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# Team Adaptation and Resilience: What Do We Know and What Can Be Applied to Long-Duration Isolated, Confined, and Extreme Contexts

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# Contents

## Abstract

Given that future space crews of long-duration exploration missions will have to be more autonomous and handle any disruptions that they may face with less assistance from ground personnel than has been the case with prior space missions, the topics of team adaptation and resilience are becoming more salient for mission effectiveness. Accordingly, with this project, we sought out to gain a deeper understanding of the team adaptation and resilience nomological networks. To accomplish this goal, we performed an extensive literature review focused, in particular, on factors that give rise to team adaptation and resilience; as well as the resulting by-products of these two related (but distinct) constructs. Additionally, we conducted nine 1-hour interviews of various NASA personnel to understand their experiences regarding team adaptation and resilience and to gain their insights in regards to how these constructs will likely be different within future long-duration missions. Upon integrating the lessons learned from each of these parts of the project, we outline our recommendations for future missions as well as some research projects that should be explored in order to better understand team adaptation and resilience.

## Executive Summary

Given the prevalent use of teams as well as the dynamic nature of many organizational contexts, the topic of team adaptation and resilience has gained in prominence over the past decade. As such, there has been a great deal of research attention given to these two constructs. Interestingly, team adaptation and resilience have at times been discussed within different literature streams. Accordingly, within this project, our initial undertaking was to systematically review these two disparate literature streams which have addressed team adaptation and resilience. In doing so, we hoped to address our first goal: to clear up the construct confusion regarding team adaptation and team resilience by introducing a definitional framework that delineates the similarities and possibly more important, the features that distinguish these two related but distinct constructs. In particular, we leveraged the input-mediator-outcome (IMO) framework that is central within the organizational team literature and within this framework, we view team adaptation as a process variable that we defined as:

> *Adjustments to relevant team processes (i.e. action, interpersonal, transition) in response to the disruption or trigger giving rise to the need for adaptation.*

Likewise, we suggest that various team input variables, including the team's own inherent capacity to adapt (i.e. team adaptability), will serve as antecedents to team adaptation processes. As such, this section of the project represents our second primary objective: to understand the features that assist in the development of team adaptation. Finally, team adaptation is important as it can lead to various consequences such as team performance and team member affective reactions (i.e. team adaptive outcomes) and we reviewed these relationships extensively to better understand the relationship that team adaptation has with various team performance outcomes.

Additionally, given that team adaptation and resilience have primarily developed within distinct literature streams, we conducted a similar review of the team resilience literature. Beyond gaining a better understanding of this literature by conducting this literature review, we were also able to come up with an approach for integrating team resilience into the team adaptation nomological network. In particular, we viewed team resilience as an emergent state construct which is impacted by a team's ability to overcome disruptions (i.e. team adaptation).

However, given the importance of team adaptation and resilience within NASA's current and future space missions, we wanted to highlight the work conducted by a smaller number of researchers who have conducted studies examining team adaptation and resilience within analogous settings. As such, we also reviewed these studies to understand how both team adaptation and resilience are formed and their resulting impacts on team dynamics and performance within settings such as MARS500, NEEMO, HERA, HI-SEAS and other similar contexts. In particular, again leveraging the IMO framework, we organize our review of this subset of the literature to include:

1) Antecedents considered in analogous settings.
2) Adaptation processes considered in analogous settings.
3) Team mediators considered in analogous settings.
4) Adaptive outcomes considered in analogous settings.
5) Future opportunities to consider in analogous settings.

In an attempt to provide practical value to NASA, based on the insights that we garnered through the various steps that we conducted during our literature review, we provided recommendations on interventions and countermeasures that NASA could employ to increase team adaptation and resilience. These recommendations were organized around the following key themes:

1) Team composition
2) Training
3) Shared mental model development
4) Tools provided to space crews
5) Learning culture
6) Team communication and debriefs

We also wanted to supplement the "picture" of team adaptation and resilience provided by researchers to include the experiences of various subject matter experts within NASA to better understand and include their perspectives regarding team adaptation and resilience into the team adaptation nomological network framework that we develop here. Accordingly, we conducted nine 1-hour long interviews of individuals within NASA (i.e. former astronauts, physicians, and analog participants and researchers). Based upon this part of the project, we were able to identify six primary themes from our discussions:

1) Types of disruptions
2) Prior performance
3) Measurement
4) Training
5) Multi-team systems
6) Leader and crew member roles and responsibilities

The value of integrating prior research that has examined team adaptation and resilience with the thoughts and experiences of NASA personnel is that it grounds our thinking within the context of space exploration and by doing so, allows us to provide practical recommendations for future long-duration exploration missions. Additionally, we also provide our thoughts regarding research opportunities that still remain unanswered but could prove especially valuable to NASA in regards to creating adaptation and resilience within their future space crews. In particular, we feel that there is great potential in conducting research and learning more about:

1) Measurement of team adaptation and resilience
2) Longitudinal examinations of team adaptation and resilience
3) Training interventions and their impact on team adaptation and resilience
4) Consideration of team adaptation and resilience within other analog environments
5) Including other pertinent constructs in future studies of team adaptation and resilience

Our hope is that our work and recommendations provided here will prove valuable for NASA.

## Introduction

*"We've had a miracle on 34th Street, I believe now we've had a miracle on the Hudson. This pilot…without any engines, was somehow able to land this plane…This is a potential tragedy that may have become one of the most magnificent days in the history of New York City."*

This is how New York Governor David A. Paterson described the events that occurred on January 15, 2009 when pilot Chesley B. Sullenberger III and his crew were able to overcome a bird strike that disabled the engines on Flight 1549 over New York City. When faced with this challenge, the crew devised and executed a revised plan whereby they safely landed their Airbus 320 in the Hudson River saving all 155 passengers on board. In part, this incident has become so widely known because it demonstrates the ability of a group of individuals to overcome challenges and disruptions and still be successful. The team had to work together and manage their emotions and collective cognition to help them adapt and be resilient to the situation they faced.

Such a message is particularly compelling to many of today's organizations that face competitive environments marked with unprecedented levels of change (e.g., Algesheimer, Dholakia, & Gurău, 2011; Harrison, McKinnon, Wu, & Chow, 2000). In fact, most work environments encounter at least some level of change which can result in "disruptions, challenges, and even trauma to people inside and outside the organization" (Hoopes, 2012, p. 80). Such challenges can include layoffs, the introduction of new technology, changes to work processes, and other changes that require individuals and teams to adapt and be resilient in order to obtain or maintain organizational success. As a result, understanding how teams adapt to both anticipated and unanticipated events and how to develop resilience within such teams has become increasingly important to organizational team researchers as they have become more aware of the dynamic and challenging contexts within most teams operate (e.g., van der Kleij, Molenaar, & Schraagen, 2011).

Given this fact, there has been a great deal of research on the topic of team adaptation and discussion centered on team resilience over the past couple of decades. Based on our review of these literatures, there has been confusion around these and other related constructs. However, we aim to try to clear up some of this confusion here as we view these constructs as being related but distinct. As described more fully below, we define team adaptation as adjustments to relevant team processes in response to the disruption or trigger giving rise to the need for adaptation. In comparison, we adopt the view that team resilience is a belief shared by the team that it can absorb and cope with such disruptions or triggers.

While the Miracle on the Hudson example may suggest otherwise, teams do not always respond favorably to challenges and disruptions. In fact, there are likewise incidents where teams for some reason are not able to overcome the disruptions that they face. For example, Weick (1993) leveraged the Mann Gulch disaster that occurred in 1949 to demonstrate the implications that can occur when team leaders and members fail to accurately interpret a changing situation as a result of improper sensemaking within the team. More recently, a 2009 survey conducted by Accenture found that 73% of U.S. respondents indicated that their organizations failed to be resilient (Accenture, 2009).

Therefore, it is important that organizations such as NASA gain a better understanding of factors that shape adaptation and resilience within their teams as these topics (adaptation and

resilience) are of significant importance within the long-duration missions that NASA is currently readying itself for in the not too distant future (e.g., Orasanu, 2005; Salas, Tannenbaum, Kozlowski, Miller, Mathieu, & Vessey, 2015). In fact, based on our review of astronaut journals, the following quote(s) from the *Behavioral Issues Associated with Long-Duration Space Expeditions: Review and Analysis of Astronaut Journals, Experiment 01-E104 (Journals): Final Report* by Stuster (2010) indicates that prior NASA missions have required team adaptation and resilience:

- I had to wait to get started, so began working on something else instead that ran into problems. Before I knew it I had 3 different partially complete things going on, which is normally fine, but the number of bags and hoses and cables and wires and boxes that were all in my way – well, I guess it got me a bit frustrated. Starting off already behind on an ambitious day is a recipe for a huge amount of stress. (p. 13)
- I was really surprised this morning to find that X had completely failed to perform a task yesterday, one required in order for me to perform a task this morning. I was quite angry and later apologized and accepted responsibility for not "monitoring" more closely. I'm still disappointed that X never took responsibility for the mistake. (p. 22)
- All is well on board, at least now it is. We had a fire—or at least smoke—out of the ___ that caused a little commotion for a couple of hours. It was brought under control right away, we never had to don masks and the filtering of the atmosphere was completed quickly. (p. 30).

While the topic of adaptation and resilience has been salient for past NASA missions as evidenced by these journal entries, it will likely be of even greater importance in future deep space missions that will be characterized as having increased autonomy for the flight crew and reduced possibilities of interventions from mission control (e.g., Neerincx, Bos, Olmedo-Soler, Brauer, Breebaart, Smets, Lindenberg, Grant & Wolff, 2008; Vassev, Sterritt, Rouff, & Hinchey, 2012). Namely, as a result of communication delays, such missions will likely be characterized as having a reduced possibility that mission control can actively engage in resolving any disruption that the flight team encounters and therefore places an increased importance on the flight team to maintain situational awareness so that they can overcome such challenges (e.g., Benbenek, Soloff, & Lieb, 2010). Likewise, in addition to health-related concerns such as radiation and loss of bone mineral density, behavioral adaptation has been noted as one of the key issues facing long-duration missions (e.g., Ball & Evans, 2001). Accordingly, the purpose of this paper is to review the team adaptation and resilience literatures, to help us unify the field, develop new insights from both the findings and gaps identified within this research, and propose directions for future research efforts. Accordingly, we review the empirical literature regarding team adaptation and resilience to pursue the following three goals.

Our first goal is to provide a clear definitional framework that teases apart the different operational forms of team adaptation and related concepts (including resilience). Specifically, this work will clarify what team adaptation and resilience truly are and how each construct is distinct from other related terms. Our intent here is to address calls for work to delineate the nature of these constructs and their nomological networks (e.g., Stagl, Burke, Salas, & Pierce, 2006). To date, the team adaptation and resilience literatures are rife with construct confusion; in part, because the development of these literatures has occurred within disjointed streams of inquiry. Accordingly, with this work, we aim to overcome this lack of a unified core in the team adaptation

and resilience literatures and alleviate confusion in this area by clarifying these constructs and how they may fit within a broader team adaptation nomological network. In turn, this should allow researchers in this area to be truly on the same page going forward.

Our second goal is to synthesize the work that has empirically considered team adaptation and resilience. Namely, we will leverage the team adaptation nomological network framework that we develop here and highlight work that has studied factors likely to serve as antecedents of team adaptation and resilience and, how team adaptation and resilience shape various team performance outcomes. Throughout this review, we will attempt to highlight particular works that are most likely to be applicable to NASA's work in isolated, confined, and extreme (ICE) contexts. Additionally, by synthesizing research that has focused on team adaptation and resilience, we will summarize what researchers have accomplished, and also highlight areas that could be opportunities for future research and practice. In particular, we will detail where the opportunities exist for investigations of team adaptation and resilience inputs, intervening variables, and outcomes.

Our final goal with this project is to supplement our literature review with insights from interview data collected from various subject matter experts (SMEs) such as former astronauts, physicians, and analog participants and researchers. The information from personal experiences, perspectives and opinions will enrich our understanding of what adaptation and resilience has looked like in prior space missions and what may be necessary for adaptation and resilience in future long-duration missions. Our intent is that by combining the results of these two sources (past literature and personal interviews), we will be able to provide recommendations for NASA's future practices (e.g. staffing, training, interventions) and where research needs exist to better understand adaptation and resilience within long-duration missions.

## Literature Review Process

We utilized four means to identify the studies included in this review:

1) a search of the most comprehensive and most used electronic databases that include journals in management, applied psychology, business, and social sciences (i.e., Web of Science, Business Source Complete, PsychInfo) as well as aerospace focused databases and journals using an extensive list of relevant terms (e.g., team and adaptation and similar words including adaptability, adapt, resilient, resiliency, flexibility, and recovery);
2) a manual scan of leading international journals in management, organizational behavior, applied psychology, information systems, communication, and health care management;
3) a review of various conference proceedings (e.g., Academy of Management, European Association of Work & Organizational Psychology, and the Society of Industrial Organization Psychology); and
4) a scan of the reference lists from the articles identified through the first three methods. In addition to journal articles and conference proceedings, we also include dissertations, and relevant thesis in our review of the team adaptation and resilience literatures.

## Definitional Model of Team Adaptation

In reviewing these literature streams, one of the first themes to emerge was that researchers have considered adaptation and resilience within disparate literatures even though they are often defined in similar fashions (e.g., Nelson, Adger, & Brown, 2007). Likewise, researchers have leveraged various terms, conceptualizations, and operationalizations of adaptation and resilience as they attempt to discuss the actions made by teams in the face of disruptions. For instance, some researchers have utilized the term "team adaptation," while others applied labels such as team adaptability, team role adaptation, and team adaptive outcomes. This same trend was also evidenced within the team resilience literature where resilience has been viewed at times as being a trait of team members and at other times as a dynamic process of teams (e.g., Fletcher & Sarkar, 2013).

Both the lack of an integrated perspective and the absence of agreed upon operational definitions have, in our estimation, hindered the development of research focused on team adaptation and resilience (in their various forms). As noted recently by Baard, Rench and Kozlowski (2014), while work on adaptation has been rich, the manner of adaptation conceptualization has been varied and diverse, thereby unnecessarily stunting the field from burgeoning as it could. Given that adaptation and resilience have been considered within different literatures, in this review we will summarize the work that has been conducted in each literature separately. We begin by providing definitional clarity regarding team adaptation as compared to factors that may give rise to adaptation and the resulting consequences of adaptation. Then, we will discuss how resilience has been defined within the literature before transitioning into our discussion of how these factors can be integrated into the nomological network introduced here.

In Table 1, the different terms and definitions used in the team adaptation studies that we identified are listed to demonstrate how far from consistent has been the definition of team adaptation within the literature. Within Table 1, we leverage the input-mediator-outcome (IMO) framework (Ilgen, Hollenbeck, Johnson, & Jundt, 2005) to group definitions in terms of whether the authors are focused on a team's ability to adapt (an input focus), the result of teams that adapt (an outcome focus), or on the actual process of adaptation within teams (process or mediator focus). Within such a framework, *inputs* represent starting conditions of a group, such as its material or human resources. Following inputs are *mediators* which can include *processes* that represent dynamic interactions among group members as they work on a group's task or *team emergent states* which are "cognitive, motivational, and affective states of teams" (Marks, Mathieu, & Zaccaro, 2001, p. 357). Finally, *outcomes* represent task and non-task consequences of a group's functioning.

This IMO categorization of some of the more prominent definitions of team adaptation-related constructs is used to demonstrate the point that researchers generally focus on one category more than the others as seen in past taxonomies (e.g., Pulakos, Arad, Donovan, & Plamondon, 2000; Pulakos, Dorsey, & White, 2006). Herein we take a balanced approach by discussing the way adaptation may be defined in each of the different IMO categories. Specifically, we acknowledge the actual process of adaptation (process or mediator), what factors give rise to it including the team's inherent capacity to adapt as well as other antecedent factors (input), and finally, what are the consequences of adaptation (outcome). In order to *kick start* our discussion regarding the use of different definitions based on the IMO categories, we build upon the

definitions introduced to date and present our own definitions of team adaptive outcomes (outcome), team adaptability (input), and finally team adaptation process (process). We will subsequently leverage this framework as we review the literature that has considered team adaptive outcomes, team adaptability, and team adaptation process.

## Team Adaptive Outcomes

As demonstrated within our review of the literature, researchers have at times used the term team adaptation but have in fact been focused on understanding the consequences of teams that adapt (e.g., Klein & Pierce, 2001). In contrast, others have used the term adaptive performance but have, in actuality, been focused on the extent to which teams adjusted their processes (e.g., Han & Williams, 2008). Accordingly, there is a need to be more precise when discussing the outcomes or consequences of team adaptation. This construct confusion is even more concerning given that Baard and colleagues (2014) acknowledge that when researchers focus on adaptation, they are particularly interested in the impact of such adaptation processes on performance. In an attempt to clarify what is meant by the outcomes following team adaptation processes, we define the impact of adaptation on outcomes such as effectiveness, performance, and affective reactions of team members as follows:

> *Team adaptive outcomes are the consequences of the adaptation process, which may include constructs such as: various emergent states such as team cognition, team member affective reactions such as willingness to work together again, team effectiveness, and team performance.*

## Team Adaptability

In addition to more clearly distinguishing the process of adaptation from its consequences, we also want to clarify factors that serve as antecedents to team adaptation process. In particular, we contend that one such salient antecedent is a team's inherent ability to adapt in the face of a disruption or what we refer to as team adaptability. This distinction is in line with Zaccaro and Bader (2003) who suggest that teams are well positioned to adapt because of the social capital, experiences, abilities, and networks possessed by team members. In part, a team's adaptability is likely derived from individual-level factors that have been demonstrated to shape individual adaptation. For example, such work suggests that cognitive ability, personality factors, past experiences and factors such as interest and task-specific self-efficacy (e.g., Pulakos, Schmitt, Dorsey, Arad, Hedge, & Borman, 2002) may influence adaptation. Much of the work on individual-level adaptability is built upon the work of Pulakos and colleagues (2000; 2002) who outlined 8 dimensions of individual adaptive performance. In particular, they highlighted that an individual's ability to remain composed and calm, enthusiastic for learning, and flexible and open-minded are constructs that can allow certain individuals to be more apt to ultimately adapt when necessary.

