fits with our second research question which inquires how can team role theory contribute to the effectiveness of academic research project teams. We collected data by conducting interviews and questionnaire surveys with multiple members who have various status in the two academic research teams. This design allows us to collect data across a large range of sources,

and thus enhance the reliability. During and after the data collection stage, we had regular debrief meetings and peer reviews to ensure the quality of data and avoid bias. We as researchers are outsiders to the two teams that we studied. It is necessary to clarify the researcher's role and status because a neutral attitude towards the cases can provide more convincible analysis. To make sure our study has a strong connectedness to theories, we made explicit description and discussion on theories that we used in the literature review section.

Internal validity of this study is ensured by using triangulation among complementary methods and data sources to reach converging conclusions. Our data was collected through multiple sources (i.e. interviews and questionnaire surveys) to enhance its credibility. And both inductive codes from data and deductive codes from the literature were developed and compared. Our data can fit in the categories of prior and emerging theories. For example, the inductive code "multiple investigators" from data collected can be sorted into the deductive code "project composition" from the IPO theory. In addition, we also identified topics that are not received enough attention in extant theory such as "authorship" and "autonomy." By adopting two theories in data analysis, we made careful consideration of different explanations.

We used the cross-case analysis to increase the external validity of this study. Important features of each case, such as team size, location, and research field, are provided in the method section and therefore permit adequate comparisons with other academic research project teams. By analyzing data collected in interviews, we also provide a rich and in-depth description of the two cases, which allows readers to assess the potential transferability to other contexts. In addition, our findings showed support evidence for prior theories (i.e. features that lead to challenges in team science) and provided a complement to knowledge and concepts as well. These three points contribute to the transferability of this study. However, we also aware that our sample teams were both working on research projects in health science. Therefore, our study results may have limitations in terms of generalizing to other academic fields (i.e. social science and natural science).

In terms of utilization, this study shows application value as it addresses real-world challenges of academic research project teams and aims at exploring solutions by adapting theories from other fields such as project management and team role theory. We used a number of paragraphs in the introduction section to provide a detailed description and analysis of the complex nature of academic research and the challenges faced by academic research project teams. We developed this study based on two academic research project teams' real experience; therefore, our findings can raise resonance with potential readers. Our adaptation of the IPO theory and the TREO theory in studying academic research project teams provides a new approach in the science of team science (SciTS) study and contributes to extant knowledge.

Limitations

There are five major limitations. First, we had only a small number of teams and of team members participated in our study. This limitation had negative effects on the richness of our data and led to the result that the research questions were not fully answered. However, we had PIs, who usually have a better understanding of the entire project, participated in data collection making our data trust-worthy.

The second limitation is that we only used two types of data collection methods in this study, interviews and surveys. Using additional methods may be helpful. For example, looking into documents such as grant proposals may provide useful information to better understand the nature of the teams and the roles of team members. We may also observe a typical day of a team member or team activities such as team meetings to collect data.

The third limitation is that we had teams in the health science field only. As we discussed in the previous sections, academic research project teams in different disciplines may have different features and face different challenges. Although we believe that there are common issues across disciplines, a study comparing teams in different disciplines may provide richer results.

The fourth limitation results from the critical incidents technique that we used in interviews. Events shared by participants were retrospective and unavoidable being subjective (Chell, 2004). It is

difficult to get an absolute narrative description of these events, but we tried to reduce the effect of bias by interviewing more than one member of each team.

The fifth limitation is related to the design and exploratory nature of the research. An in-depth case study may help us better understand an academic research project in its full process (Yin, 2018c).

Conclusion

Our study addressed two research questions focusing on academic research project teams. We used both literature review and empirical study to identify factors which influence academic research project teams' effectiveness. We picked the input-process-output (IPO) theory to help us understand how academic research project teams work. The IPO theory has been widely used in research on team effectiveness, and it is believed to be a useful organizing heuristic to study team effectiveness (Cooke & Hilton, 2015c; Kozlowski & Ilgen, 2006). Therefore, we think it is applicable to use the IPO theory in this exploratory study. We further used the team role experience and orientation (TREO) theory, in particular, to see how academic research project teams' effectiveness can be enhanced. Team member roles have been recognized as an important factor in team processes that are closely related to effectiveness in academic research project teams (Cooke & Hilton, 2015c). The TREO theory is very useful in understanding team members' role predispositions and interactions which can influence team effectiveness (Mathieu, Tannenbaum, Donsbach, & Alliger, 2014; Mathieu et al., 2015). Considering that the connection of team member roles and team effectiveness is also our study of interest in this paper, we think using the TREO theory is reasonable. Our results show that the IPO theory can provide an overarching structure to better understand the function of academic research project teams. Another finding is that the TREO theory can be adapted to this specific context, while new roles addressing the features of academic research project teams are needed. Our study is imperfect due to several limitations, but we believe that research on academic research project teams was and still is important.