However, in our mind being positioned to adapt based on the composition of individuals and leaders who make up a team and their individual tendencies toward adaptation is quite different from the actual process of adapting. Likewise, being clear about the differences we are suggesting, leads to research questions such as: do all teams possess the same levels of team adaptability and are all teams equally able to leverage these inherent characteristics? These rhetorical questions point to the fact that some teams may inherently possess a higher capacity to

adapt, in part, based on the characteristics possessed by team members and leaders. As such, we conceptualize team adaptability as an input variable or antecedent to team adaptation. This line of thinking is in keeping with the views of Hollenbeck, Ellis, Humphrey, Garza, and Ilgen (2011), Randall, Resick, and DeChurch (2011) and Zaccaro and Bader (2003) in that, high levels of team adaptability will promote the process of team adaptation. Accordingly, we define:

> *Team adaptability as the capacity of a team to make needed changes in response to a disruption or trigger.*

**Team Adaptation Process**

Beyond defining a key antecedent to team adaptation process (i.e.., team adaptability) as well as the consequences of such adaptation (i.e., team adaptive outcomes), we now turn our focus to what we envision as quintessentially adaptation – team adaptation process. Given that many definitions of adaptation include the process of change (e.g., Burke, Stagl, Salas, Pierce, & Kendall, 2006(c); Burtscher, Wacker, Grote & Manser, 2010; Klein & Pierce, 2001; Marks, Zaccaro, & Mathieu, 2000), herein we consider team adaptation to be a mediator or process variable. Such a categorization is in keeping with the actual definition of adaptation noted in Merriam-Webster's Online Dictionary (2013): the act or process of adapting. Additionally, as noted by Stagl and colleagues (2006) team adaptation is focused on change and thus can be thought of as the process by which a team alters in response to some stimuli or trigger.

That said; the literature has considered a multitude of ways that teams can adapt – some general in nature, while others are quite specific. For instance, Klein and Pierce (2001) merely state that adaptive teams are "able to make the necessary modifications to meet new challenges" (p. 3), but provide no specifics in terms of what those modifications could include. In contrast, others suggest that adaptation entails member roles within the team being altered (e.g., LePine, 2003; LePine, 2005); alteration of strategies within the team (e.g., Cannon-Bowers, Tannenbaum, Salas, & Volpe, 1995; Marks et al., 2000); adjusting processes (e.g., Burke et al., 2006(c); Manser, Howard, & Gaba, 2008); structural changes (e.g., Burtscher et al., 2010; Gorman, Cooke, & Amazeen, 2010); or the modification of team behaviors (e.g., Entin & Serfaty, 1999; Marques-Quinteiro, Curral, Passos, & Lewis, 2013; Randall et al., 2011). Likewise, Qureshi and Vogel (2001) suggest that teams can adapt their:

1) work,
2) social interactions, and
3) the technology they use.

While the wealth of ideas presented in the literature regarding what a team adjusts during the adaptation process is impressive, the literature currently lacks consistency regarding the content area or focus of team adaptation. As such, our operational definition highlights areas in need of research attention going forward. Given that we have conceptualized team adaptation as a process variable and recognizing that there are team process frameworks within the broader organizational team literature, we integrate team adaptation and team process typologies in order to provide a nuanced model for team adaptation.

Herein, we utilize the team process framework introduced by Marks and colleagues (2001) as it provides an extensive typology of the processes within a team that may be adjusted in the

face of an adaptation trigger. Leveraging this framework is likewise supported by the fact that it is rooted in the team literature while subsuming much of the adaptation behaviors detailed by Pulakos et al. (2000) and examined in Pulakos et al. (2006) at the individual-level of analysis. Likewise, this framework and its underlying dimensions have been empirically supported in a recent meta-analytic review of the team process literature (e.g. LePine, Piccolo, Jackson, Mathieu, & Saul, 2008). To be precise, Marks and colleagues (2001) suggest that teams engage in three types of processes – namely, transition, action, and interpersonal. During *transition* team process phases, members are engaged in activities such as mission analysis, planning, goal specification, and formulating strategies. Subsequently, during *action* phases, members address task accomplishment, monitoring progress and systems, coordinating with team members, as well as monitoring and backing-up teammates. Finally, *interpersonal* processes that are salient throughout a team's lifecycle, address activities such as conflict management, motivation and confidence building, and affect management. By integrating the Marks et al. (2001) team process taxonomy, we define:

> *Team adaptation process as adjustments to relevant team processes (i.e. action, interpersonal, transition) in response to the disruption or trigger giving rise to the need for adaptation.*

A framework for distinguishing team adaptability, team adaptation process, and team adaptive outcomes is depicted in Figure 1 and can be illustrated with the following example. Kahol, Vankipuram, Patel, and Smith (2011) observed 10 trauma teams in the field and provided evidence that more deviations in team processes (i.e. adaptation process) occurred in instances where the teams included more experienced leaders, and such adaptation resulted in improved performance. Using this as an example, and based on our taxonomy, we define *adaptability* as a characteristic possessed by teams or members of the team (i.e., experienced leaders), which enabled *team adaptation process* (i.e., deviations in team processes from standard procedure) and shape team *adaptive outcomes* (i.e., surgical outcomes).

In subsequent sections where we review empirical studies conducted to date, regardless of the actual terminology that the researchers utilized in their original studies, we will apply our framework and the labels we identified and defined: team adaptability (input), team adaptation process (mediator) and team adaptive outcomes (outcome). To be precise, we categorized prior team adaptation studies so that the constructs examined by prior researchers would be placed into the appropriate categories in our framework based on how the prior researchers conceptualized their constructs and not based on the label or terminology that they used. However, given that the process of adaptation is central to many of the studies conducted to date (which is also consistent with our positioning of adaptation process as central within the team adaptation nomological network), team adaptation process will be emphasized throughout our review. That said; in keeping with the framework we have introduced above, while there is less work focused on team adaptability and other antecedents, we will also consider and review work that has considered antecedents to the adaptation process. Similarly, in order to fully review the entire team adaptation nomological network, we will also include in our review of the literature, studies that have emphasized the consequences of the adaptation process – team adaptive outcomes.

## Integration of Team Resilience into the Team Adaptation Nomological Network

### Team Resilience

In addition to teasing apart the various team adaptation constructs (i.e. adaptability, adaptation process, and adaptive outcomes), Figure 1 also integrates team resilience into the adaptation nomological network. We feel that integrating resilience into the framework is appropriate given its conceptual overlap with team adaptation. For example, as detailed in Table 2, Luthar, Cicchetti, and Becker (2000) defined resilience as "a dynamic processes encompassing positive adaptation within the context of significant adversity" (p. 543). Additionally, van der Kleij and colleagues (2011) acknowledge that while resilience "has many commonalities with adaptation" (p. 2158), they are distinct constructs.

Accordingly, we argue that team resilience is salient in considerations of team adaptation. While attention to resilience has primarily occurred at the individual-level of analysis, more recently researchers have argued that a team-level consideration of resilience is important (e.g., Steijger, van der Beek, Gallis, van der Vorm, 2010). In fact, Boermans, Delahaij, Korteling, and Euwema (2012) acknowledge that within a military context, interpersonal conflicts, team morale, and cohesion are seen as salient in shaping resilience. Furthermore, researchers argue that resilient teams are better at coordinating and responding when faced with crises (Gomes, Borges, Huber, & Carvalho, 2014). However, there is much confusion about how to conceptualize team resilience and therefore, how to study it. Herein, we aim to provide a bit of clarity about that conceptualization.

A main point of confusion regarding team resilience is whether it exists inherently, is developed, or produced after-the-fact. That is, the construct of resilience (at both the individual- and team-level of analysis) has been viewed as a trait, a process, and as an outcome. As detailed in Figure 1, we envision team resilience as an emergent state or as was stated earlier - "constructs that characterize properties of the team that are typically dynamic in nature and vary as a function of team context, inputs, processes, and outcomes" (Marks et al., 2001, p. 357). We feel that treating team resilience as an emergent state as compared to other treatments (e.g. as a trait or as a process) is appropriate given that researchers suggest resilience is dynamic (e.g., Luthar et al., 2000) and is influenced by adaptation and other team processes (e.g., Moran & Tame, 2012). In fact, Reich, Zautra, and Hall (2010) suggest that resilience is the outcome of successful adaptation to hardships which is consistent with our view of team resilience as an emergent state impacted by various input and process variables including adaptation. Likewise, treating team resilience as an emergent state is consistent with those who have defined it as "a team's belief that it can absorb and cope with strain, as well as a team's capacity to cope, recover and adjust positively to difficulties" (Carmeli, Friedman, & Tishler, 2013, p. 149).

Although team resilience is a relatively new phenomenon in the research literature, efforts are being made to flesh out the important dimensions of team resilience. For example, Carmeli and colleagues (2013) provide a more nuanced view of team resilience by suggesting that it is composed of two dimensions consisting of "efficacious beliefs of coping with the difficulty and the capacity to adapt" (p. 149). They label the efficacious beliefs *resilience-efficacious beliefs* which are the shared beliefs held by the team members regarding their ability to absorb and cope with strain. They label the second dimension of team resilience as *resilience-adaptive capacity* which they define as the "ability to sense, interpret, and respond to complexities such that

problems are noticed, and capitalized upon to cultivate a work system that is capable of adjusting to setbacks and continues to grow" (p. 149).

Recently, Alliger, Cerasoli, Tannenbaum, and Vessey (2015) describe a framework of behaviors that their research has tied to resilient teams to include actions taken before the arrival of the problem (i.e. minimize), actions taken during the challenge (i.e. manage), and those actions taken after the disruption (i.e. mend). Additionally, Lopes (2010) provides a succinct theoretical framework for unit-level resilience in which he indicates that the most salient characteristics of team resilience consists of:

| Unit Resilience Characteristic | Description |
|---|---|
| Concerted Leadership | Providing guidance direction and proper allocation of resources to accomplish group goals with minimal dysfunction as well as skillfully building teams capable of facing adversity |
| Adequate Resources | To include human, social support, emotional and material capital necessary to overcome obstacles, encourage growth, and improve competence and efficacy |
| Organizational Learning | Accumulating knowledge, enhancing competences, and increasing efficacy through processes that increase the capability of the group to handle future stressful situations and environments |
| Flexibility/Adaptability | Ability to adapt, improvise and provide flexible responses to adverse situations that do not waste the unit's resources |
| Goal Oriented | The unit contains a common set of values and moves collectively towards a common goal. |

Taken together, the framework put forth by Carmeli et al. (2013) and Lopes (2010) suggests that resilience may not necessarily be an inherent trait; rather, the characteristics that promote resilience may be gained and developed on their own or through training.

Thus, we contend that viewing team resilience as an emergent state is the proper conceptualization and as a result of such a treatment, it allows for the heretofore disparate literatures of adaptation and resilience to be integrated. Specifically, as detailed in Figure 1, given the conceptual overlap that exists between team adaptation processes (similar to Carmeli and colleagues' (2013) resilience-adaptive capacity dimension of team resilience), we view adaptation processes and team resilience to be a part of a reciprocal relationship that is central to the team adaptation nomological network introduced here. Such a relationship is consistent with those who have previously suggested a link between resilience and adaptation (e.g., Cholez, Tillement, & Reverdy, 2009; Sutcliffe & Vogus, 2003). Namely, Lopes (2010) suggests that resilience increases each time a team (or individual) successfully overcomes an obstacle or adapts.

## Team Adaptation: A 15 Year Review of the Literature

Given that research about organizational teams is constantly focused on finding levers to enhance team effectiveness, and the prolific practical use of teams in the workplace for projects and various functions, the topic of team adaptation has gained in popularity over the past decade and a half. This is not to say that the process of team adaptation was not considered within the organizational team literature prior to this period; in fact, that teams adapt to various changes was heralded as an essential characteristic of effective teams over four decades ago (e.g., Behling, Coady, & Hopple, 1967). However, it is only within the last 15 years that team adaptation has been included in empirical examinations of organizational teams. As noted by Marks et al. (2000), "very little research on how teams adapt to novel environments" (p. 971) had been conducted by the year 2000. At a similar time, Klein and Pierce (2001) echoed the sentiment that while it is commonplace for organizations to assert they want to encourage their teams to adapt, little had been written about what it means to actually adapt. In response to these calls, research on team adaptation has proliferated to develop a substantial body of knowledge. Thus, we concentrate on the literature of the last 15 years to assess the current state of research focused on team adaptation, and provide directions for future research.

Again, within this manuscript, our view is that team adaptation is a process variable that is impacted by various antecedents including team adaptability, and results in various outcomes including team adaptive outcomes. We leverage the IMO framework in providing our synthesis of empirical considerations of team adaptation over the past 15 years. In particular, Table 3 is used to summarize the way exemplar research on team adaptation and resilience within organizational studies has operationalized:

1) the antecedents of adaptation process to include team adaptability and
2) the adaptation trigger(s), the team adaptation process, and how it has been measured to date. Then, we consider work that has investigated
3) how team adaptation impacts mediators such as team emergent states, and
4) finally the ultimate consequences or outcomes of team adaptation process.

Within each section of our literature review, we organize our discussion to include a synthesis of the research conducted to date and recommendations for future research.

## Antecedents of Team Adaptation

Teams need to adapt to the changing conditions they face when trying to accomplish their task. To do so, teams may follow a process of adaptation that configures the way the team addresses new and dynamic conditions (Burke et al., 2006(c); Kozlowski, Gully, Nason, & Smith, 1999; Rosen, Bedwell, Wildman, Fritzche, Salas, & Burke, 2011). However, the effectiveness of team adaptation may depend on the antecedents brought to bear in the process. Indeed, the team's effectiveness in the way processes unfold may be predicated on the team's underlying inputs (LePine et al., 2008; Mathieu, Maynard, Rapp, & Gilson, 2008). To better understand the inputs (i.e., antecedents of team adaptation process), we turn to the literature to see what has been measured and assessed. As demonstrated in Table 3, we found that most studies only considered

team-level antecedents of team adaptation – a point we revisit in our discussion of research opportunities concerning antecedents to team adaptation process.

## Team-level Antecedents

We used a typology suggested by McIntyre and Salas (1995) to categorize the type of antecedents studied. Specifically, these researchers labeled constructs as either being task- or team-focused. The design of work facilitates the subsequent interactions of team members and emergent states (Hackman & Oldham, 1976; Marks et al., 2001). As such, *task antecedents* characterize the task and the way members engage in taskwork and therefore, influence whether and in what way adaptation may occur. For example, researchers have considered the inputs that describe how teams will work on the task by examining team design and structure (DeRue, Hollenbeck, Johnson, Ilgen, & Jundt, 2008; Diedrich, Freeman, Entin, & MacMillan, 2005; Hollenbeck et al., 2011; Moon, Hollenbeck, Humphrey, Ilgen, West, Ellis, & Porter, 2004), as well as the team's reward structure (Beersma, Hollenbeck, Conlon, Humphrey, Moon, & Ilgen, 2009; Johnson, Hollenbeck, Humphrey, Ilgen, Jundt, & Meyer, 2006). In particular, when examining structure, researchers have found that some structural forms are easier to adapt from, to, or within than others. These include the shift from functional to divisional forms (Moon et al., 2004), from centralized decision making structures to decentralized structures (Hollenbeck et al., 2011) and from competitive reward structures to cooperative reward structures (Johnson et al., 2006). As such, the structure under which the team must work may "set the stage" for more or less effective team adaptation.

Researchers also indicate that the characteristics of the team are important when understanding variations in processes and outcomes (Klein & Kozlowski, 2000). These *team antecedents* (e.g., mental models, experience, and collective efficacy) have been used to characterize the membership at the team-level and explain team adaptation process and ultimately the team's performance. The team antecedents measured in the study of team adaptation include those characteristics team members possess or create together (e.g., collective efficacy (Chen, Thomas, & Wallace, 2005), conflict (Langfred, 2007), and mental models (Randall et al., 2011; Resick, Murase, Bedwell, Sanz, Jiminez, & DeChurch, 2010)). Mental models and other team cognitive constructs are interesting to consider within the team adaptation literature as they have been considered as both an antecedent (discussed here) as well as a mediators of the team adaptation process – outcome relationship (discussed subsequently). In fact, Resick and colleagues (2010) found an interaction between quality and similarity of team mental models such that high quality models of strategic alternatives produced more efficient responses to task disruptions. Thus, team antecedents appear to influence the effectiveness with which team adaptation is carried out.

## Antecedents at Other Levels of Analysis

In addition to the team-level antecedents, researchers suggest that factors at higher and lower levels of analysis should be recognized to fully understand organizational phenomena (e.g., Klein & Kozlowski, 2000). That is, taking a "bracketing" approach by accounting for constructs at a level above and a level below the phenomenon of interest provides a valuable approach for theoretical and practical assessment (Hackman, 2003). However, few researchers have espoused and tested individual- and organizational-level inputs that may enable or constrain a team's adaptation process effectively.