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APPENDIX 1 - ETHICS CERTIFICATE

File Number: 08-17-23 **Date (mm/dd/yyyy):** 01/23/2018

Université d'Ottawa University of Ottawa
Bureau d'éthique et d'intégrité de la recherche Office of Research Ethics and Integrity

Certificate of Ethics Approval

Social Science and Humanities REB

Principal Investigator / Supervisor / Co-investigator(s) / Student(s)

First Name	Last Name	Affiliation	Role
François	Chiocchio	School of Management / School of	Principal Investigator
Xinxin	Zhang	School of Management / School of	Co-investigator

File Number: 08-17-23

Type of Project: Professor

Title: Managing Scientific Research Projects: A Research on Collaboration and Project Management

Approval Date (mm/dd/yyyy)	Expiry Date (mm/dd/yyyy)	Approval Type
01/23/2018	01/22/2019	Initial

Special Conditions / Comments:
N/A

550, rue Cumberland 550 Cumberland Street
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(613) 562-5387 • Téléc./Fax (613) 562-5338
http://www.recherche.uottawa.ca/deontologie/ http://www.research.uottawa.ca/ethics/index.html

File Number: 08-17-23 **Date (mm/dd/yyyy):** 01/23/2018

Université d'Ottawa University of Ottawa
Bureau d'éthique et d'intégrité de la recherche Office of Research Ethics and Integrity

This is to confirm that the University of Ottawa Research Ethics Board identified above, which operates in accordance with the Tri-Council Policy Statement and other applicable laws and regulations in Ontario, has examined and approved the application for ethical approval for the above named research project as of the Ethics Approval Date indicated for the period above and subject to the conditions listed the section above entitled "Special Conditions / Comments".

During the course of the study the protocol may not be modified without prior written approval from the REB except when necessary to remove participants from immediate endangerment or when the modification(s) pertain to only administrative or logistical components of the study (e.g. change of telephone number). Investigators must also promptly alert the REB of any changes which increase the risk to participant(s), any changes which considerably affect the conduct of the project, all unanticipated and harmful events that occur, and new information that may negatively affect the conduct of the project and safety of the participant(s). Modifications to the project, information/consent documentation, and/or recruitment documentation, should be submitted to this office for approval using the "Modification to research project" form available at: http://recherche.uottawa.ca/deontologie/submissions-and-reviews.

Please submit an annual status report to the Protocol Officer 4 weeks before the above-referenced expiry date to either close the file or request a renewal of ethics approval. This document can be found at: http://recherche.uottawa.ca/deontologie/submissions-and-reviews.

If you have any questions, please do not hesitate to contact the Ethics Office at extension 5387 or by e-mail at: ethics@uOttawa.ca.

Signature here was hidden for privacy protection

Germain Zongo
Protocol Officer for Research Ethics
For Dr. Barbara Graves, Chair of the Social Sciences and Humanities REB

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APPENDIX 2 - CONSENT FORM

CONSENT FORM

Title of the study
Managing Scientific Research Projects: A Research on Collaboration and Project Management

Principal investigator
Professor François Chiocchio, Telfer School of Management, 613.562.5800 ext 8840, francois.chiocchio@telfer.uottawa.ca

Co-Investigator
Xinxin Zhang, Telfer School of Management, 613.255.3966, xzhan269@uottawa.ca

Source of Funding
The office of the Vice-Rector Research and the Telfer School of Management.

Invitation to Participate
I am invited to participate in the abovementioned research study conducted by Professor François Chiocchio

Purpose of the Study
This study aims at gaining a better understanding of team and project dynamics at play in science teams in order to improve theory and practice relevant to innovation and scientific discovery by answering the following overall question "What are the factors relevant to teams and the management of research projects that help or hinder innovation and scientific discovery". Part of the data collected in this study will be used by Xinxin Zhang in her thesis project as a part of the abovementioned research study conducted by Professor François Chiocchio.

Participation
I am invited to participate in the following <u>two</u> activities

1. Answer a 20-minute secured electronic questionnaire. Questions are simple (*On my team we know 'who' does 'what'*) and easy to answer (i.e., 1 = Completely disagree; 7 = Completely agree). I will be able to use any computer, tablet or phone to answer my questionnaire.
2. Take part on a first come first serve basis in a 40-minute confidential face-to-face or phone interview. Questions researchers will ask have to do with my experiences as a

team member in an academic research project. The interview will be recorded for analysis purposes

Confidentiality and anonymity

I have received assurance from the researchers that the information I will provide will remain strictly confidential. I will use a numerical code instead of my name. Any information that may identify me such as name, email, phone number will be discarded. Researchers will be the only people aware of and have access to the link between my answers, my name and my numerical code; they will not share this information. My specific answers will not be shared. The university and/or other people on my research team will not be informed of my participation or of my answers. Results will be published in research reports and scientific peer-reviewed journals but without mentioning sources. For example, numerical results from the survey will be summarized across participants (e.g., group means) to ensure my contribution will remain confidential and anonymous. Similarly, written portions of my interview (e.g., quotes) may be published if they represent of an important topic; but my identity will never be disclosed because the quotations will be identified by a code or generically such as 'a graduate student'. Finally, general conclusions on how to improve teamwork, collaboration and the management of research projects will be shared with the research community to help researchers increase chances of successful completion of research projects and in order to improve support to faculty.

Risks

My participation in this study will entail that I volunteer personal information such as my name, email address and/or my phone number to receive the link for the consent form and questionnaire, and to set-up the interview. By doing so, my personal information such as my name, email address and/or my phone number will be known by the principal investigator and the co-investigator so they can contact me. But personal information will never be included as data for this research project. Part of the data for this study will be collected using a secured web platform. In order to minimize the risk of security breaches and to help ensure my confidentiality I am recommend using standard safety measures such as signing out of my account, closing my browser and locking my screen or device when I am no longer using them or when I have completed the study. I acknowledge that choosing work place as the location of interview may lead to difficulty in protecting my anonymity.

Benefits

The interview and the survey will allow me to reflect on how teamwork and collaboration impacts research project teams, and how the management of a research project influences the process of innovation and scientific discovery. In addition, once the study is over, you will receive tailored feedback that will help you improve teamwork and research project management relevant for current and future research projects.

Conservation of data

My answers will be kept in password-protected electronic files on password-protected computers/servers located in locked offices. Only the researchers will have the passwords and/or the keys. After a maximum of 5 years from the end of the study, the electronic files will be permanently destroyed using ShredIt™ or similar technology. If I choose to withdraw from the study, my data will be immediately permanently removed from the database.

Compensation
There is no compensation for taking part in this study.

Voluntary Participation
I am under no obligation to participate. If I choose to participate, I can withdraw from the study at any time and/or refuse to answer any questions, without suffering any negative consequences. If I choose to withdraw, I can ask that all data gathered until the time of withdrawal be permanently deleted.

If I have any questions regarding the ethical conduct of this study, I may contact the Protocol Officer for Ethics in Research, University of Ottawa, Tabaret Hall, 550 Cumberland Street, Room 154, Ottawa, ON K1N 6N5
Tel.: (613) 562-5387
Email: ethics@uottawa.ca

You can get a PDF version of this form by clicking here.

- ○ By clicking here I indicate that I have read this consent form, that all my questions were answered in written or verbal communications with the researchers, that I agree to participate in the study described above, and that I want to be directed to the questionnaire.
- ○ By clicking here I indicate that I prefer to not participate in this study and that I want leave this site without prejudice.

APPENDIX 3 - INTERVIEW PROTOCOL

[redacted]

GREETINGS

Mandate

My name is (insert name here) and I am conducting a study on research teams involved in research projects in universities.

Goal of the interview

I am conducting interviews with various scientists (i.e., academics, research professionals and assistants, graduate students). I will ask you to recount different important events / stories that you experienced. This is not an evaluation, I just want to benefit from your experience.

Interview process

The interview will take approximately 40 minutes. In order to fully understand all the elements you bring up and to facilitate the synthesis of the information thereafter, I will take notes during our interview and it will be recorded. I want to assure you that the content of this interview will remain anonymous and the information collected will remain strictly confidential. Your answers will never be associated with your name. Do you have any questions before we begin the interview?

INTRODUCTION

Explanation of critical incidents

What we are trying to gather are what we call "critical incidents". A critical incident is a short story describing an event that reveals important behaviours that are either very effective or rather ineffective. Specifically, we are looking for examples of observable behaviours or situations that would help us understand what makes research teams work well or not.

We want examples of behaviours or situations that are both positive and negative because it is important to have a full view of what factors may have influence on research team.

In concrete terms, we would like you to tell us a story, an important event that took place as part of your work in a research team. This event would have brought either something happy, a good ending, a success or, conversely, something less happy, an unfortunate outcome, a failure.

MAIN QUESTIONS

Critical incidents

- Could you describe to us the most recent situation in which you demonstrated (or someone you observed has demonstrated) a behaviour which was helpful to the functioning of the research team?