### *Individual-level inputs*

For individual-level inputs there is burgeoning research regarding the way team member characteristics shape a team's ability to adapt through members' rating of cognitive ability (LePine, 2003; LePine, 2005; Randall et al., 2011), psychological collectivism (Randall et al., 2011), team member roles (Burtscher, Manser, Kolbe, Grote, Grande, Spahn, & Wacker, 2011), individual adaptive performance (Han & Williams, 2008), learning and performance orientation (LePine, 2005; Porter, Webb, & Gogus, 2010), member achievement, dependability, and openness to experience (LePine, 2003). For example, the results of LePine's (2005) laboratory simulation indicate that an interaction exists between goal difficulty and learning orientation which had a subsequent impact on team adaptation such that teams with more difficult goals paired with high member learning orientations experienced a greater rate of adaptation. However, we can envision more work at the team-level of analysis leveraging such individual-level work by either aggregating such individual-level constructs or by examining upward influence-type models (e.g., Mathieu & Taylor, 2007). For instance, different coping styles may have either beneficial or detrimental influences on adaptation (e.g., Bishop, Kobrick, Battler, & Binsted, 2010). Namely, there is evidence to suggest that individuals with task coping styles are more able to adapt (e.g., Endler & Parker, 1994), however, research has not fully examined such factors at the team-level and whether there is an optimal mix of coping styles within a team to better enable the team to effectively handle disruptive events.

### *Organizational-level inputs*

For organizational-level inputs, we are even less informed about the effects on team adaptation. Gibson and Birkinshaw (2004) consider organizational context, through dimensions of social context and performance management, as an antecedent to team ambidexterity. Ambidexterity allows teams to reconcile the tensions between alignment and adaptability. Their findings indicate that organizational context relates to ambidexterity such that a more supportive context promotes ambidexterity. In turn, ambidexterity mediates the relationship between context and business unit performance. As such, the contextual inputs were found to enable business units to, among other things, adapt (Gibson & Birkinshaw, 2004).

## Summary and Future Opportunities

Although the recognition of inputs from multiple levels has been discussed in theoretical models of team adaptation (Burke, Pierce, & Salas, 2006 (b); Kozlowski et al., 1999), the lack of empirical studies that test such antecedents is striking. Indeed, while researchers have called for more multi-level approaches to understanding team-level phenomena (e.g., Joshi, Pandey, & Han, 2009), such cross-level considerations are not evident within the team adaptation literature. We therefore advise researchers to consider antecedents at different levels of analysis, as it appears to be an important factor that has yet to be examined within the team adaptation literature. Thus, it would be interesting for future research to consider more multi-level variables within the team adaptation nomological network.

### *Individual-level antecedent opportunities*

As an example, the individual-level construct of team member flexibility has been evidenced as being relevant for achieving team responses to contextual changes (Lee & Xia, 2010), complexity (McComb, Green, & Compton, 2007), and other outcomes (Chang, Wong, Li, Lin, & Chen, 2011; de Jong, de Ruyter, & Lemmink, 2004). Accordingly, future research could explore the role that team composition in general, and team member flexibility in particular, plays in shaping team adaptation. Likewise, researchers have started to consider individual adaptability and have introduced theories regarding its impact in social settings (e.g., Ployhart & Bliese, 2006). Logically, teams consisting of members who are individually more capable of adapting (i.e. member adaptability) are more likely to adapt their processes in the face of disruptions. However, this is an empirical question that needs to be addressed by future work in this area. As we highlight later within this review, this is an area that is in need of attention going forward. Namely, research needs to coalesce around how adaptability is measured so that examinations of the impact of adaptability can be ascertained as well as whether adaptability is a construct that develops over time or in response to training and other interventions.

### *Organizational-level antecedent opportunities*

Moreover, future researchers need to consider the impact that organizational-level factors such as climate and culture play in shaping team adaptation. For example, work by Harrison and colleagues (2000) demonstrated that culture plays a role in the propensity of individuals to adapt. As well, the way organizations manage information was reportedly important for teams that work in high risk environments such as nuclear power plants (Carroll, Rudolph, & Hatakenaka, 2002), hospitals, airlines, and disaster response (Ren, Kiesler, & Fussell, 2008). Likewise, while there is work within the broader organizational literature that considers the impact of resource availability on the extent to which the organization as a whole can be innovative (e.g., Kuratko, Montagno, & Hornsby, 1990), work has yet to investigate the role that resource availability or scarcity can have on the teams within these organizations and the extent to which they adjust or adapt their processes. Given that work suggests that organization-level inputs may trickle down to sub-units and work teams and shape behaviors, more work following this line of thinking is needed with team adaptation process.

### *Team-level antecedent opportunities*

Additionally, future research is needed that explores additional team-level inputs. In particular, resilience is considered as anticipation or planning for the unexpected (Weick & Sutcliffe, 2001). More specifically, resilience is defined as the capacity to rebound from a challenge and withstand setbacks (Sutcliffe & Vogus, 2003; Wagnild & Young, 1993). While consideration of resilience at the team-level of analysis is limited, we contend that resilience may provide some interesting results when considered in studies of team adaptation given the implications that team resilience may have in situations where teams face unexpected triggers. Further consideration of team resilience is explored in a later section of this review. Likewise, our suggestion that researchers should start to consider the impact of teams consisting of members with higher/lower adaptability begs the question of whether adaptability is an isomorphic construct (e.g., Kozlowski & Klein, 2000) whereby it can also be conceptualized and operationalized as distinct constructs at both the individual- and team-levels of analysis. Again,

teams with higher adaptability scores, all else being equal, should be more able to adapt, but empirical investigations of such a relationship are needed to make such a statement definitively.

## Team Adaptation Process

Within subsequent sections, we will consider the outcomes of team adaptation process. However, within this section, we will discuss the various ways in which team adaptation has been conceptualized as well as the manner in which researchers have measured team adaptation process. As others have noted (Rosen et al., 2011), creating a solid empirical measure of team adaptation is needed for the continued development of this literature. In fact, too often when research examines team adaptation, the construct of adaptation is not actually assessed. For example, numerous examples exist within the literature where researchers manipulate a team's task and then assess team performance and assume that for those teams that performed better after the change, it was adaptation that made this performance enhancement possible (e.g., Han & Williams, 2008; Johnson et al., 2006; Klein, Ziegert, Knight, & Xiao, 2006). Other researchers examine teams that are faced with a challenging task and then assess what is different in those teams that performed well versus those that did not attain high performance levels (e.g., Waller, 1999). Accordingly, while adaptation is an oft-discussed construct, it is too often viewed as occurring within a *black box* that goes unmeasured.

### Type of Team Adaptation Process

As suggested in Figure 1 and in our definition of team adaptation process introduced above, we envision the process of adaptation as being adjustments to certain team processes as dictated by the type of disruption or trigger. That said; it is also interesting to assess which types of processes have been included in prior investigations of team adaptation processes even though we are the first to envision team adaptation process in this fashion. Specifically, as detailed in Table 3, while the actual measurement of team adaptation does not always happen within this literature stream, it is interesting to examine which types of team processes have been examined when adaptation is actually assessed.

By examining the literature with this lens, it becomes clear that researchers have almost exclusively envisioned team adaptation as adjustments to *action process*es. For instance, LePine (2003; 2005) considered the extent to which roles within the team were altered following a communication breakdown and found that role structure adaptation mediated the relationship between various team adaptation antecedents (e.g., cognitive ability, member openness to experience) and post-change performance. Similarly, Diedrich and colleagues (2005) demonstrated that naval officer teams that changed their team's organizational structures in the face of information suggesting the need for such adjustments achieved higher mission effectiveness scores. Vera and Crossan (2005) examined a construct they labeled improvisation, or the extent to which teams dealt with unanticipated events on the spot.

Given that almost every study that examined adaptation processes within a team has focused on the factors that lead to the adjustment of team action processes and the resulting implications of such adjustments, it begs the question of the impact of team adaptation involving the other categories of team processes. Accordingly, we see this as a huge opportunity for future research examining team adaptation process. In addition to understanding which types of

processes are adapted, we also considered the overall study design and measurement of team adaptation – a topic that we turn to now.

**Study Design and Measurement of Team Adaptation Constructs**

Beyond gaining a deeper understanding regarding antecedents, and the type of processes being examined when studying team adaptation, as detailed in Table 3, we also assessed the settings in which team adaptation studies took place. As such, it became clear that the majority of team adaptation studies reviewed utilized a laboratory setting. This study design has facilitated the use of raters or objective measures of team adaptation. A rating approach has been fairly popular in the literature (e.g., Chen et al., 2005; LePine, 2003; 2005; Woolley, 2009) as exemplified by Diedrich and colleagues (2005) who rated the adaptation of teams in their study of naval officers engaged in a simulated decision-making task. Other researchers have relied upon objective measures of adaptation. For example, Resick and colleagues (2010) assessed adaptation by measuring the time teams took to implement the desired strategy for their lab-based decision-making task. A final approach that has been utilized within the literature is surveying team members (e.g., Marques-Quinteiro et al., 2013; Wiedow & Konradt, 2011). For example, Vera and Crossan (2005) assessed adaptation with 7 survey items such as "the team deals with unanticipated events on the spot."

While the primary means of evaluating team adaptation has been through laboratory simulations and activities, our review does indicate that a high number of studies utilize real-world professionals rather than students. Moreover, some of these populations may be seen as near analogs to NASA mission crews. Indeed, researchers have involved naval officers (Diedrich et al., 2005; Entin & Serfaty, 1999) and airline cockpit crews (Grote, Kolbe, Zala-Mezo, Bienefeld-Seall, & Kunzle, 2010; Waller, 1999) in laboratory simulations – see subsequent section on analogous settings. In the field, researchers have involved trauma teams (Kahol et al., 2011; Klein et al., 2006) and nuclear power plant personnel (Stachowski, Kaplan, & Waller, 2009; Waller, Gupta, & Giambatista, 2004). Thus, the research regarding team adaptation may hold relevant implications for those working in isolated, confined, and extreme (ICE) contexts.

**Team Adaptation Process Study Design Future Opportunities**

While we acknowledge the value of leveraging both field- and laboratory-based study designs given the ways in which these two approaches can complement each other, we would encourage researchers interested in the topic of team adaptation to rely more heavily on field-based studies. By considering adaptation in the field, future research could assess the adaptation process that happens across organizational sub-units or across organizations. Such a dynamic would be more in line with the reality of instances when an organization faces a crisis situation because when such incidents occur, the adaptation that is needed likely occurs across units or organizational boundaries. For example, when the Deep Horizon oil spill occurred, resources needed to be mobilized across states and countries to enable BP and other entities to adapt to that crisis situation and work together to bring specialized skills and equipment to help clean up the oil spill (e.g., Gaines-Ross, 2010).

In addition to conducting more field-based studies, there are additional opportunities that exist within this literature from a study design and measurement perspective. For instance, even though numerous scholars have called for more longitudinal examinations of organizational teams

(e.g., Gully, 2000), like many literatures, the adaptation literature appears to still have many opportunities in this area. Specifically, while there is some evidence of longitudinal research involving both individual- and team-level adaptation (e.g., Lang & Bliese, 2009; LePine, 2003; 2005), we believe that more can be done and thus suggest that future research on team adaptation consider temporal factors more fully. By doing so, researchers could investigate teams over an extended period of time in order to ascertain the role that prior performance may have on a team's adaptation process. We contend that this could be an interesting avenue for future research given that prior success may lead to persistence, solidification of routines, and hesitance to adapt even with the awareness of a trigger requiring change within the team (e.g., Audia, Locke, & Smith, 2000). Finally, by leveraging longitudinal designs, future research can utilize more robust statistical approaches (e.g., latent growth modeling) and consider team adaptation over time which will be relevant for long-duration engagements, such as missions to Mars or other lengthy space missions.

Likewise, as we mentioned above, many studies reviewed here did not actually measure adaptation and those that did utilized a variety of scales and measurement approaches. Although the variety of measurement approaches has helped develop knowledge, we suggest that the team adaptation literature could now benefit from a coalescence regarding how the adaptation process is measured. In fact, researchers who leverage the conceptualization of team adaptation introduced here may find it valuable to *adapt* survey items utilized to measure team processes (e.g., Mathieu & Marks, 2006), as well as leveraging work that has measured adaptation at the individual-level of analysis (e.g., Pulakos et al., 2000; Pulakos et al., 2006; Pulakos et al., 2002).

## Mediators

The preceding sections reviewed literature that considered a team's adaptability and other antecedents, as well as the adaptation process itself. However, we would be remiss to ignore the intervening variables that explain variation in team outcomes as a result of such adaptation process. Indeed, our review of the literature noted several considerations of mediators to the relationship between team adaptation process and adaptive outcomes. As shown in Table 3, a majority of the mediational relationships hinge on communication and information sharing (Entin & Serfaty, 1999; Johnson et al., 2006; Marks et al., 2000), coordination activities (Burtscher et al., 2010; Burtscher et al., 2011; DeChurch & Haas, 2008; Moon et al., 2004; Riethmuller, Castelao, Eberhardt, Timmermann, & Boos, 2012; Wiedow & Kondradt, 2011), and team cognition (e.g., Marks et al., 2000). As such, these mediators are considered important to the way effective adaptation processes are applied and therefore are assumed to influence the adaptation process-outcome relationships.

### Communication and Information Sharing

Given its central role in team effectiveness frameworks (e.g., Hackman & Morris, 1975), it is not surprising that researchers within the team adaptation literature have also considered the role of communication and information sharing. For instance, Johnson and colleagues (2006) studied 80 student teams and found that information sharing mediated the relationship between changes in team reward structures and team decision accuracy. Relatedly, Stachowski and colleagues' (2009) research involving nuclear power plant teams suggest that teams that exhibited fewer, shorter, and less complex patterns performed better. Finally, Entin and Serfaty (1999) demonstrated the value of team adaptation training as they linked such interventions to improved communication, and

ultimately enhanced performance. Communication makes for an interesting factor to consider within the long duration missions that are envisioned to the moon and ultimately to Mars as the communication networks will have to deal with a communication delay varying from 3-22 minutes (e.g. Benbenek et al., 2010).

### Coordination

In addition to considering communication, researchers have also examined whether the manner in which teams coordinate impacts the relationship between team adaptation process and performance. For example, Moon and colleagues (2004) suggest that teams who adapted in the face of structural changes were those that coordinated their actions through the use of supportive behaviors. Similarly, DeChurch and Haas (2008) examined a team's ability to adjust their initial plans and found that those that did exhibit such reactive strategy adjustments impacted team performance via its effect on team coordination. Likewise, Burtscher and colleagues (2010) studied 40 anesthesia teams and demonstrated that higher performing teams who faced non-routine events had higher levels of task management activities. Finally, Waller (1999) found that teams performed better in the face of non-routine events when they took less time to engage in task prioritization or task distribution activities.

### Cognition

While such constructs have not been examined extensively within examinations of team adaptation, certain researchers have suggested that emergent states are salient when considering team adaptation (Burke, Salas, & Diaz, 2008; Burke et al., 2006(c)). Furthermore, of the work that has considered emergent states, much of it has centered on various team cognitive constructs (i.e. transactive memory systems, shared mental models, etc.). For example, Margues-Quinteiro and colleagues (2013) examined police tactical teams and found that the relationship between implicit coordination and adaptive behaviors is positively moderated by team transactive memory systems. Similarly, Uitdewilligen, Waller, and Pitariu (2013) examined undergraduate student teams engaged in a command-and-control firefighting simulation and detailed how teams adapted their shared mental models over time in reaction to a task situational change and the resulting implications on team performance. Likewise, Marks and colleagues (2000) demonstrated the salient role that team mental models play as they found that these cognitive structures are even more important in teams that face non-routine tasks.

### Team Mediators Summary and Future Opportunities

As detailed above, while only a limited amount of research focused on team adaptation has considered intervening variables that may shape the relationship between team adaptation process and adaptive outcomes, those that have done so, have primarily focused on other categories of team processes (communication and coordination). Therefore, there is an opportunity for future research to give greater attention to the role that other team emergent states may play within the team adaptation nomological network. For example, opportunities exist to consider the role that constructs such as team empowerment may play within the team adaptation nomological network. Such considerations are especially salient for NASA's ICE missions given the increased autonomy and empowerment that mission crews are likely to possess (e.g., Vassev et al., 2012).

### Empowerment

While initially considered an individual-level construct (e.g., Spreitzer, 1995), more recently researchers have extended considerations of empowerment to the team-level of analysis (e.g., Kirkman & Rosen, 1999). Here, team empowerment has been defined as members' perceived authority and responsibility for work outcomes (e.g., Hechanova-Alampay & Beehr, 2001). Similarly, Kirkman and Rosen (1999) building upon the work of Spreitzer (1995) viewed team psychological empowerment as including four dimensions: *potency* – team members' collective belief regarding their effectiveness, *meaningfulness* – team's task is valuable and worthwhile, *autonomy* – level of discretion over its task, and *impact* – significance of the team to organizational objectives. While team empowerment has gained in prominence within the organizational team literature (e.g., Maynard, Gilson, & Mathieu, 2012), it has only been considered in a single study involving adaptation. Namely, within their study of Dutch banking teams, de Jong and colleagues (2004) found support for a relationship between empowerment and adaptive behaviors at the individual- but not team-level of analysis. Additionally, while he did not consider empowerment as a composite construct, Langfred (2007) examined MBA teams and demonstrated that teams who restructured in response to conflict also reduced individual autonomy levels. Accordingly, given this relationship with a dimension of empowerment (i.e., autonomy), we recommend that future researchers examining team adaptation also assess its potential relationship with team psychological empowerment as well as the four dimensions that make up such perceived feelings regarding team authority and responsibility. In particular, such work is needed given that meaning within work has been demonstrated to reduce the level of stress felt by high job demands (e.g., Bakker, Hakanen, Demerouti, & Xanthopoulou, 2007; Britt & Bliese, 2003).

## Team Adaptive Outcomes

As mentioned previously, a primary reason for considering team adaptation is to better understand its implications on team performance. Accordingly, the vast majority of studies included in our review of the literature examined the relationship that team adaptation has with various team-level outcomes. Interestingly, in terms of the impact that team adaptation has on team-level outcomes, the picture is fairly consistent. In fact, each of the studies that have examined the impact of adaptation has demonstrated a positive relationship with the outcome variable included. For instance, LePine (2003) was one of the first studies to actually measure team adaptation as a process and his study evidenced a positive relationship between role structure adaptation and team decision making performance.

Likewise, research has demonstrated positive relationships between adaptation and performance (DeChurch & Haas, 2008; DeRue et al., 2008; Gibson & Birkinshaw, 2004; Gorman et al., 2010; Hollenbeck et al., 2011; Johnson et al., 2006; van der Vegt, Bunderson, & Kuipers, 2010; Woolley, 2009), mission effectiveness (Diedrich et al., 2005), decision making effectiveness (LePine, 2005; Randall et al., 2011; Resick et al., 2010), and innovation (Vera & Crossan, 2005). To be more precise, research has demonstrated that flight crews who adapt (although not measured) encountered a reduction on errors (e.g., Waller, 1999). Additionally, DeChurch and Haas (2008) documented that teams that altered their plan were able to complete a scavenger hunt in less time.

### Team Adaptive Outcomes Summary and Future Opportunities

In part, based on the way that adaptation has been conceptualized, it is not surprising to see the consistent positive relationship evidenced to exist between adaptation process and various team-level outcomes. Indeed, each study included in our review has evidenced a positive relationship between adaptation and various performance outcomes (e.g., Burke et al., 2006(c); Burtscher et al., 2010; Gorman et al., 2010; Klein & Pierce, 2001; Manser et al., 2008; Marks et al., 2000) which coincides with theoretical discussions of team adaptation (e.g., Burke, Hess, & Salas, 2006(a)). However, research at the individual-level of analysis focused on adaptation has demonstrated that adaptation does not universally result in positive outcomes. For example, Denrell and March (2001) suggest that imprecise adaptation can have adverse impacts on individual outcomes. Accordingly, we stress the need for work to consider the *dark side* of team adaptation (e.g., LePine, 2003) and under what conditions adaptation may actually impair team performance, as there is limited research in this area.

Additionally, future research that focuses on team adaptation process could examine its impact on team creativity as this construct has become increasingly popular within the broader organizational team literature. In fact, team creativity has been studied extensively of late and has been noted as a salient factor in shaping team effectiveness (e.g., Vera & Crossan, 2005). Such creativity has been defined as engaging in activities that may develop novel solutions for a variety of tasks (e.g., Drazin, Glynn, & Kazanjian, 1999). Accordingly, team creativity is apt to be a by-product of team adaptation process and as such is a ripe area for future research. Likewise, given the underlying assumptions of Ilgen and colleagues' (2005) IMOI framework, it is likely that teams that encounter early team creativity outcomes likely enter into a virtuous spiral (e.g., Lindsley, Brass, & Thomas, 1995) whereby they are able to more easily adapt when faced with subsequent triggers. As such, future research could benefit from considering a potential reciprocal relationship between team adaptation process and team creativity.

Likewise, our review indicates that no studies have considered the impact that team-level adaptation may have on organizational- or individual-level outcomes. In response, we strongly encourage future research in this area to consider the cross-level implications of team adaptation. For example, research has yet to consider the impact that working in a team that is or is not able to adapt has on the individual members of the team in terms of individual-level affective reactions (e.g., Mathieu & Gilson, 2012). This gap in the team adaptation literature is surprising given that researchers have discussed the need to consider individual-level affective reactions such as satisfaction, propensity to leave a job and wellbeing (e.g., Medina, Munduate, Dorado, Martinez, & Guerra, 2005). However, given the increased importance that employee turnover has in certain industries, understanding such affective reactions and factors that shape such reactions are becoming more salient. Accordingly, if teams that are able to adapt in the face of triggers enhance team member affective reactions, there are multiplicative positive results that can accrue from such adaptation given its team- and individual-level positive implications.

## Team Resilience: A Review of the Literature

To date, the team resilience literature is not as developed as the team adaptation literature. However, as elicited below and highlighted in Table 4, we reviewed the work that has examined team resilience to date. Resilience has been examined within organizations at the individual-level of analysis where it has been studied in various contexts such as business organizations (e.g.,

Riolli & Savicki, 2003), military (e.g., Palmer, 2008), sports (e.g., Galli & Vealey, 2008), education (e.g., Gu & Day, 2007), and communities (e.g., Brennan, 2008). Likewise, while resilience was first examined within the developmental psychology and childhood psychopathology literatures (e.g. Garmezy, 1991), resilience has been studied in various literature streams including health and psychology (e.g., Bonanno, 2004; Fergus & Zimmerman, 2005), military psychology (e.g., Bartone, 2006), as well as organization and management studies (e.g., Lilius, Worline, Dutton, Kanov, & Maitlis, 2011; Waldman, Carmeli, & Halevi, 2011).

Within such work, researchers have attempted to quantify the dimensions that make up individual resilience. For example, Hoopes (2012) summarized the components that are included in the Personal Resilience Questionnaire (PRQ) (ODR, 1993). Specifically, the PRQ suggests that resilient individuals are positive, organized, proactive, focused and flexible. Similarly, Gillespie, Chaboyer, Wallis, and Grimbeek (2007) examined operating nurses and found that hope, self-efficacy, control, coping, and competence led to more resilient nurses. Likewise, individual-level resilience research has largely focused on understanding factors (or what has been referred to as protective factors) that contribute to individual resilience and these have included constructs such as: optimism, sense of meaning, self-efficacy, flexibility, and close relationships (e.g., Masten & Reed, 2002).

Accordingly, much of the individual-level resilience research has focused on individual dispositions that provide one the capacity to be resilient when needed; however, given that many considerations of individual resilience highlighted the impact that teams and the relationships that exist between team members (e.g., Reivich, Seligman, & McBride, 2011; Riolli & Savicki, 2003; Paton, Johnston, Clarke, Violanti, Burke, & Keenan, 2008), research has more recently considered the topic of team resilience. Below we use a similar framework as utilized in our review of team adaptation above as we highlight the findings of research that have considered antecedents and outcomes of team resilience. Likewise, we detail some of the key themes involving the design and measurement of team resilience and close each section by highlighting some of the more fruitful directions for research.

**Team Inputs and Team Resilience**

Leveraging a case study methodology, Gomes and colleagues (2014) examined teams in a simulated nuclear power plant emergency and noted that certain factors appeared to be sources of team resilience. Specifically, these authors leveraged work suggesting that more diverse teams make better decisions (e.g. Hong & Page, 2004) to suggest that diversity of team members may enhance team resilience. Indeed, Sutcliffe and Vogus (2003) suggest that three factors are key to group or team resilience, including the accumulated knowledge that promotes new knowledge acquisition, group diversity that can expand the group's ability to sense, acknowledge, and regulate complexity, and experiential diversity that can broaden a group's ability to grasp the situation and cope with the details. In addition to the knowledge on the team, empirical research suggests that other team factors influence team resilience. Stephens, Heaphy, Carmeli, Spreitzer, and Dutton (2013) found that, at the individual level, emotional carrying capacity positively influenced individual resilience and mediated the relationship between closeness and resilience. Similarly, at the team level, emotional carrying capacity positively influenced team resilience and mediated the relationship between trust and resilience.

The case study conducted by Gomes and colleagues (2014) also emphasized the important role that the team leader has in shaping the level of resilience present within the team. The focus

on leadership and its positive impact on team resilience is in keeping with prior work in the area of team effectiveness (e.g., Kozlowski & Ilgen, 2006). In fact, Harland, Harrison, Jones, & Reiter-Palmon (2005) demonstrated that *transformational leadership* impacted subordinate resilience and that a training program focused on this leadership style resulted in higher levels of resilience for up to fifteen weeks following the training intervention. Burke and colleagues (2006(c)) suggest that shared leadership may provide teams the requisite level of autonomy needed to engage in adaptation as well as resilience (e.g., van der Kleij et al., 2011) as a by-product of enhanced team processes (cf. Hackman & Oldham, 1980). Similarly, van der Kleij and colleagues (2011) empirically studied team resilience and found that resilience was higher when shared leadership was enforced through transformational leadership behavior training. Moreover, Lundberg & Rankin (2014) found that resilience was a positive side effect of improvised work; however, there could be a negative side effect by getting stuck in an improvised role. As such, leaders may not only help build resilience but maintain resilience by assisting in the clarification of roles, reconciling task incongruities, and providing resources and time for followers (Campbell, Campbell, & Ness, 2008).

Furthermore, Gomes and colleagues (2014) also found that the physical environment played a role in team resilience. Specifically, their investigation showed evidence that the way individuals were distributed in the room as well as whether the team had access to visual support (e.g. display panels, tactile table, or computer resources) was salient for increasing team resilience. Given the various analogous simulated environments that are being examined for ICE missions, it could be interesting to consider the varied physical environments that exist in such simulations and consider their impact on team resilience and adaptation.

This study was also interesting given that it also emphasized that team size also plays an important role shaping team resilience; that is, if the team is too large, then members can become disengaged or the utility of their contributions is less than their cost, leading to suboptimal results. A study by Edmondson & Nembhard (2009) also provides insights about the way environments affect resilience. The authors indicate that one of the obstacles new product development teams face is organizational structures. While this attribute may create a need for the team to identify a project champion and locate resources over time, such actions made to overcome the obstacle may build boundary spanning skills and resilience.

**Team Processes and Team Resilience**

In addition to suggesting that team diversity is a salient factor that may enhance team resilience, Gomes and colleagues (2014) also highlighted the important role that team communication can have in shaping resilience. In fact, these authors found that team conversations in smaller groups and those that utilized briefing/debriefing dialogs were more resilient. Relatedly, Patterson, Woods, Cook, and Render (2007) suggest that collaborative cross-checking is critical for resilience as such processes allow erroneous assessments or actions to be detected in time to address them. Additionally, Carmeli and colleagues (2013) examined the impact of top management team (TMT) strategic decision comprehensiveness and found that this assessment of team decision making processes fully mediated the impact of TMT connectivity on both dimensions of team resilience (resilience-efficacious beliefs and resilience-adaptive capacity).

## Team Outcomes and Team Resilience

Although researchers have primarily focused on the empirical examination of antecedents of team resilience (e.g., Gomes et al., 2014; Lundberg & Rankin, 2014; Stephens et al., 2013), a few researchers have studied the ways in which team resilience may impact team outcomes. For example, West, Patera, and Carsten (2009) found that initially, team optimism positively influenced cohesion, cooperation, coordination, and satisfaction. Later, team resilience positively related to cohesion and team resilience and efficacy related to cooperation; team optimism was positively related to coordination and satisfaction at later stages. Other researchers provide anecdotal evidence of the way team resilience matters. Specifically, Stevens, Galloway, and Lamb (2014) rated the resilience of junior office submarine navigation teams. Using EEG headsets, the authors found that teams with higher resilience ratings may have been less challenged by routine and unexpected events (i.e., they did not exhibit the neurodynamic patterns suggesting neurophysiologic synchrony).

Interestingly, our search for empirical team resilience literature returned very few exemplars, and of those that we identified, none focused on the way resilience impacted team performance. However, conceptually, there is a strong argument that team resilience is salient for team performance, especially in the face of a disruptive event, threats, or crisis. When faced with threats, individuals proceed with cognitive narrowing, where information processing is reduced, and control is heightened, leading to rigid responses (Staw, Sandelands, & Dutton, 1981). As well, threats often lead decision-makers to simplify and streamline the information that they seek and use in coming to a decision, "consequently narrowing the range of possible behavioral responses" (p.94, Sutcliffe & Vogus, 2003).Yet, researchers suggest that resilient teams "nurture confidence in their members' abilities to overcome the odds" (p. 62, Campbell et al., 2008). Being resilient, teams may feel in control of their destiny in stressful situations, can promote creative brainstorming, and draw on unused resources and capabilities to respond effectively to the most challenging scenarios (Weick, Sutcliffe, & Obstfeld, 1999; Campbell et al., 2008; Contu, 2002). Moreover, team resilience can provide adaptability to future threats by creating resources that can be drawn upon, combined, or molded to new situations as needed (Sutcliffe & Vogus, 2003; Wreathall, 2009). Taken together, it is clear that more research is needed to understand the value of team resilience on team outcomes, specifically performance, in routine situations as well as in crisis, and in teams working together over long durations.

## Study Design and Measurement of Team Resilience

As detailed in Table 4, there are various means by which team resilience has been studied and operationalized. That said; recently researchers have begun to operationalize resilience through the use of survey instruments as this approach was leveraged quite well at the individual-level of analysis (see Bartone, Ursano, Wright, and Ingraham (1989) Dispositional Resilience Scale for example). Specifically, McCann, Selsky, and Lee (2009) measured organizational resilience with a 5-item survey. Likewise, given that our view of team resilience as an emergent state is consistent in part with Carmeli and colleagues' (2013) view of the construct, it is interesting to look at how they actually measured resilience. In particular, building upon prior self-efficacy scales (e.g., Chen, Gully, & Eden, 2001), they asked top management team (TMT) members from 74 organizations three items to assess resilience efficacious beliefs:

- "When encountering a new and difficult task, we are certain we can do it successfully."
- "We will be able to successfully overcome many new challenges that face us."
- "Even when the situation is challenging, we can do what is necessary rather successfully."

Likewise, they asked three questions which assessed team members' resilience-adaptive capacity (all reverse coded):

- "We do not make the necessary changes and adaptations to respond effectively to changes in the industry."
- "We stick to our old ways and do not adjust to the changing circumstances in our industry."
- "We do not adjust to the changing conditions in the environment, because we do not make the vital changes and implement them effectively."

In the research by Stevens and colleagues (2014), a rating system was used to evaluate team resilience. Table 5 provides the ratings levels given to teams based on an assessment of dialogue, decision making, critical thinking, bench strength, and problem-solving capacity.

**Team Resilience Summary and Future Directions**

We agree with Rahimnia, Nazemi, and Moradian (2014) who state that "it is essential to do more studies to establish a deeper understanding of resilience at the group level" (p. 1974). Indeed, our review revealed a small but burgeoning interest in team resilience. However, within this literature there were inconsistencies and gaps that we tried to reconcile and highlight. In particular, to facilitate the development of team resilience research, we argued that team resilience is an emergent phenomenon; one that can be developed through training and learning. As such, team resilience may fluctuate over time, building and degrading over time. Indeed, the study by West et al. (2009) suggests that the importance of team resilience to cohesion and cooperation changed over two time periods for newly formed teams. Thus, an investigation to understand the nuances of team resilience over longer time periods is an opportunity for future research. Fortunately, research methods are continually developing in regards to longitudinal analyses and will be invaluable in studying analogous simulated mission teams in preparation for long duration space exploration (LDSE) missions given the longer tenure that such teams will experience.

In addition, our review found that researchers have generally focused on the antecedents of resilience. These studies highlight the importance of certain factors for increasing team resilience including diverse teams (Gomes et al., 2014), emotional carrying capacity (Stephens et al., 2013), the team leader (Campbell et al., 2008; Gomes et al., 2014; van der Kleij et al., 2011), autonomy (e.g., van der Kleij et al., 2011), improvised work (Lundberg & Rankin, 2014) the physical environment (Edmondson & Nembhard, 2009; Gomes et al., 2014), team communication (Gomes et al., 2014), and decision making processes (Carmeli et al., 2013). Further, literature provides preliminary evidence that team resilience influences team outcomes in general (West et al., 2009), and more specifically, the team's ability or inability to perform in routine and crisis events (Stevens et al., 2014; Weick, 1993). Given that the extant conceptual literature suggests that resilience is important for responding to disruptions, threats, and crisis (e.g., Weick et al., 1999; Campbell et al., 2008; Contu, 2002), future researchers need to target efforts to uncover these

effects. Moreover, we believe that specific insights may be revealed through the use of our proposed framework; that team resiliency may be an input and outcome of the team adaptation process; affecting transition, action, and interpersonal processes differentially. Thus, researchers can be guided in this line of inquiry through our proposed model to investigate the link between team adaptation, team resilience, and team performance.

## Review of Applicable Research in Analogous Settings

Beyond the literature that we obtained and reviewed from the broader organizational team and organizational psychology literatures, there have been numerous studies that have examined teams within analogous settings that simulate space missions. The purpose of analog settings is to extract lessons learned from teams functioning in these settings that can be applied to future space missions. The analog settings are necessary given the difficulty in accessing sufficient data on teams in space. In particular, work described here will include missions conducted in MARS500, NASA Extreme Environment Mission Operations (NEEMO), Human Exploration Research Analog (HERA), the Hawai´i Space Exploration Analog and Simulation (HI-SEAS) and other similar contexts which have received substantial interest over the past decade as they provide "a good arena to test psychological aspects of long duration missions before real interplanetary missions are pursued" (De La Torre, van Baarsen, Ferlazzo, Kanas, Weiss, Schneider, & Whiteley, 2012, pg. 588).