Could you describe to us the most recent situation in which you demonstrated (or someone you observed has demonstrated) a behaviour which was harmful to the functioning of the research team?

Probing questions

The technique of critical incidents must allow to collect stories that are complete. A story is complete when it allows us to understand the context, the actions, the justification of actions and the outcome, that is to say, what results from the actions undertaken. Few people know how to tell a story as they are seen in a film and therefore they find it difficult to respond appropriately with all of these elements. As such, probing questions are necessary as a function of the situation and according to the style of the interviewee.

With a person who talks too much

Context

- If you had to identify a single trigger in this situation, what would it be?
- If you were to summarize the situation, what would be the elements that stand out?

Actions

- Could you summarize your role in this situation in one sentence?
- If I understand correctly, what you did was to [...]?

Justifications

- If I summarize, you did this behaviour for the purpose of [...]?
- You did several things. If you had to name a single reason that would explain your actions, what would it be?

Outcomes

- If I understand correctly, that behaviour had a significant and important impact?
- This event had important repercussions because [...]
- What was the most important result of your actions?

With a person who does not speak enough

Context

- The "5 W": Who, What, When, Where, Why
- In what context was this behaviour adopted?
- Could you give me more details on [...]?
- Who were the people involved in [...]?
- What was your concern at that time?

Actions

- What did you do to resolve the situation?
- What is the behaviour that was adopted during this event?
- Concretely, what action did you take?

Justifications

- What prompted you to act this way during the event?
- What was your intention when you did it?
- What was the purpose of this action?
- What problem this action was aiming at?

Outcome

- What was the outcome of the situation?
- Was the result of the event happy or unhappy? A success or a failure?
- Has the behaviour been effective or ineffective?
- Finally, what did your actions changed?
- What was the impact of your actions on the problem?

CLOSING

In your opinion, are there other important elements related to barriers and/or levers to the success of your research team and to your work context that we have not covered? Do you have any questions or comments regarding our interview?

ACKNOWLEDGMENTS

Thank you very much for your participation. Your testimony will be very useful to us.

APPENDIX 4 - SURVEY QUESTIONS

Roles- TREO

This question refers to the role or roles you are playing in your project team.

Read the description of each role. For each role you have played, drag its description in the box to the right. If you played more than one role, rank order the roles according to the amount of time you spent in that role, starting with the role you spent the most time on.

If you did not play any of these roles, you have nothing to do and can move on to the next question.

Items	
TEAM BUILDER. Helps establish norms, support decisions, and maintains a positive work atmosphere within the team, calms members when they are stressed, and motivates them when they are down.	This is a role I have played in the last six months
ORGANIZER. Structures what the team is doing, keeps track of accomplishments and how the team is progressing relative to goals and timelines. INNOVATOR. Regularly generates new and creative ideas, strategies, and approaches for how the team can handle various situations and challenges, often offers original and imaginative suggestions. CHALLENGER. Pushes the team to explore all aspects of a situation and to considers alternative assumptions, explanations, and solutions, often asks "why," comfortable debating and critiquing. CONNECTOR. Helps bridge and connect the team with people, groups, or other stakeholders outside of the team, ensures good working relationships between the team and "outsiders." DOER. Willingly takes on work and gets things done, can be counted on to complete work, meet deadlines, and take on tasks to ensure the team's success.	

APPENDIX 5 - DETAILED DESCRIPTION OF ALL EVENTS

(+) means positive events; (-) means negative events

<table>
<tr><td colspan="6">Interview with 1001 from team A</td></tr>
<tr><td colspan="6">Event 1: critical literature review (+)</td></tr>
<tr><td>Stage</td><td>“One of the first steps”/
After the project was funded</td><td rowspan="3">Behaviours</td><td rowspan="3">Positive
1. Reviewed and critiqued the literature in a small group and gave feedback.
2. Team members took this work seriously.
3. Team members were “engaging”.
4. PI met most team members face to face individually/in a small group.
5. Infrequent telephone and teleconferences.
6. PI asked for group meetings and RA organized them.
7. Positively include people in the feedback and ask for opinions.

Negative
1. The whole team never met completely.</td><td rowspan="3">Impacts</td><td rowspan="3">Positive
1. Contribute to knowledge.
2. Get heard by the practitioner in charge.
3. Team building
4. A follow-up project.

Negative
N/A</td></tr>
<tr><td>Challenges/barriers</td><td>1. Need to think differently from current practice.
2. This project is in four locations
3. Members were unstable (dropped out and joined in)
4. Have 2 ethics to go through.
5. Four investigators using different approaches to do research.</td></tr>
<tr><td>levers</td><td>1. PI knew many team members before (exist “links”).
2. “Have something concrete”.</td></tr>
</table>

<table>
<tr><td colspan="6">Event 2: Difficulties in management (-)</td></tr>
<tr><td>Stage</td><td>Initial months</td><td rowspan="3">Behaviours</td><td rowspan="3">Positive:
1. PI did “goofy things” in telephone meetings to ice-breaking.
2. “Clinical people involved with administering” decided the best person to be involved in the project.