As expected, teamwork also appears salient within such settings (e.g., Kahn & Leon, 1994, Sandal, Leon, & Palinkas, 2006) but may also create challenges. For instance, Lapierre, Bouchard, Martin, and Perreault (2009) discuss a physical altercation that occurred with team members within a State Biomedical Institute of Russia (IBMP) isolation chamber. Interestingly, while publications about analog settings discuss team adaptation and resilience, like our earlier review of the literature, there has not been a great deal of studies that have specifically addressed team adaptation or resilience by actually measuring such constructs. However, in the section below, we make an attempt to integrate any applicable work that has been conducted within analogous settings that may be valuable for the current discussion centered on the team adaptation framework that we introduce here.

### Antecedents Considered in Analogous Settings

While adaptation specifically has not been the primary focus of most of the studies within analogous settings (a gap that we highlight below as needing to be addressed in future research), we did find a few studies that are still relevant to the conversation. In particular, we found studies which would suggest that there are specific antecedent constructs that may increase team adaptation within analogous settings. For instance, the individual traits that are brought together when a team is initially built will likely play an especially salient role in subsequent team adaptation. Support for this contention comes from Bishop and colleagues (2010) that point to the prior experience in the arctic Mars simulation as relevant for team adaptation. Likewise, Suedfel, Brcic, Johnson, and Gushin (2015) conducted interviews of 20 retired Russian cosmonauts and also found that those with more experience tended to report a higher level of active coping.

Beyond experience, there have been other team composition variables that have been examined within analogous settings that may be relevant to team adaptation and resilience. Namely, Leon, Sandal, Fink, and Ciofani (2011) studied a North Pole Expedition team and

provide support that the compatibility between members allowed for each member to better cope with the challenges that the team faced. Likewise, in terms of personality, research would suggest that those with high levels of instrumentality and expressivity coupled with lower levels of interpersonal aggressiveness may be ideal for ICE settings (e.g., Sandal, Bergan, Warnche, Vaernes, & Ursin, 1996; Sandal, Endresen, Vaernes, & Ursin, 1999). However, some researchers have questioned whether these same personality characteristics will maintain salience as mission duration becomes extended. In fact, Ursin, Comet, and Soulez-Lariviere (1992) suggest that moderate levels of motivation, flexibility, and empathy and low levels of aggressiveness and vitality may be more ideal for longer missions. Additionally, research has evidenced that possessing flexibility in terms of coping strategies (e.g., Leon, Atlis, Ones, & Magor, 2002; Leon, McNally, & Ben-Porath, 1989; Leon et al., 2011) as well as compatible coping strategies amongst the team may help individuals deal with situations during missions (e.g., Atlis, Leon, Sandal, & Infante, 2004). Furthermore, a survey of 576 employees of the European Space Agency suggests that cultural diversity plays a role in the ability of people to interact with teammates (e.g., Sandal & Manzey, 2009) and therefore, may impact team adaptation and resilience. Specifically, there appears to be a difference across space agencies in terms of the extent to which written procedures are utilized versus relying on expert opinions which could certainly alter the way mission members respond to a disruption (e.g., Kanas & Manzey, 2003).

Other articles suggest additional variables that extend beyond initial composition factors may impact team adaptation and resilience. For instance, Urbina and Charles (2014) provide a detailed description of the Mars500 mission and mention that the crew had to address several out of limit (OOL) events. Specifically, the crew had to address a scrubber that impacted CO2 levels as well as the crew having to address power loss. However, even though the team was exposed to such disruptions, team adaptation or resilience was not explicitly measured in this study and yet it appears that the team did in fact adapt as the authors state that over the course of the mission, the team made decisions for themselves on how to address such disruptions rather than asking for help from mission control. That said, Urbina and Charles (2014) suggest that the training program that the crew was exposed to may have played a role in the team being able to ultimately adapt in this mission.

The training program referenced by Urbina and Charles (2014) was conducted as part of the final selection process and included psychological coping techniques through their exposure to stressful situations as well as afforded the team the opportunity to build a bond. Similarly, Lapierre and colleagues (2009) echoed the sentiment that creating a bond is important in creating the foundation upon which adaptation can occur. In fact, they suggest that activities such as spending free time together by sharing meals and watching movies may assist the team in this regard. Finally, leadership and specifically, sharing the leadership role has been evidenced to be a potentially strong contributor to the adaptation that occurred within a simulated Mars habitat (e.g., Bishop et al., 2010).

**Adaptation Processes Considered in Analogous Settings**

The literature regarding teams in analogous settings also provides evidence of team adaptation, as defined earlier, whereby adjustments to team processes were made in response to a disruption or trigger. For instance, Urbina and Charles (2014) discussed an episode in which the Mars500 crew had to address a power malfunction and work collectively to save food and assess the magnitude of the disruption. While the authors do not provide enough information to tell which type of team processes where ultimately adapted during this episode, they do suggest that as a result of this disruption, the crew realized "the importance of the implementation of a full culture of transparency in the

communication from mission control" (pg. 381). Similarly, Gushin, Shved, Vinokhodova, Vasylieva, Nitchiporuk, Ehmann, and Balzs (2012) found that in a MARS105 experiment, one group changed their communication strategy after receiving more autonomy while the other subjects maintained their prior communication strategy. However, more fully understanding the impact of changes in autonomy on the team adaptation nomological network is needed given its salience to long-duration missions.

Suedfel and colleagues (2015) examined coping strategies utilized by Russian cosmonauts and found that problem-oriented strategies were used significantly more than emotion-oriented strategies. Interestingly, Palinkas (2003) suggests that individuals are able to adapt to ICE environments more quickly if they do not rely on their crew members for social support – a finding that was also evidenced by Sandal, Gronningsaeter, Eriksen, Gravrakmo, Birkeland, and Ursin (1998). However, Leon and colleagues (2002) provide an interesting contrast to such findings in their study of a three-couple expedition to the Arctic. Namely, while crew members did not go to other teammates for support, they did in fact rely on their couple for assistance and support. Accordingly, it may be fruitful for future research to examine whether team interpersonal processes are managed differently within such long-duration missions or whether certain dimensions of team processes compensate for others that receive less attention given the nuances of such missions. These are some of the empirical questions that should be examined by future researchers.

**Team Mediators Considered in Analogous Settings**

Team mediators are those intervening variables that help explain variation in team outcomes. In analogous settings, we find that mediators may play a role between team adaptation and adaptation outcomes. While adaptation was not the focus of their study, Wu and Wang (2015) found that cohesion scores of the three Chinese crew members who were part of the simulated experiment within an analog space station at Beihang University were lower at the beginning of the experiment as compared to later time periods. The authors suggest that this may "indicate that when the crewmembers were trying to adapt to their new environment and crewmates…, they were confronted with some issues or conflicts" (pg. 4). Cohesion has likewise been evidenced as being related to adaptation (individual-level though) within space missions as research on Mir missions found that crew members experienced increasing levels of cohesion at the beginning of the mission as they were adapting to one another and their new environment (e.g., Ritsher, Kanas, Ihle, & Saylor, 2007). Accordingly, adaptation (at least at the individual-level) has been tied to cohesion but future work should examine teams in analogous situations and track the development of cohesion and other emergent state constructs over time to ascertain the impact that such development has on the processes of adaptation enacted by the team.

Another mediator is suggested by the work of Urbina and Charles (2014). In their study, the authors state that constancy of work played a key role in maintaining team motivation within the Mars500 mission. Likewise, the authors mention that while conflict resolution was noted, it seemed to be very subtle in that team members relied on implicit compromises so that frictions never escalated to extreme levels. Additionally, each team member played a videogame in their free time to partially ameliorate the impact of sensory deprivation as well as give the team another means to maintain their collective bonds.

### Adaptive Outcomes Considered in Analogous Settings

Again, while researchers mention adaptation and resilience within studies of teams in analogous settings, given that neither construct has been explicitly measured within such studies, there is not a clear link between adaptation and resilience and specific team-level outcomes within analogous settings. However, within their study of a crew of seven individuals who spent four months in a simulated Mars habitat, Bishop and colleagues (2010) found that negative moods declined for most participants which they suggested was an indication of individual-level adaptation. Similarly, a three-man crew in a Mir space station simulator also demonstrated improved mood and social climate and the authors suggested this documented an adaptation effect (e.g., Kanas, Weiss, & Marmar, 1996).

### Future Opportunities to Consider in Analogous Settings

As mentioned several times in the sections above, while numerous research projects within analogous settings have been conducted to better understand how the individuals and teams will be able to handle such long-duration missions, we did not find specific studies that truly assessed team adaptation and resilience. Accordingly, the first step in gaining an understanding of such constructs within analogous settings will be to explicitly measure adaptation over the course of such missions to understand the dynamics at play. Thus, we echo the sentiments of Kanas and colleagues (2009) who state that "more empirical work is needed on defining individual characteristics and group characteristics that promote optimum coping and adaptation during different kinds of multinational space missions, both short- and long-duration" (pg. 665). Subsequently, we provide our targeted suggestions centered on how such research should be conducted going forward. Further, we provide a number of potential interventions and countermeasures for teams in ICE contexts. These included: focusing on team composition, the way training is carried out before the mission, the development of shared mental models, and the potential of training during the mission such as through the development of tools such as the Mission Execution Crew Assistant (MECA). In addition, we also suggest that it is important for the team to have the support and resources that encourage a learning culture and facilitate team communication and debriefs.

## Interventions and Countermeasures to Increase Team Adaptation & Resilience

Given the increased duration of missions, the multicultural nature of teams, as well as their increased heterogeneity and increased autonomy that are likely within ICE missions, countermeasures that can minimize the detrimental impact of such changes are essential (e.g. Leon, 1999). However, systematic assessments of potential interventions to enhance levels of adaptation and resilience within teams is needed as this is a topic that has, of yet, not received significant empirical consideration. That said; based on our review of the literature, there is some support for the following interventions as being potentially valuable to enhancing team adaptation and resilience, especially for teams that will work for long durations in ICE contexts. In part, some of these interventions have been valuable at the individual-level of analysis in terms of adaptation and resilience and thus may likewise be conducive at the team-level. Likewise, these interventions are primarily focused on the team itself as compared to the individual team members as some have suggested that interventions may enhance resilience (and adaptation) even more by capitalizing on group interactions (e.g., Boermans et al., 2012).

**Team Composition**

The selection of team members will likely shape the resulting adaptation and resilience present within such a team. Researchers have focused on the way performance is influenced by dispositional characteristics (Pitcher & Smith, 2001; Pitsis, Clegg, Marosszeky, & Rura-Polley, 2003; Van Knippenberg, Kooij-de Bode, & van Ginkel, 2010) and personality characteristics which were identified using the five characteristics of emotional stability, extraversion, openness, agreeableness, and conscientiousness, (Barry & Stewart, 1997; Moreland, Levine, & Wingert, 1996; Neuman & Wright, 1999). In fact, Sandal, Leon, and Palinkas (2006) provide a synthesis of work which has examined the impact of personality characteristics on individual outcomes within ICE settings including the idea of *absorption* or a person´s ability to become engrossed in a particular activity and as a result not attending to other events in one´s life (Atlis et al., 2004). Future research could benefit by considering the personality and individual characteristics that exist within the team to ascertain the impact that such factors have on team dynamics and performance. For example, does the presence of group faultlines (e.g., Rico, Sanchez-Manzanares, Antino, & Lau, 2012) in terms of individual characteristics assist or impede team adaptation and resilience?

However, much is still unknown about the benefit or difficulties in regards to adaptation and resilience as a result of having diverse teams (e.g., Gomes et al., 2014). Indeed, there is evidence that there have been differences in the way crews worked together on past NASA missions that may need to be overcome for a multi-national, diverse crew on a long-duration mission. For example, in Stuster's (2010) report on journal entries in *Behavioral Issues Associated with Long-Duration Space Expeditions: Review and Analysis of Astronaut Journals, Experiment 01-E104 (Journals): Final Report* statements appeared that suggest compositional obstacles may emerge:

W carries on his twice-daily arguments with his mission control center as usual, but I've learned that what appears to an American to be a dispute is actually just their normal mode of conversation. To me it's interesting to hear the difference in the US and Russian interactions. US radio conversation is minimal—sometimes we go all day without saying a word to Houston. The Russians, however, have marathon discussions on nearly every subject that comes up. (p. 15)

We had our first heated discussion, yesterday. It was over lunch and he flew off very emphatically that irresponsible scientists [were] trying to find favor with politicians—I am not sure if we were getting towards oil and global warming, but he went on for about 5 minutes, got interrupted by an activity he had to do, and came back to say he realized he had been very adamant, but he felt it was all a big problem with scientists pushing theories as fact to a gullible populace, and worse, scheming politicians. I just listened and let it all calm down. I cannot afford to have arguments of any type with [my crewmate]. (p. 21)

I get the feeling the US and Russian teams are a little stressed with each other. An incredibly unnecessary and pedantic US procedure to ___ should have no consequence to the Russian side, but my whole morning activity carrying out this procedure was cancelled, because it involved X helping me read a meter for 5 minutes, so opening the door to have the Russians review and probably ridicule the US procedure. Houston simply told me when I pressed them that the Russians had not blessed the procedure, and I jumped to these conclusions. It is probably a reaction by the Russians to Houston nagging Moscow about the upcoming ___, making them take a bit of their own medicine. I am not sure what X and I can do to ease all this. At least we can work together calmly and make that evident to Moscow and Houston. (p. 31)

These statements suggest that cultural and interpersonal issues may impact the effectiveness of team processes; and therefore may impact adaptation and resilience. To overcome these issues, it may be necessary for a leadership role to mitigate the hypersensitivity and exaggeration of small issues. For example, Bartone's (2006) work on leader hardiness would indicate that having a leader who possesses a personality consisting of hardiness should help the team be more resilient. Another approach, described below is to better train teams to overcome compositional issues.

**Training**

The U.S. Military, in particular, has relied heavily on training programs to enhance individual and team resilience. For instance, the U.S. Army Master Resilience Trainer (MRT) course centers on providing noncommissioned officers (NCOs) resilience skills as well as training these individuals to train the rest of the units (i.e. train-the-trainer methodology) so as to enhance the overall resilience levels of such units. A part of this training is based upon the Penn Resilience Program (PRP) curriculum which has been empirically validated (e.g., Seligman, Ernst, Gillham, Reivich, & Linkins, 2009).

As well, Morie, Verhulsdonck, Lauria, and Keeton (2011) propose a training approach that may help crew members overcome the adverse effects of stress and trauma by attending to personal well-being and positive group interactions. Their approach is through the use of virtual worlds to provide formal and fun simulations for crew members (Morie et al., 2011). Their report on *Operational Assessment Recommendations: Current Potential and Advanced Research Directions for Virtual Worlds as Long-Duration Flight Countermeasures*, presents a number of capabilities that may be provided or developed through interactions with virtual worlds. In particular, the authors suggest that paramount for long-duration space flights will be training for resiliency, "the ability to withstand hostile conditions and long-lasting adversity by using techniques to maintain a strong and positive outlook on a group and individual level" (p. iv, Morie et al., 2011).

In particular, Morie and colleagues (2011) identify some key factors that are obstacles to the development and maintenance of resilience including (1) intercultural factors that will challenge group communication; (2) preparedness in terms of physical, intellectual, and psychological resilience; and (3) tracking procedures for gaining information about the mental and physical responses made during situations. Moreover, from interviews conducted by these authors, they found that specific training on resilience was, at the time of their study, lacking when an employee indicated "I don't think there was any training that specifically catered to that [resiliency]" (p. 16). Yet, the authors advocate that resiliency will be critical for the success of crews going on long-duration space missions where stressful situations and adverse conditions will likely be encountered.

**Shared Mental Model Development**

In part, the benefits of training initiatives focused on team adaptation and resilience can be attributed to the development of shared mental models within the team as such cognitive structures are often the by-product of such training programs. Mental models are basic cognitive structures used by team members to explain what is going on in the world, draw inferences, and make decisions (Cannon-Bowers, Salas, & Converse, 1993). Over time the content of team members'

mental models evolve as they encode, process, and store new information gathered through team interaction (McComb et al., 2007). This evolution continues until the content of the team members' mental models has become similar. These resulting cognitive structures are often called shared mental models (Cannon-Bowers et al., 1993) and have a positive relationship with team performance (DeChurch & Mesmer-Magnus, 2010). In part, the increased performance may occur because team members with shared mental models have similar expectations about the way the team will function and the responsibilities assumed by teammates (Marks, Sabella, Burke, & Zaccaro, 2002).

Burke, Wilson, and Salas (2005) propose that creating resilience may take compatible cognitive frameworks, such as the form of shared mental models, training of monitoring and back-up behaviors so that errors can be caught earlier, and by having regulatory agencies and associations that help compile and update the complexities of competencies needed. As such, team interactions that build shared mental models about processes and resources, such as a transactive memory system (Lewis, Lange, & Gillis, 2005), may help members prepare for routine and non-routine situations. Thus, there may be benefits to creating a training that builds shared mental models about the way team adaptation processes will unfold. However, it has been shown that shared mental models may be difficult to develop during interactions (Levesque, Wilson, & Wholey, 2001) and degrade over time (Mathieu, Heffner, Goodwin, Cannon-Bowers, & Salas, 2005). As such, there needs to be a mechanism for teams to help call upon mental models and maintain mental models when facing an adaptation trigger.

**Tools such as Mission Execution Crew Assistant (MECA)**

Mission teams may benefit from having a mechanism to evaluate adaptation triggers and receive possible input and alternative approaches for adaptation. As detailed by Neerincx and colleagues (2008), tools such as the Mission Execution Crew Assistant (MECA) are being developed to add to the cognitive capacities of human-machine teams during planetary exploration missions. Such tools hold the potential to be invaluable when the mission team faces disruptions as such tools can help the team assess the situation, and determine viable solutions and thus, enhance the mission team's situational awareness and sense making. Likewise, leveraging MECA-type tools should help mission teams develop and maintain shared mental models (see above), or the team's overall and scenario-specific knowledge.

Mission teams could potentially use these tools to continue to train (see point above) during the mission to maintain performance levels needed to accomplish mission objectives. Continual emphasis on the tools needed to adapt and be resilient as a team is key given that resilience, in particular, is not built on a single event, but instead is built over time (e.g., Department of the Army, 2010, p. 32). Each of these by-products of leveraging these human-machine interfaces hold the potential to be a key asset to mission teams given the communication delays with mission control that might be possible in future LDSE missions creating the need for greater self-direction, adaptation, and resilience. Likewise, these tools could be used during the mission crews "down time" such as during the flight to Mars which could allow for adaptation and resilience to be developed not just during the training activities on ground but also during flight. However, given an increased reliance on such tools in future missions, it may become more imperative that crew member selection includes consideration of individual´s ability to leverage technology to access information.

### Encourage a Learning Culture

In line with Rochlin's (1999) suggestion regarding learning, Smith, Blandford, and Back's (2000) examination of London Underground control rooms suggests that it is beneficial for team resilience to have a culture that enables team members to learn in an exploratory way, reflect on their actions, and engage in problem solving. Likewise, Wybo (2004) suggested that learning is "paramount for groups trying to build resilience (p. 32) and thus, creating a culture in which such learning is valued is essential. Accordingly, addressing the creation of a learning culture within the mission crew as well as within NASA as a whole appears to be a salient intervention that deserves some attention.

### Team Communication and Debriefs

A prominent approach for enhancing individual resilience which has likewise been leveraged to enhance team performance is team debriefing (e.g., Boermans et al., 2012). While some of the tools described above, including virtual worlds and MECA, may provide decision making support in the moment, our review leads us to suggest that debriefing situations will benefit future adaptation and resilience. Indeed, creating a way to track, store and filter past actions may be used to remind teams of their mental models at later time periods. Indeed, in conceptual models of team adaptation, researchers argue that a feedback mechanism is a salient input for future adaptation (e.g., Burke et al., 2006 (c)).

Further, researchers show that team planning processes are important over time (DeChurch & Haas, 2008). Specifically, team performance can be attributed to team planning efforts in setting deliberate and contingency plans initially and reactive plans later in team work. As well, researchers have investigated the importance of plans for behavioral guidelines and plans for performance (Mathieu & Rapp, 2009). Over time, both types of plans were important for achieving performance. Thus, debriefing so that teams can set future plans, including deliberate, contingency, and reactive plans, may help teams stay on target when performing routine and non-routine tasks (e.g., Tannenbaum & Cerasoli, 2013).

## Conclusion from Literature Reviews of Team Adaptation & Resilience Literatures

Our review of the literature led to a unifying framework for bringing together team adaptation antecedents including team adaptability, the team adaptation process, and team adaptive outcomes. As well, the literature suggests that in part, team adaptation may both influence and depend upon team resilience. To further understand the factors that influence team adaptation and resilience, we summarized the empirical research that has examined these constructs at different levels of analysis. Our summary indicates that team adaptation is influenced by antecedents at the team level including team design, mental models, efficacy, and conflict; and at other levels of analysis, team adaptation is affected by individual cognitive ability, team roles, psychological collectivism, individual adaptive performance, learning and performance orientations as well as organizational context.

Our review also showed that the way team adaptation unfolds may be mediated by team communication and information sharing, coordination activities and team cognition. Further the benefits of team adaptation may include team performance, mission effectiveness, decision making effectiveness, innovation, and reduction of errors. While we did assess the methods in

which data collection occurred, our assessment is that the empirical studies provide at least initial insights for ICE contexts given the use of near analog populations.

In our separate review of team resilience literature, we found a limited amount of empirical investigations. However, the exemplar studies reviewed showed that team resilience might benefit from having diverse teams that provide accumulated knowledge and experiential diversity, have higher emotional carrying capacity, a team leader, autonomy, improvised work, physical environment (e.g., visual support), a smaller team size, a conducive organizational structures, and communication (e.g., debriefing). These factors may help teams achieve better cohesion, cooperation, and feel less challenged. Finally, we summarized several interventions that have been discussed as assisting teams in ICE contexts. Interestingly, several of these interventions and countermeasures were discussed during the operational assessment interviews which we conducted as part of this project. In the section that follows, we summarize the themes that emerged during our interviews of pertinent NASA personnel to learn more about their experiences with team adaptation and resilience in actual NASA missions and sponsored-analog environments.

## Operational Assessment

*"It is all about adaptation in our business…if we can't master (adaptation), it won't be a pretty picture." – Operational Psychologist*

*"For long duration flights, decision making is going to change." – Astronaut*

*"The crew will have to adapt, cannot deny something will be out of the ordinary." – Flight Director*

In an attempt to learn more about the topics of team adaptation and resilience, specifically within the context of space missions, we prepared an interview protocol and conducted an operational assessment. We prepared an initial interview protocol and then with the consultation of personnel from NASA's Behavioral Health & Performance Research Element (and in an effort to couple our interview questions with another research team), we ultimately arrived at the final interview protocol. During the period from April – August, 2015 we conducted nine 1-hour interviews in combination with the other research team. The interviewees included NASA astronauts, analog participants, ground personnel, and researchers. The above quotes from interviewees underscore the relevance and importance of adaptation and resilience for long-duration missions.

From the interviews conducted, we identified a number of key themes that informed our recommended countermeasures. We have pulled together supporting quote(s), summary statements, and general provider acknowledgements for each theme and included the information in tables below. Specifically, the key themes that have emerged include:

Types of disruption triggers. As seen in the table below, the interviewees suggest that there are at least as many interpersonal disruptions among crews as there are technical disruptions. This point is particularly interesting given that the research conducted thus far (see Table 1) has predominantly focused on technical disruptions (e.g., mechanical failures) and how teams adapt from such triggers.

## Types of Disruptions

| Supporting quote or summary statement | Provider |
|---|---|
| (at the end of the simulation) [the participant] was more touchy … than usual. | Analog Participant |
| Task disruptions may happen more often; Interpersonal [disruptions] more problematic and needs more discussion to overcome. | Analog Researcher |
| There will undoubtedly be technical problems – will spend enough time in advance to "iron out" interpersonal problems – if so, should reduce disruptions. | Astronaut |
| Most things are complex enough to require more than 1 input… most things need a team | Astronaut |
| There are cultural issues, suggested looking at military; lack of ability to get away, needs to be dealt with in real time – usually in a sub-group – it's like moving in with someone charming but later [everything they do] is annoying. No different in space – but stakes are higher | Astronaut |
| Virtual teaming –miscommunications between mission center and crew | Astronaut |
| Threats to safety are everything; teaming, interpersonal relationships, etc, how does safety play into how the team works when they are under this constant pressure. | Astronaut |
| One issue comes about from communication. There can be informal conversations between crew members and between ground and flight crew – but it is good for everyone to know and hear the operational info. The private communication has led to one group not keeping the other group informed. | Flight Director |
| Cultural differences even now [as to when international partners talk to the crew in space] | Flight Director |
| There was debris …so the crew had to enter the safe haven pod, locked in. The debris was, of course, unplanned. It is on the crew to reconfigure the schedule and get back to normal – they could not execute the plan for [that day]. | Operations Planner |
| Even split between technical and team disruptions. Bit more for technical but they "wash out quicker" Interpersonal is more chronic. | Operational Psychologist |
| There are thousands of ways things can go wrong but usually it goes right. Things like personalities, previous problems with one another, roles (are they happy with their tasks, workload), leadership – who is in charge? | Operational Psychologist |
| Problems at home (like someone loses a loved one) so it doesn't seem like member is functional; International events back home could affect ground interactions and trickle up to crew. | Operational Psychologist |
| Before they launch you can't predict the issues that will arise in the first 1/5 or last 1/5 of the mission. | Operational Psychologist |
| If an experiment has an issue or there are any changes to the timeline, the effect ripples down for days and/or weeks. | Payload Communications |
| There are stowage issues; crew needs to know where things are stowed…there is a daily stowage report – were stuff is and where it should be put back – but stuff does not always get put back. | Payload Communications |

Performance on prior disruptions. Although not often brought up by interviewees, the information in the table below suggests that thinking about longitudinal effects of adapting to disruptions will be important. The former astronauts that we interviewed shared with us the fact that from their experiences "getting over the hump" is key in terms of adaptation and resilience. Specifically, our interviewees suggested that teams can reach a stage when the crew gets brittle because of too

much success or failure. Given that there has not been a great deal of longitudinally designed examinations of team adaptation and how teams overcome multiple triggers and how their performance on such prior disruptions plays a role on subsequent adaptation episodes, this too will be a point we address in our recommendations for future research.

**Prior Performance**

| Supporting quote or summary statement | Provider |
|---|---|
| Spiral effect of disruptions and how handled- Vicious spirals where it is hard to mend relationships long-distance … until mission was over; Virtuous spirals when [crew] overcame something, it helped the mood/attitude of the team. | Analog Researcher |
| Has a lot to do with confidence and to creatively deal with surprise, a brittle team does really good in the box | Astronaut |
| After a long period can resiliency become brittle? The enemy of resiliency is complacency so can continued success negatively affect resiliency? | Astronaut |
| Can't (expect members to) maintain their performance level. | Flight Director |

Measurement of team adaptation. As shown in the table below, interviewees from different functional areas recognize the need for measurement. One interviewee in particular stressed the need for future research in this area to ascertain the best approach for measuring team adaptation. As we have mentioned previously, we agree with this sentiment and contend that by first delineating a team adaptation nomological network and clarifying how the various constructs included within the network are defined, the next step will be creating an appropriate means by which to measure each of these related (but distinct) constructs.

**Measurement**

| Supporting quote or summary statement | Provider |
|---|---|
| Participating in [a disruption] may build confidence, but that's not easy to measure. | Analog Participant |
| There were fluctuations in resilience. At [the end] point it was difficult to cope and got angry more easily. | Analog Participant |
| There is distributed knowledge and skills – but how do you know if you have enough? There needs to be assessment with an unknown required outcome. | Astronaut |
| It is important to look for signs. In terms of signs, when someone says "nothing's wrong" may need to realize that they are introverted and something is wrong. | Flight Director |
| [After a disruption] …can tell that people are still on their toes and there is a heightened sense of awareness and an atmosphere of stress. | Operations Planner |
| There needs to be a systematic way to assess the level of readiness – not just at a gut level | Operational Psychologist |
| Adaptation needs to be a critical competency with a way to verify it exists and promote the confidence that they are ready (to use it). | Operational Psychologist |
| Need a greater understanding of team resilience – make it part of self-checks as a team – make it explicit. Can lead into other issues – gateway conversation | Operational Psychologist |
| Not currently assessing adaptability quantifiably in training; yes in selection though | Operational Psychologist |

Training. Several individuals discussed the salience of training as a team as shown in the table below. This includes training the group prior to the mission as well as taking the opportunity to

train teams in flight given the longer duration of future missions. Related to the comment above regarding measurement, once the issue of measurement is addressed, a key next step will be to study training interventions within analogous settings to ascertain whether team adaptation training interventions are effectively altering the level of adaptability and resulting adaptation that occurs within the teams studied.

## Training

| Supporting quote or summary statement | Provider |
|---|---|
| An opportunity for the mission is to make use of virtual reality to create stimulating environments | Astronaut |
| Preflight training – to learn people's boundaries, build personal relationships. | Astronaut |
| Training can't be artificial | Astronaut |
| Better training is needed so that crew members are not disillusioned about what it will be like on the flights to Mars. | Astronaut |
| Teams will need to train in situ for tasks they have not trained for before. | Astronaut |
| Crew needs to know more – need more IT to get information on their own. Need skills on how to find information and how to use the information you don't know. | Astronaut |
| Some training for critical actions for new phenomena they may face. | Astronaut |
| Information flow is important for long duration flights. | Astronaut |
| Time is critical because space flight is about avoiding failure: "failure recognition, assessment and plan of action" …Failures are serious because there is no book that can help astronauts when they face a catastrophe. | Astronaut |
| Try to have established plans – i.e. what happens if this breaks? (what ifs). Usually the answer is not in the "books" – but it gives you a framework for what to do. | Astronaut |
| Team needs skill based training and task based training. The team will need to use old skills and apply them to new tasks. | Astronaut |
| Training – you can only simulate no-gravity so much; can train for fatigue though. | Astronaut |
| Knowing how to work something [is not as useful as] knowing how something works. | Flight Director |
| There will need to be normalizing of mistakes and errors and training that people give themselves permission to bring up issues. | Operational Psychologist |
| Key to create confidence within team | Operational Psychologist |
| There is a crew resource management training with the crew that is evolving but may need more integration (suggests issues of a multi-team system). Currently the crew gets Space Flight Resource Management training (SFRM) where they learn to surface technical reports, tactical decision making, and increased situational awareness. Whereas this helps free crew up from decision making so they could do more science there is possibility to improve training that doesn't cover emotional and interpersonal issues. | Operational Psychologist |
| Team should build a house, tear apart a car. Put team together to solve a problem…Want to see how they handle extreme/life threatening situations | Operational Psychologist |
| They get to know each other through limited training. Trainings are continuous and for a long time but team trainings are limited. Training is basically based on each individual. | Operational Psychologist |
| Astronauts train to overcome different things that may happen is the space… when they are trained well they are feeling safe…members need an unquestionable faith in | Operational Psychologist |

| | |
|---|---|
| their teammates. | |
| Trusting each other's knowledge is really needed…we can't train astronauts for everything because we can't predict everything | Operational Psychologist |
| More training can result in less interpersonal issues. | Operational Psychologist |
| Pertinent activities might be tasks oriented for when they get there/mock ups/sims for when they reach their destination: things that have to do with radiation issues, depressurization, appendicitis, contingency issues; those issues that are mission essential and mission relevant. | Operational Psychologist |
| Technical problems happen more currently but interpersonal are also prevalent. Training needs to happen on-ground but could do activities (problem solving); Do simulations/ etc. in transit so they are familiar with some issues they may see when they get there. | Operational Psychologist |
| The crew is achievement oriented – they get discouraged when experiments do not go as intended. [They need to know] "failure is an option" when doing science, and "that's how you learn." | Payload Communications |
| Ground crew and space crew … always have a back-up plan. The plans are based on years of experience – plan for the worst and hope for the best. | Payload Communications |

Other points. Finally, the interviewees touched on two ancillary issues that may affect team adaptation and resilience. The first is the *multi-team system* aspect of work; this system encompasses the current and future interactions between the flight crew and ground crew in mission control, CAPCOM, and PAYCOM. The statements in the table below suggest that everyone acknowledges the interdependence between crews. Yet, there is uncertainty as to how communication delays and autonomy of the crew will affect the interactions and interdependence of crews on long duration flights. The evolution of these interactions may also influence the management and training of team adaptation and resilience by both ground and flight crews for future missions.

**Multi-Team System (ground crews and flight crew)**

| Supporting quote or summary statement | Provider |
|---|---|
| If there were disruptions/off-nominal events, the crew tried to work it out internally. Only if a device could be damaged due to actions taken did the crew report it (and wait for response). The crew worked autonomously as much as possible. | Analog Participant |
| A challenge comes with crew-ground disconnect. | Analog Researcher |
| May need to get the office in shape first, before imposing structures on crews – as what you see in flight is what you see in the office (shows culture). | Astronaut |
| Ground has more insight into vehicle than the crew – but how quickly do you need to make a decision. | Astronaut |
| [For the] day-to-day activities on ISS …voice and written communication between teams (ground and flight crews) is important | Flight Director |
| The ground crew is an equal part of "the team" | Flight Director |
| Ground changes activities in how/when/ or if at all it is completed, but doesn't explain why and that's frustrating – which is why we always try to include flight AND ground crew why. | Flight Director |
| For long duration, we have to focus on all teams not just crew | Operational Psychologist |
| The crew will have to be more autonomous, for example, [operations planning] might | Operations Planner |

| | |
|---|---|
| not schedule exercise for them but only schedule time critical events. And scheduling specific things would be close to earth but as [the flight crew] move farther away [operations planning] would only provide high level scheduling. … jobs will be similar to now but will transition when the mission is across years. The skills and knowledge needed over years will depend on mission profile, ship, assent/descent will be different, light time delay and communication delay will create differences. | |
| Equipment issues …usually the issues get noticed on the ground first, often it can't be tackled by the ground crew alone – crew involved to do things such as a hard drive failed, batteries died, or cable needs to be fixed. | Payload Communications |
| [At PAYCOM] there is a mix of people and almost every day or every other day there are new people – so there are new dynamics. Every day is really a different day – there are multiple crew members so there are always new interactions – and there are slow days and hectic days. | Payload Communications |

The second ancillary issue that emerged from the interview data was in the way *roles and responsibilities of leaders and crew members* develop currently and what will be needed for long duration missions. The table below shows several approaches and concerns about in-flight leadership (i.e. whether it should be rotated within the team) that may impact team adaptation and resilience on long duration missions.