Negative:
1. PI felt nervous about being slower at the timeline.</td><td rowspan="3">Impacts</td><td rowspan="3">Positive:
N/A

Neutral:
1. The PI needed someone to talk to about the project.
2. Need techniques on organizing initial meetings.
3. Need knowledge on establish relationships and keep them healthy.

Negative:
1. Discouraged team members (PI perceived).</td></tr>
<tr><td>Challenges/barriers</td><td>1. Uncertainty on the result of applying for the grant
2. Need to organize a large-scale meeting involving influential practitioners.
3. Telephone meetings were difficult to organize.</td></tr>
<tr><td>Levers</td><td>1. Avoided wasting money.</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td colspan="6">Interview with 1002 from team A</td></tr>
<tr><td colspan="6">Event 3: Being always included in the team (+)</td></tr>
<tr><td>Stage</td><td>“The culmination” of the project</td><td>Behaviours</td><td>Positive:</td><td>Impacts:</td><td>Positive:</td></tr>
</table>

Challenges/barriers	1. Different expertise leads to difficulty in involvement. 2. The investigator hasn't worked with other members except for PI. 3. It's difficult to fit into a project in a discipline other than one's own discipline. 4. Being disconnected in previous experience on other projects.		1. Had extensive input in the paper and was valued by other team members. 2. The team met by phone, teleconference or email. 3. "Everybody contributes". 4. The paper was drafted by PI and two other people and then get the comment from the rest of the team members. 5. Talked to PI "one on one".		1. Became the fourth co-author. 2. This event was important to paper publishing. 3. "It certainly validates the research." 4. It will be "positive for everybody" if the paper gets published. 5. Contributed to policies and further research. 6. It's "important to be involved with practitioners".
Levers	1. PI was good at "being very inclusive". 2. Was able to see PI in person. 3. Had a good relationship with PI.		Negative: N/A		Negative: N/A
Event 4: Unperfect telephone conversations (-)					
Stage	Middle stage	Behaviours:	Positive: 1. PI invited everybody to meetings. 5. PI asked "a silly question" for ice-breaking and help relax. Negative:	Impacts:	Positive: 1. Despite having some problems, the project functioned well. Neutral:
Challenges/barriers	1. Had the risk of being ignored. 2. "Can't really participate" in teleconferences. 3. The topic of the meeting wasn't "conducive to everybody participating".				

	4. "Challenge of multidisciplinary projects". 5. It was difficult to network with other team members.		1. Less participation 2. Had nothing to say in some meetings. 3. Once raised a suggestion during a meeting but was ignored.		1. Wasn't discouraged. Negative: 1. Team activities could not involve everybody at the same level.
Levers	1. Team members were respectful to others' views. 2. Knew "what's going on".				
Interview with 1003 from team A					
Event 5: Effective communication (+)					
Stage	(All through the project)		Positive: 1. "Do all the groundwork and keep things on track and moving". 2. Had conversations with team leads. 3. Team members could "jump onto it as a team" when facing difficulties. 4. Watched and lead the logistics in ethics applications and recruitment. 5. Scheduled meetings and heard from team members.		Positive: 1. Kept the project moving. 2. "Make sure everybody is on the same page". 3. Team members felt appreciated and involved. 4. Good communication helped to "keep the team strong".
Challenges/ barriers	1. The project happened in different cities. 2. Sub-projects worked on different paces and speeds. 3. The progress was delayed due to difficult ethics applications. 4. Team members worked "at different stages". 5. Professionals were very busy. 6. The big project needs a lot of "logistical coordination".	Behaviours		Impacts	

	7. Ethics board tended to answer non-professionals slowly. 8. The ethics are a "wild challenge".		6. Made sure other team leads "feel appreciated" and "their time is valued". 7. Provided autonomy for choosing to be a team leader. 8. "Set up opportunities for conversations". 9. Either PI or RA attended bigger team meetings. 10. Had a constant conversation with PI to get information updated. Negative: N/A		5. Autonomy promoted awareness of responsibility. Negative: N/A
Levers	1. Team leads were able to "communicate effectively". 2. Team members were "very responsive". 3. Team members could reach out for help. 4. Team leads played a "very active role". 5. Team members have a "willingness to overcome the obstacles".				
Interview with 1301 from team B					
Event 6: A group retreat and a successful hiring (+)					
Stage	Near the end of a previous project and "just submitted a big grant" for a new project	Behaviours	Positive: 1. Had a meeting on "the scope of all the work" need to do. 2. Research manager helped to clarify the skills needed and tasks.	Impacts	Positive: 1. The team "come up with a plan together". 2. Hired the right person and can contribute to result.
Challenges/barriers	1. A new role may have difficulty to fit in the team. 2. Heavy task burden to current team members.				