**Leader & Crew Member Roles & Responsibilities**

| Supporting quote or summary statement | Provider |
|---|---|
| If there were any difficulties the crew would talk it over with the commander – he was the main channel to convey issues to mission control. | Analog Participant |
| [Crews may like to] cycle team members in each role….when one crew rotated commander position the original commander became upset by how members took on the role to change everything put in place. | Analog Researcher |
| Communication styles - there can be a mismatch, for example one commander wanted consensus whereas members wanted more direct orders. | Analog Researcher |
| Patterning from leadership that "we not me" from very high level NASA managers needed. | Astronaut |
| Roles should change – key for resilience but can't be perceived as he's doing my job! | Astronaut |
| Everyone has good days and bad days, the key it be able to read people. The leader's most important assets are the team members…the difference between leaders and managers – leaders look down at the troops to make sure they have what they need; managers look up to their boss to see how to make him/her happy. | Flight Director |
| It is important to know roles of other team members …have people rotate and know how to deal with issues of other people to show that you know what other people deal with. | Flight Director |
| The flight director has a primary role and it has been a partnership with the commander on the ship. But on long direction space missions the commander may get more responsibility and they will also need to see the big picture | Flight Director |
| The commander is key for implementing plans – fundamentally that will stay the same on long duration missions, but people have different goals and you got to get it all out in the open – have everyone throw out ideas and facilitate the process when communication faces difficulties. | Flight Director |
| On the crews that the interviewee has experienced, the commander had some specific times to offer an open forum to all members to talk-out their issues but the | Operational Psychologist |

| | |
|---|---|
| interviewee thinks that it was not the best idea. | |
| There was a flight that commander made everyone be together on the meals and it was a good action | Operational Psychologist |
| Commander or designated leader is necessary | Operational Psychologist |
| Team structure will need to be different than it is now." Horrible and good commanders effect all astronauts' actions and performances. | Operational Psychologist |
| Repairing as a team - Depends on team – commander key in this (but what if they are the problem?), confidence plays a role. They need a team that can take the charge if someone gets out of order. | Operational Psychologist |

While the review synthesizes the vast amount of work that has examined team adaptation and resilience in organizational and analogous settings, the operational assessment has provided a number of key themes about the need for adaptation and resilience from what crews have faced, and are likely to face in long-duration missions. We feel that the importance of this review is also a result of the gaps we are able to identify in the literature regarding ICE contexts for long duration missions. When these gaps are more fully fleshed out, they may provide specific suggestions for building, maintaining, and integrating team adaptation and resilience into the team's IMO lifecycle. Accordingly, in the section that follows, we provide some specific recommendations that we feel are needed within the team adaptation and resilience literatures and would likewise be valuable for future NASA missions.

## Recommendations for Future Research

The primary gaps that have emerged via our literature review and the interviews that we conducted include:

1) a need to create a more robust and consistent manner in which to measure adaptability, adaptation processes, resilience, and adaptive outcomes,
2) a lack of longitudinal research about team adaptation and resilience,
3) a deeper understanding of the impact that training interventions can have on team adaptation and resilience,
4) an opportunity to explore these and other team-related aspects in other types of analog populations and/or situations than have been examined thus far, and
5) an unclear picture of how other important factors of long-duration missions may shape the team adaptation nomological network.

### Measurement

To start, research needs to actually measure adaptation and resilience within analogous settings so that lessons learned there can be applied to future ICE missions. However, as noted within our literature review, researchers have yet to truly coalesce around a common methodology for measuring such constructs. We have outlined here a framework that we feel best captures the nomological network of team adaptation. In so doing, we view adaptation as a process and leverage our earlier work which suggested that teams adapt their transition, action, or interpersonal processes depending on certain features of the disruption trigger which prompts the team to adapt in the first place (Maynard, Kennedy, & Sommer, 2015).

Given that Mathieu and Marks (2006) have developed specific questions which target each of these three team process dimensions, we can envision leveraging these scales to ask team members how their team is adapting or has adapted such processes. For example, in Mathieu and Marks´ (2006) questionnaire, team members provide insights on their action processes by answering items such as: "To what extend does your team actively work to develop standards for acceptable team member performance?" In order to actually measure the extent to which the team is actually adapting their processes, we suggest altering this same question to read something along the lines of: "To what extend has your team had to adjust your standards for acceptable team member performance?" Beyond the benefit that using such a process to measure team adaptation may provide in terms of actually measuring team adaptation, by leveraging such an approach, research may also overcome the issue of supposing that adaptation has occurred after a specific event has occurred (e.g., Wood, Lugg, Hysong, & Harm, 1999).

However, it will likewise be essential to not only measure how the team is adapting their processes but also what the impact that such adaptation is having on various emergent state and team performance measures. Therefore, future research needs to occur within settings in which various processes, emergent states, and outcome measures can be assessed (see point below). In an attempt to assess more than individual member´s perception of team processes, researchers may want to leverage tools such as sociometric badges, data transmissions, and/or video-recordings where available to assess the actual behaviors that are occurring within the team (e.g., Tafforin, Vinokhodova, Chekalina, & Gushin, 2015). Likewise, capturing objective measures of team performance and assessing emergent states from those outside of the team (i.e. team managers) may assist in reducing same source biases (e.g., Podsakoff & Organ, 1986) and thus strengthening the overall study design of future work in this literature stream.

Given that we suggest the need to track team members and entire teams over time (see point below), future projects in this domain will also need to assess individual and team adaptability in order to quantify how such constructs change following instances such as training interventions as well as having to deal with various types of disruption triggers. One of the only studies that we found that comes close to our suggestion here was the study of Japanese residents in the Antarctic who were found to demonstrate a decline in hardiness by the end of winter (e.g., Weiss, Suedfeld, Steel, & Tanaka, 2000). However, this study was at the individual-level of analysis while we are advocating for a similar examination at the team-level. Accordingly, as suggested by Suedfeld (2001), researchers could take a more positive approach by leveraging scales that assess team members´ resilience and hardiness (e.g., Kobasa, 1979) as well as individual tendency to actually develop and thrive within such settings – salutogenesis (e.g., Antonovsky, 1987).

**Longitudinal Research**

We also believe that studying these constructs longitudinally is important given the acknowledgements in the literature to temporal and dynamic factors that may affect both team adaptation and resilience. Indeed, an opportunity lies in assessing the impact of other team adaptation process antecedents, especially those that are dynamic such as emergent states like psychological empowerment. Also, given that team resilience is an emergent state, the level of resilience on the team may fluctuate over time. As such, research needs to be designed and exercised that captures team adaptation and resilience in a longitudinal approach. By conducting examinations of team adaptation over time, future researchers would also be able to address those

who suggest that adaptation may occur in stages even though empirical evidence to this point is currently equivocal (e.g., Kanas et al., 2006; Palinkas, Gunderson, & Holland, 2000). However, given that stress levels (which have been tied to adaptation) (e.g. De La Torre et al., 2012) are likely to ebb and flow within long-duration missions, taking a longitudinal perspective seems appropriate as adaptation is likely more salient in certain phases (e.g., approach and landing to Mars and Earth) as compared to others (e.g., transit). Likewise, while team breakdowns are often viewed as a sudden event, by conducting research over a period of time, future research would be able to assess the process that lead to such degradations as well as positive adaptive outcomes (e.g., Smallidge, Jones, Lamb, Feyre, Steed, & Caras, 2013).

**Training Interventions**

Our review of the academic literature has noted some initial attempts to understand the impact of training on team adaptation and resilience. In particular, Entin and Serfaty (1999) and Marks and colleagues (2000) evidenced a positive relationship between team interaction training and adaptation. Likewise work suggests that cross-training may be beneficial for teams that need to adapt (e.g., Cannon-Bowers, Salas, Blickensderfer, & Bowers, 1998; Marks et al., 2002). However, while this work certainly provides evidence for the positive impact that training can have on adaptation and resilience, it can also increase stress levels within the crew if not properly planned and executed (e.g., Lapierre et al., 2009).

Additionally, numerous research questions remain unanswered regarding the role of training which are certainly relevant to future ICE missions. Specifically, there is a need to more fully understand the impact that training such teams prior to the missions may provide. For instance, it would appear that training together as a team would be beneficial as well as having joint crew and mission control training sessions (e.g., Kanki, Rogers, Bessone, Parke, Sandal, & Whiteley, 2009). However, there is a lack of evidence regarding the impact that such training sessions may have for NASA teams as well as analogous team settings. In part, this evidence is lacking given the limited data that is currently being collected during NASA crew training sessions. Currently, teams are being exposed to crew resource management (CRM) curriculum (e.g., Musson, Sandal, & Helmreich, 2004), as well as participating in training sessions in outdoor environments such as those offered by the National Outdoor Leadership School (NOLS) and thereby theoretically gaining some of the psychosocial training suggested by Kass and Kass (1999). Yet, data are not currently being collected during such sessions and thus, it is impossible to truly ascertain whether such training programs are actually enhancing the levels of adaptability possessed by such teams.

By collecting such information and tracking these teams over time, researchers would be able to understand whether the adaptation gains earned during such training programs start to erode after a period of time following training. There is evidence that training-performance intervals can contribute to errors as evidenced by the collision of the Russian spacecraft Progress 234 which collided with the Mir space station and was attributed in part to the fact that the crew last received training four months before the docking incident (e.g., Shayler, 2000). Accordingly, understanding how long such training effects are likely to last within a team thus impacts the decision regarding whether, how much, and what types of training the team will need during transit to reinforce the lessons previously learned prior to the mission (e.g., Urbina & Charles, 2014). Given the long duration of the transit that the proposed future missions will require, it begs the question of how best to use time and training programs before and during flight to increase and

sustain adaptability levels. For example, the use of virtual simulations may allow team members to train during this time period and thus keep them occupied and avoid monotony during this period of the mission. Likewise, transit training sessions could focus on developing contingency plans when the team faces disruptions, as well as practicing debrief sessions given their importance in shaping team effectiveness (e.g., Tannenbaum & Cerasoli, 2013).

Research centered on training should also seek to better understand the specific facets that should be included within such training programs. For instance, some researchers have suggested that for these types of future missions, skill-based as compared to task-based approaches should be emphasized as the general skills garnered from such skill-based sessions will enable the teams to actually perform on the unknown disruptions they may ultimately face (e.g., Baer, 1996, Kaiser, Allen, Barshi, Billman, & Holden, 2010). That is, skill-based training may allow crews to rely on basic learned skills to address many disruptions that are similar at their core (i.e., in the essential disruption characteristics) rather than needing to train for the variety of specific task issues that may arise.

**Other Analog Environments**

As discussed previously, we see great value in future research involving team adaptation and resilience occurring in field settings. In particular, for NASA's interests, we think that by examining adaptation in numerous settings, the true story about adaptation within teams can be discovered. Bishop and colleagues (2010) recently noted that most examinations of groups in ICE contexts have been conducted in "pure simulation conditions" (pg. 1353). As mentioned here, there are numerous settings in which teams have been examined within settings such as the Mars Desert Research Station (e.g., Bower, 2014) as well at NEEMO (e.g., Todd & Reagan, 2004) and HI-SEAS (e.g., Kizzia, 2015). Such research environments are certainly needed as they allow researchers to manipulate certain key factors that may be salient to consider within long-duration missions such as communication delays (e.g., Bishop et al., 2010) and increases in autonomy (e.g. Sandal et al., 2011). As such, we would suggest that they continue to be used as they allow researchers to isolate certain aspects of missions to Mars that are difficult to replicate in most field settings. As we detailed here, there is a gap in the team adaptation literature that needs to be addressed going forward as studies conducted in such settings have yet to truly measure and examine team adaptation and resilience over the course of such missions even though as part of such missions, the teams are exposed to disruptions such as short circuits and breakdown of ground-based services (e.g., Sandal & Bye, 2015).

However, while research within such simulated environments is beneficial, some have argued that the fact that they cannot replicate the life threatening environments that future space missions will encounter, there should also be research conducted in other settings (e.g., Leon et al., 2002). For example, there have been studies of groups in other analogous settings such as submarines (e.g., Sandal, Endresen, Vaernes, & Ursin, 2003), Antarctica missions (e.g., Lugg, & Shepanek, 1999, Tafforin, 2004), and a variety of expedition groups (e.g., Leon et al., 2011). While each of these settings provide an excellent opportunity to learn more about groups in such contexts, it is almost impossible to truly mimic all of the team composition factors (e.g., team size, team member backgrounds, etc.) as well as contextual challenges that a mission to Mars may present (e.g., Leon, Sandal, & Larsen, 2011). Likewise, some of these contexts do not provide large samples which restricts the research questions and methodologies that can be leveraged. Accordingly, we would suggest that future work in the area of team dynamics in long-duration ICE contexts use a more diverse sampling of populations in order to triangulate the nuances that are context-specific and those that will likely translate to future long-duration space missions.

Specifically, we can see great value in examining the dynamics of officer crews in ocean carriers given that they are typically made up of individuals from various countries and may be a better comparison for astronauts than other members of ocean carrier crews (e.g., Thomas et al., 2003). Likewise, such a sample would allow research to examine the impact that multicultural membership can have on team adaptability, team adaptation processes, resilience and team adaptive outcomes. Similarly, teams in offshore energy platforms have been examined previously (e.g., Flin, 1997; Palinkas, 2003) and by leveraging such a setting to a greater extent going forward, research within the team adaptation literature could examine how team adaptation works within ICE environments given that these teams are together for relatively long periods of time and work in confined environments where the actions of team members can have life and death consequences (e.g., Flin, Slaven, & Stewart, 1996).

**Consideration of Other Pertinent Constructs**

While there has been a great deal of momentum around the topics of team adaptation and resilience over the past 15 years, there still remain numerous constructs that have not been examined within the team adaptation nomological network. Likewise, some of the under-examined constructs are those that will be of increasing importance within the type of long-duration missions that NASA envisions. In particular, while there has been research attention given to factors that may serve as antecedents to team adaptation as well as consideration of the outcomes of such adaptation, the majority of such work has been conducted in settings that are not particularly analogous to the context within which future space missions will likely encounter and thus, our suggestions regarding analogous settings discussed previously.

Likewise, there has been less work focused on the relationship between team adaptation processes and various team emergent states. Specifically, while crew autonomy will likely be higher in such missions (e.g., Sandal, Bye, & van de Vijver, 2011), the relationships between autonomy as well as team empowerment and team adaptation constructs (adaptability, adaptation processes, and adaptive outcomes) have not been fully examined. Similarly, while cohesion has been linked to individual resilience to stress and trauma in various contexts (e.g., Eid & Johnsen, 2002; Phipps & Mulhern, 1995), arguments have been made to suggest that too much team cohesion can, in fact, be detrimental because of its potential to result in groupthink (e.g., Janis, 1972). Thus, there is a need to examine the relationship between adaptation and cohesion within teams. Likewise, while some have suggested a link between individual confidence and adaptation (e.g., Palinkas & Suedfeld, 2008), research has yet to consider such relationships at the team level. Namely, it would be interesting for future researchers to examine the possible links between team adaptation and confidence constructs such as group potency and collective efficacy.

Beyond the need to more fully consider emergent states within the team adaptation nomological network, there are significant gaps in the team adaptation literature involving what factors serve as moderating influences on the relationships noted here as existing within the team adaptation nomological network. For instance, team interdependence is considered by many to be a defining characteristic of teams (e.g., Cohen & Bailey, 1997; Ilgen et al., 2005; Kozlowski & Bell, 2003; Shea & Guzzo, 1987). In fact, Kozlowski and Bell (2003) submitted "… new research that fails to consider the effects of task interdependence for the team phenomenon in question has little relevance to building knowledge in the work groups and teams literature (p. 363)." However, research on team adaptation has yet to fully heed this suggestion. In particular, research has investigated various forms of interdependence (e.g., task or outcome) and has demonstrated differential impacts of these various

forms on team processes and performance (e.g., Wageman, 1995). As such, future research can examine whether teams are able to adapt when they are more (or less) interdependent and whether such relationships are also influenced by the type of interdependence present within the team.

Likewise, research has not provided adequate attention to the role that the disruption that is giving rise to the need for team adaptation plays in shaping the relationships suggested in the current framework. For instance, when mission teams have to adapt in the face of minor disruptions, it is completely different from severe disruptions. Accordingly, research needs to more fully explore different types of disruptions to better understand their differing impacts on the adaptation processes and outcomes that follow. We suggest that future research give greater consideration to the role that contextual factors play in shaping team adaptation processes, and the relationships between such processes and various antecedents as well as outcomes.

Additionally, there is a need to consider such constructs across multiple levels of analysis. In particular, the team adaptation literature has yet to fully consider that teams are nested in organizations in which they may need to interact with other teams. These structures have come to be labelled as multi-team systems (MTSs) (e.g., Marks, DeChurch, Mathieu, Panzer, & Alonso, 2005). While MTSs are relevant to almost every organization, they are certainly present within NASA as evidenced by the interactions required between mission control and crew. However, this interface has been shown to be impacted in various ways during missions and may be altered during long-duration missions. In particular, research has evidenced displacement-type behaviors as crew members refrain from expressing tension with crewmembers but instead direct their emotions to those outside the team such as mission control (e.g. Kanas et al., 1996). In part, this may explain the refusal of the third Skylab crew to respond to Houston for an entire day (e.g., Shayler, 2001). As such, future research should seek to gain a deeper appreciation for how adaptation and resilience will be impacted when considering the interaction between multiple teams within NASA, and outside of NASA to include other space agencies.