	3. Need to hire the right person. 4. Need to keep writing papers as the priority.		3. Research manager helped to keep the meeting on track. Negative: N/A		3. Team members have really grown and benefited. 4. Kept the team "on focus". Negative: N/A
Levers	1. The research manager worked on both "research related responsibilities "and "organizational stuff".				
Event 7: Hired a person (person A) who cannot fit in the team (-)					
Stage	A similar time with event 6	Behaviours	Positive: 2. Had a meeting trying to solve the problem. Negative: 1. Made a wrong decision of hiring the person. 2. Tried to solve the problem by having a "three-way discussion" instead of "one-on-one". 3. PI was "kind of vague" about expressing expectations. 4. Person A "didn't come forward early enough" to ask for help. 5. Someone in the team made it "black or white" (without	Impacts	Positive: N/A Neutral: 1. The team moved on "once that person left". Negative: 1. "People became frustrated in different ways with this person". 2. Person A ended up leaving the team. 3. This result could be harmful because the team may
Challenges/barriers	1. Person A had energy and experience in a different area. 2. The event happened during "a very busy time of preparing a new grant". 3. PI needed techniques to handle interpersonal problems. 4. The team was "constrained by human resource policies". 5. PI felt "fatigue" of taking the role of a scientist and a manager at the same time. 6. PI felt lack of "confidence as a leader".				

Levers	N/A		attempting to solve the problem). 6. It was too late to find the mismatch. 7. Other members complained to PI. 8. The team "ran out of options for how to help [the person] fit".		not have a reflection on this event.
Interview with 1303 from team B					
Event 8: Received help from another team member (person B) (+)					
Stage	"The end stage"	Behaviours	Positive: 1. The content of the poster was written by 1303 and reviewed by others 2. Person B offered help to improve the design of the poster. 3. Person B sent back the poster instead of spreading it to the whole team. 4. 1303 wanted the team to acknowledge the improvement on the poster made by Person B. Negative:	Impacts	Positive: 1. Person B can be "more inclined to ask […] for similar help" to 1303. 2. Hopefully, there can be open communication between 1303 and Person B. 3. Built trust. 4. Created a good poster for project result presentation. Negative:
Challenges/barriers	1. The team "have multiple projects always on the go". 2. Person B was new to the team				
Levers	1. Team members had enough autonomy to make decisions on their tasks.				

			1. Person B's effort in this event "wasn't really acknowledged by the whole team".		N/A
Event 9: A new member's work (Person A) was not valued (-)					
Stage	(Not mentioned)	Behaviours	Positive: 1. 1303 talked with Person A for debriefing. 2. 1303 showed the willingness to support if the person needed and shared tips on interpersonal issues. Negative: 1. The completed work of person A was asked to re-do by others without obvious reasons. 2. This situation was not communicating with Person A. 3. "Nobody spoke about it openly". 4. Person A and 1303 kept their talking a secret from supervisors. 5. Other members didn't show much care about the situation. 6. Person A "ended up doing a lot of admin work" which she was over-qualified.	Impacts	Positive: 1. Person A's left can be a good thing to both the team and the person. Negative: 2. The unfitness of the person led to the progress of projects slow down.
Challenges/barriers	1. The team "never really go back" for reflection. 2. 1303 didn't get a lot of feedback 3. The team didn't have enough open communications. 4. The team lacked skills in managing individual task failure. 5. Person A's role wasn't very clear. 6. The team was busy and stressed during that time. 7. The supervisor (PI) "was so stressed at that time".				
Levers	1. The team had very regular meetings and good communication. 2. The supervisor (PI) was very "hands-on".				

			7. Person A acted passively to get assigned tasks only.		

APPENDIX 6 - COMPARISON OF TEAM A AND B USING IPO THEORY

IPO theory		Codes	Sub-codes	Common to A and B	Unique to A	Unique to B
Inputs	Organization level	Policy	--	--	"[…] They won't give you more money, but they say you can stretch your money into the following year if you want." <1001>	"We're so constrained by human resource policies, […] that human resource burden can prevent us actually from doing well as a group." <1301>
	Team level	Composition	PI; team lead	"She's very hands-on" <1303>	"Very accessible person. Very generous in her time." <1002>	"She doesn't even see that you might want something very specific." <1303>
			Post-doc fellow	--	N/A	"[…] Because I started as a research associate, I think a lot of my role is kind of blurred." <1303>
			RA	--	"I kind of do all the groundwork and […] keep things on track, keep things moving." <1002>	N/A
			RM	--	N/A	"She can have some research related responsibilities […] and […] a lot of the

						organizational stuff." <1301>
		Funds	--	--	"You're not burning through money that maybe you don't know how to use yet." <1001>	"We were going to spend […] a good chunk of our team funds on something that felt a bit new and scary." <1301>
		Geography	--	"We're doing a project that involves work in a number of different cities across the province." <1003> "There are teams in other provinces" <1301>	"The project is happening in four locations." <1001>	"Our core leadership team here is […] about five or six people." <1301>
		Hierarchy	--	--	"If it's one of the professionals […] they are often able to get a quicker response (e.g. from an ethics board) […]." <1003>	"Like you're my supervisor; I have to go with what you tell me" <1303>
		History	--	"While there were interconnections of people, there was trust already and we could build on that." <1001>	"I knew a number of people [in this team] relatively well already." <1001>	"I felt […] a sense of obligation to other people who I knew […] who might be a nice fit for the team." <1301>

		Member change	Hiring	--	"They were making the decision about whether they were the best person to be involved with the project or whether someone they supervised […]" <1001>	"So we decided we needed a certain team member with certain skills to help us accomplish the work, and even though it wasn't the usual team member […]" <1301>
			Drop out	"People have moved on to new jobs or delegated to someone else." <1001>	"The person that was originally involved with the project moved on to something else." <1001>	"She ended up leaving our team." <1301>
			New members	"There are people that we're working with that are […] relatively new to the project." <1001>	"I've never met them face to face." <1001>	"That person's been able to really contribute for everyone." <1301>
		Mismatch	--	--	"They were making the decision about whether they were the best person to be involved with the project or whether someone they supervised […]" <1001>	"That person didn't necessarily have the research skills we needed" <1301>
		Project composition	Multidisciplinary	--	"My area of study is quite different than theirs." <1002>	N/A
			Multiple investigators	--	"There were four investigators and they	N/A

					did not know each other." <1001>	
			Multiple projects	"There's projects in all stages" <1303>	"[These projects are] at different paces and different speeds." <1002>	"We have multiple projects always on the go." <1303>
		Size	--	--	"Between 13 and 20 people involved with the project." <1001>	"Group of six, our research group." <1301>
Mediators	Processes	Authorship	--	--	"How do you recognize the work of everyone in these large teams?" <1001>	N/A
		Autonomy	--	"We asked them their opinions on who would be a good fit and if they were interested." <1003>	"We gave them the opportunity to express if they wanted a team lead role." <1003>	"[…] We are giving enough autonomy to make decisions like that [do certain tasks]." <1303>
		Busy	--	"Everybody's really, really busy" <1001>	"Everybody's really, really busy" <1001>	"We were writing two grants at the same time too, which made everybody quite stressed" <1303>
		Collaboration	Blur function	--	N/A	"[…] Her role wasn't very clear." <1303>
			Concrete work	--	"I think […] having something concrete that was circulating [...] did	"It's hard for researchers to write [papers], right? We're

					make a difference." <1001>	busy. We get distracted with our other tasks. We're not always that good at writing." <1301>
			Connections	--	"It's important to be involved with practitioners" <1002>	N/A
			Distract	--	N/A	"It had been easy for the new project to take over and those things [in the previous project] to never get done." <1301>
			Involve	--	"It's just like everyone's included." <1001>	N/A
			Plan	--	N/A	"We were able to come up with a plan together" <1301>
			Provide help	"People have been extremely helpful" <1001>	"[…] She's really helped us figure out what the ethics procedure we need to go through […]." <1001>	"Bringing someone in who has a very different perspective can make your work richer" <1301>
			Social loafing	--	"There are two things that can go wrong […] the other one is that you have people who are quite visibly not contributing." <1001>	N/A

		Communication	General	"We have very regular meetings and we have good communication […]" <1303>	"We've had really, really great experience with communication across the city" <1003>	"I think I could have been clearer about my expectations […]" <1301>
			Face to face	"[…] Less than ideal, not having a face to face meeting initially" <1001>	"I had met most of the people face to face" <1001>	"She said to me she wanted to initiate a meeting with the supervisor and the manager to share how she felt" <1303>
			Feedbacks	--	"We really were asking for people's opinions and really including them in the feedback" <1001>	"I don't get a lot of feedback on how I'm doing." <1303>
			One on one	"I think it was important that I had access to her, one on one." <1002>	"I think it was important that I had access to her, one on one." <1002>	"She didn't have that one-on-one time." <1303>
			Reflection	--	"[…] What I'm seeing as being potentially helpful for me is some sort of coaching around that or somebody to reflect with" <1001>	"I think we could have done more reflection [on such event]." <1301>
			Team meeting	"We schedule quarterly meetings with all of the different teams to make	"Our initial telephone meetings difficult because so many people	"We met together to […] get a sense of what the scope of all

				sure everybody knows what's going on." <1003>	didn't know each other." <1001>	the work we have to do is" <1301>
			Virtual	--	"We meet either by phone, teleconference or through email through the major paper […]" <1003>	N/A
		Interpersonal		"I thought that was very respectful too […]" <1303>	"Everybody was respectful of everybody else's views." <1003>	"[…] People became frustrated in different ways with this person, myself included." <1301>
		Relationships	Problems	"Some help with determining […] how best to establish those relationships and keep them healthy." <1001>	"Some help with determining […] how best to establish those relationships and keep them healthy." <1001>	"We didn't really understand that fundamentally going into the relationship" <1301>
			Solve problems	--	N/A	"We didn't necessarily handle it the best way for her and for our team." <1301>
	States	Commitment	--	"People have […] shown a lot of commitment to the project" <1001>	"We've been able to jump onto it as a team and work together to get it moving to the next step." <1003>	"I thought that was very nice of him to offer like that, as a team member, to be a real team member." <1303>

		Confidence	--	"Sometimes when any lack of confidence about those collide, it can be hard to navigate a team, to lead a team." <1301>	"I get quite nervous about, you know, whether I'm doing the right thing or not." <1001>	"Even though I knew what the facts were of what we needed, my concerns were […] I had to take a chance that this was going to work out." <1301>
		Passion	--	--	"[…] People have been very active." <1001>	"She was kind of […] kept waiting for them to give her a project" <1303>
		Pressure	--	"I think I felt a lot of pressure." <1301>	"I think something that might be helpful would be someone to talk to […]" <1001>	"[Because] other people's dissatisfaction, […] things weren't getting done, […] this person was meeting the job requirements; but also we really had to just keep moving." <1301>
		Trust	--	--	"[…] There was trust already and we could build on that." <1001>	"I […] kind of wondered […] how safe was it for her to speak up?" <1303>
Outputs	Team effectiveness	Publish	--	"It will be published somewhere hopefully someplace that	"The project was to […] either publish, well, publish paper and also recommendations […]" <1002>	"It (the paper) is under review right now to be published." <1303>

				people will see it." <1001>		
		Research contribution	--	--	"[…] We have suggested a new way of looking at post-discharge [the research topic]." <1001>	N/A
	Viability	Future project	--	"We were looking to potentially start a new project" <1301>	"[…] We're going on to do a related project." <1001>	"[…] We were looking to potentially start a new project" <1301>
		Grow	--	--	N/A	"I think everyone has really grown." <1301> "[in some circumstances] I haven't gotten that feedback, and it would probably help me grow too." <1303>

APPENDIX 7 - COMPARISON OF TEAM A AND B USING TREO THEORY

TREO theory	Codes	Common to A and B	Unique to A	Unique to B
Organizer	Team meeting	--	"I'm the one that has asked [to have meetings]. I have a wonderful research assistant […] who organizes it all." <1001>	"There was one team member in particular who helped to really make us clear on what skills we needed to meet those tasks […]" <1301>
Doer	Concrete work	"You can see the progress happening and that everyone in the team is getting those updates." <1003>	"The principal researcher with two other people […] crafted a major paper together, and they asked the rest of the team […] to comment." <1002>	"Near our wrap-up phase […] we really had […] papers that needed to be written, [and] other dissemination outputs." <1301>
Challenger	Concrete work New members	--	"I think they were part of the group because they felt that current practice needed to change but it was still quite challenging. […] I was concerned that it just might be too different from current practice for them to support." <1001>	"Just that sometimes bringing someone in who has a very different perspective can make your work richer." <1301>
Innovator	Provide help New members	--	"She's really helped us figure out what the ethics procedure we need to go through" <1001>	"[…] Even though it wasn't the usual team member that we would include in our team, that really helped us to galvanize together around the evidence of what we needed." <1301>
Team builder	Involve	--	"The project leader […] was really good about being very inclusive." <1002>	"We did try to have a meeting to understand a little bit of what was going

				on with that person," <1301>
Connector	Hierarchy Policy	--	"If it's one of the professionals […] they are often able to get a quicker response (e.g. from an ethics board) […]." <1003>	"We're so constrained by human resource policies, […] that human resource burden can prevent us actually from doing well as a group." [1301]