## Conclusion

In closing, our review of the team adaptation and resilience literatures and the interviews that we have conducted have provided many insights in terms of what has been learned over the past couple of decades. In particular, there is a substantial body of research that has focused on understanding factors that give rise to adaptation and resilience within teams. To a lesser extent, research has gained an appreciation of factors that are influenced by adaptation processes and an emergent state of resilience within teams. Therefore, there are certainly numerous future research opportunities that need to be explored to gain a deeper understanding of the relationships that exist within the nomological network that we introduce here.

Additionally, it will be important that future research give increased attention to how to intervene in teams to enhance adaptation and resilience given that team composition is not always malleable. We have identified here some of the key interventions that appear most promising. Likewise, we detail several gaps in our understanding regarding team adaptation and resilience which should be given more attention in the coming years. We look forward to seeing the knowledge that is gained over the coming years and how it will be applied within future ICE missions given the salience of these constructs within such settings and hope to assist NASA in the development of projects over the coming years to better understand the role of adaptation and resilience in analogous settings and how best to develop such processes and emergent states.

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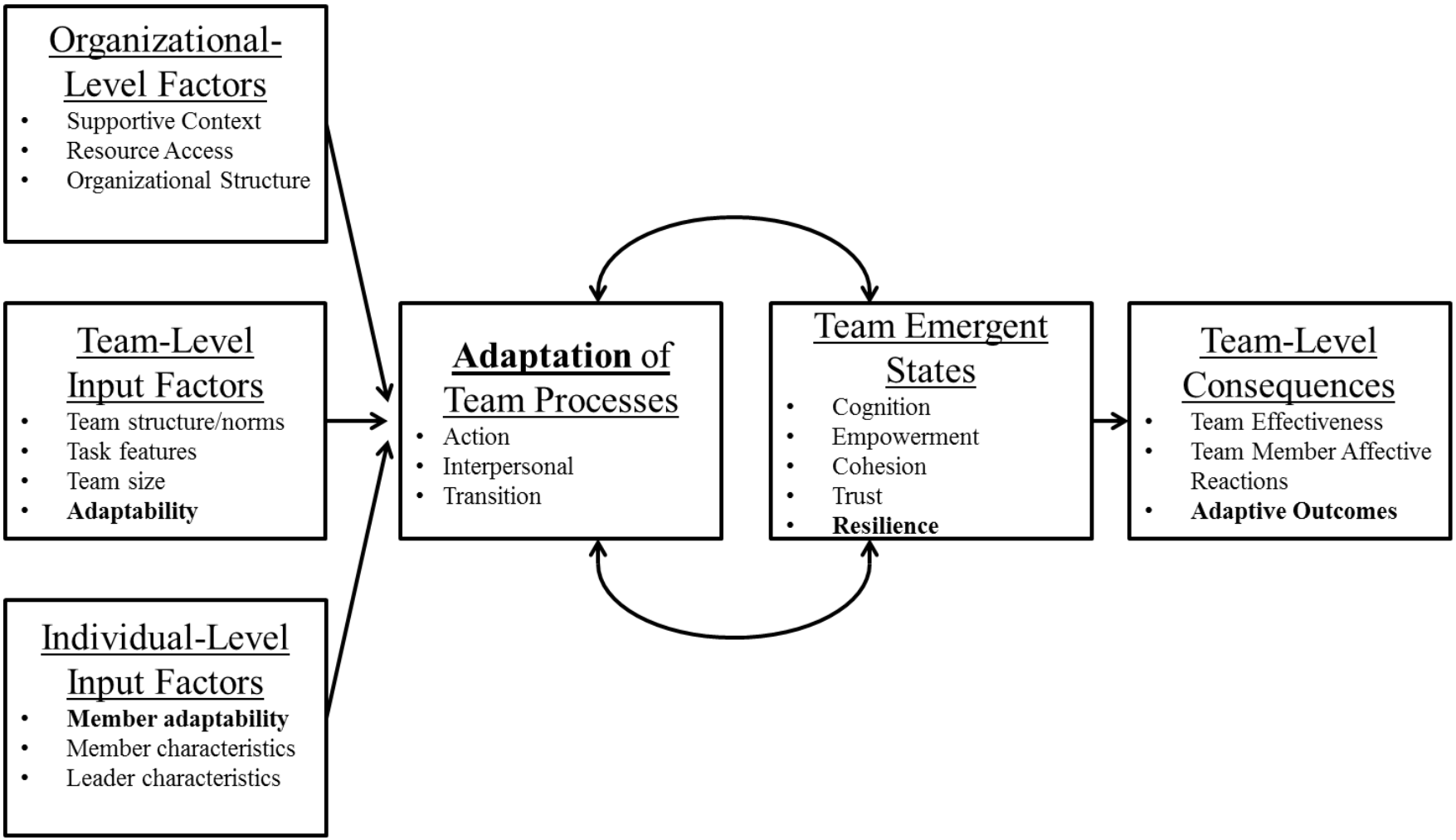


**Figure 1: Team Adaptation Nomological Network**

## TABLE 1: EXEMPLAR DEFINITIONS OF TEAM ADAPTATION AND RELATED CONSTRUCTS

| Citation | Definition |
|---|---|
| Team Adaptability (Input): | |
| Kozlowski et al., 1999 (1) | "capability of the team to maintain coordinated interdependence and performance by selecting an appropriate network from its repertoire or by inventing a new configuration" (p. 273). |
| Gibson & Birkinshaw, 2004 (1) | "…the capacity to reconfigure activities in the business unit quickly to meet changing demands in the task environment." (p. 209-210) |
| Burtscher et al., 2010 (4) | "the ability to change its coordination activities in response to changing situational demands, such as the occurrence of unexpected events and varying task characteristics" (p. 283). |
| Gorman et al., 2010 (5) | "have the ability to coordinate their activities not only under routine conditions but also under novel conditions for which they have not been explicitly trained. Adaptation is the altering of structure in accordance with changes in the environment" (p. 295). |
| Randall et al., 2011 ( 2) | "capacity to gather information from the performance environment and use it to make functional adjustments to team strategies, behaviors, role structures, and resource allocations" (p. 526). |
| Team Adaptation (Process): | |
| Cannon-Bowers et al., 1995 (1) | "the process by which a team is able to use information gathered from the task environment to adjust strategies through the use of compensatory behaviors and reallocation of intra-team resources" (p. 344). |
| Entin & Serfaty, 1999 (5) | "…adapt their (a) decision-making strategy, (b) coordination strategy, and (c) behavior and organization structure to the demands of the situation in order to either maintain team performance or to minimize perceived stress" (p. 314). |
| Marks et al., 2000 (3) | "derive and use new strategies and techniques for confronting novel elements in their environment" (p. 972). |
| Klein & Pierce, 2001 (5) | "make the necessary modifications to meet new challenges." (p. 3) |
| LePine, 2003 (6) | "reactive and nonscripted adjustments to a team's system of member roles that contribute to team effectiveness" (p. 28). |

**Note:** Terminology utilized within original study (1=team adaptability; 2=adaptive capacity; 3=team adaptation; 4=adaptive coordination; 5=adaptive teams; 6=role structure adaptation; 7=adaptive performance). The definitions are listed in chronological order.

## TABLE 1 (continued). EXEMPLAR DEFINITIONS OF TEAM ADAPTATION AND RELATED CONSTRUCTS

| Citation | Definition |
|---|---|
| Team Adaptation (Process): | |
| Burke et al., 2006(c) (3) | "the innovation of new or modification of existing structures, capacities, and/or behavioral or cognitive goal-directed actions" (p. 1190). |
| Stagl et al., 2006 (3) | "a change … in response to a salient cue or cue stream, which leads to a functional outcome for the entire team" (p. 122). |
| Manser et al., 2008 (3) | "includes adaptations concerning a) the input into the teamwork process, such as mobilization of additional resources or a structural reconfiguration of the team, as well as b) process adaptations, i.e. changes in coordination mechanism, decision making and communication patterns in response to unexpected events" (p. 1154). |
| DeRue et al., 2008 (3) | "team-level behavioral change." (p. 183) |
| Nelson et al., 2010 (1) | "reflects a fundamental shift in the types of performance strategies used in response to changing conditions in the environment" (p. 132). |
| Adaptive Performance (Outcome): | |
| LePine et al., 2000 (1) | "…the focus of this study is on learning and performance when there is a change in the task context that results in novelty and complexity." (p. 566) |
| LePine, 2005 (1) | "the extent to which a team is able to modify its configuration of roles into a new configuration of roles using knowledge acquired through interaction in the course of task execution as well as through more explicit exploration of transaction alternatives" (p. 1154). |
| Porter et al., 2010 (1) | "the extent to which a team achieves correspondence between its behavior and a set of novel demands it faces." (p. 935) |
| Shoss et al., 2012 (7) | "Adaptive performance is a facet of job performance that reflects such effectiveness. Specifically, it consists of acquiring enhanced competencies in response to changing job requirements" (p. 910) |

**Note:** Terminology utilized within original study (1=team adaptability; 2=adaptive capacity; 3=team adaptation; 4=adaptive coordination; 5=adaptive teams; 6=role structure adaptation; 7=adaptive performance). The definitions are listed in chronological order.

## TABLE 2: EXEMPLAR DEFINITIONS OF INDIVIDUAL PSYCHOLOGICAL & TEAM RESILIENCE

| Citation | Definition |
|---|---|
| Individual Psychological Resilience: | |
| Masten, Best, & Garmezy, 1990 | "The process of, capacity for, or outcome of successful adaptation despite challenging or threatening circumstances" (p. 426). |
| Fletcher & Sarkar, 2013 | "Resilience refers to the ability of individuals to maintain normal levels of functioning" (p. 16). |
| Sutcliffe & Vogus, 2003 | "the capacity to rebound from adversity strengthened and more resourceful" (p. 97). |
| Meredith et al., 2011 | "the process of coping with or overcoming exposure to adversity or stress" (p. xiii). |
| Gillespie et al., 2007 | "mitigating the effects of stress through the use of behaviors that facilitate adaptation and allow individuals to function above the norm in spite of significant stress" (p. 428). |
| Luthans (2002) | Resiliency is the "capability of individuals to cope successfully in the face of significant change, adversity, or risk" or simply put "the positive psychological capacity to rebound, to 'bounce back' from adversity, uncertainty, conflict, failure or even positive change, progress and increased responsibility" (p.702). |
| Morie & Chance, 2012 | "the ability of a person to cope with negative life events in a manner that allows for positive growth and rapid return to a healthy psychological state" (p. 13-2). |
| Team Resilience: | |
| Carmeli et al., 2013 | "a team's belief that it can absorb and cope with strain, as well as a team's capacity to cope, recover and adjust positively to difficulties" (p. 149). |
| Altman-Dautoff, 2001 | Resilient individuals, groups, or organizations "typically regain their equilibrium faster, maintain higher levels of productivity and quality in their work, preserve their physical and emotional health, and achieve more of their objectives" (p. 16). |
| Sutcliffe & Vogus, 2003 | Group level resilience focuses on the collective ability of the group to learn new skills, build collective efficacy, and positively adapt and adjust to change, challenging conditions, environments, and stressors over the long-term (p. 101-103). |
| West et al., 2009 | Team resilience is "the ability to either thrive under high liability situations, improvise and adapt to significant change or stress, or simply recover from a negative experience are less likely to experience the potentially damaging effects of threatening situations" (p. 254). |

## TABLE 3: SUMMARY OF TEAM ADAPTATION STUDIES

| Study Citation | Sample and Participants (Setting of Study) | Antecedent(s) (Level of Analysis) | Type of Adaptation Trigger (details regarding trigger) | Adaptation Variable(s), (Measurement Approach) | Mediator(s) | Moderator(s) | Outcomes | Key Findings (include any moderating relationships noted) |
|---|---|---|---|---|---|---|---|---|
| Beersma et al., 2009 | 75 four person teams (Lab) | Reward structure history (T) | Task-based (reward structure change – competitive or cooperative between Time 1 and Time 2) | N/A - adaptation assumed to be the means by which teams overcome changes. | N/A | Team role discussions, behavioral coordination, expectations regarding conflict | Performance: Speed and Accuracy (T) | Teams with a history of competitive rewards performed worse than those with cooperative rewards experience. This relationship was neutralized when teams conducted team role discussions. |
| Burtscher et al., 2011 | 15 two person (anaesthesia trainees and nurses) anaesthesia teams engaged in a simulator (Lab) | Team member role (I) | Task-based (A critical event - asystole was introduced) | N/A - adaptation assumed to be the means by which teams overcome critical event. | Coordination activities (information and task management) | N/A | Decision latency and execution latency.(T) | Complication resulted in more information management. Trainees spent more time on task management. The more the trainee increased information management, the faster the team came to a decision regarding treatment. |
| Burtscher et al., 2010 | 40 two-person (anesthetists and nurses) anaesthesia teams engaged in a simulator (Lab) | Presence of non-routine events (T) | Task-based (presence of non-routine events). | N/A - adaptation assumed to be the means by which teams overcome non-routine events. | Coordination activities (information and task management) | N/A | Team performance (T) | Non-routine events predicted changes in task management coordination. High-performing teams showed a greater increase in task management in non-routine events. |

**Note:** Setting of Study (Field; Lab); Level of Antecedent (O= Organizational; T=Team; I=Individual composition variables aggregated to team-level); Type of Adaptation (task- or team-based); Level of Outcome (O= Organizational; T=Team; I=Individual); Measurement Approach ([1]=survey; [2]= raters; [3]=objective measurement).

## TABLE 3 (continued): SUMMARY OF TEAM ADAPTATION STUDIES

| Study Citation | Sample and Participants (Setting of Study) | Antecedent(s) (Level of Analysis) | Type of Adaptation Trigger (details regarding trigger) | Adaptation Variable(s), (Measurement Approach) | Mediator(s) | Moderator(s) | Outcomes | Key Findings (include any moderating relationships noted) |
|---|---|---|---|---|---|---|---|---|
| Chen et al., 2005 | 78 two-person teams (156 undergraduates) engaged in a flight simulator task (Lab) | Collective Efficacy (T), Regulatory Processes (T) | Task-based (non-routine task) | Adaptive Performance[2]; (measured by 3 SME who observed performance and processes following the transfer mission - non-routine task). | N/A | N/A | N/A | Regulatory processes mediated the relationship between collective efficacy and adaptive performance |
| de Jong et al., 2004 | 61 teams from a large Dutch bank | Empowerment and team support (T) | N/A | Team adaptive recovery behavior[1] (measured with 6 survey items) – sample item: "When we feel that one service recovery effort is not working, we can easily change to another." | N/A | N/A | Customer satisfaction and loyalty; service revenues | Intrateam support impacts adaptive and proactive recovery behavior, which in turn impacted external performance measures. |
| DeChurch & Haas, 2008 | 132 undergraduate students who were part of 38 3- and 4-person teams working on an on-campus | N/A | N/A | Reactive strategy adjustment[1] (measured with 3 survey items) – sample item: "To what extent did you team…effectively | Team coordination | N/A | Team performance (minutes needed to complete the scavenger hunt) (T) | Reactive strategy adjustment impacted team coordination (but only later on in the action phase). Reactive strategy adjustment was positively associated with team performance. |

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| | scavenger hunt (Lab) | | | make needed adjustments to your initial plan?" | | | | |
| DeRue et al., 2008 | 355 undergraduate students comprising 71 5-person teams working on a decision-making task (Lab) | Change in team hierarchy (maintaining or integrating hierarchies) (T) | Team-based (team member removed) | Team adaptive behaviors[2 & 3] Change in team launches and identified tracks between time 1 and 2 (quantitative behaviors); change in team information sharing and assistance (qualitative behaviors) | N/A | N/A | Team performance (extent of effective engagements) (T) | Team adaptive behavior (quantitative behavior) mediated the relationship between structural hierarchy and team performance. |

**Note:** Setting of Study (Field; Lab); Level of Antecedent (O= Organizational; T=Team; I=Individual composition variables aggregated to team-level); Type of Adaptation (task- or team-based); Level of Outcome (O= Organizational; T=Team; I=Individual); Measurement Approach ([1]=survey; [2]= raters; [3]=objective measurement).

## TABLE 3 (continued): SUMMARY OF TEAM ADAPTATION STUDIES

| Study Citation | Sample and Participants (Setting of Study) | Antecedent(s) (Level of Analysis) | Type of Adaptation Trigger (details regarding trigger) | Adaptation Variable(s), (Measurement Approach) | Mediator(s) | Moderator(s) | Outcomes | Key Findings (include any moderating relationships noted) |
|---|---|---|---|---|---|---|---|---|
| Diedrich et al., 2005 | 25 officers and non-commissioned Naval officers participated in a decision-making task (Lab) | Teams provided targeted instruction about the benefits of structural change, and feedback to show performance decrements and need to adapt (T) | Task-based (incongruence between current and ideal organizational structure) | Adaptation[2] - assessed by examining the teams' changes in team's organizational structures | N/A | N/A | Mission effectiveness (T) | When faced with incongruence and information about the alternative structures, teams did in fact alter their structures and improved mission effectiveness. |
| Entin & Serfaty, 1999 | 59 officers and 1 civilian organized into 12 five-person teams who engaged in a simulation activity (Lab) | Team Adaptation Training (control, TACT, or TACT+) (T) | Task-based (work load stress manipulated) | N/A - adaptation assumed to be the means by which teams overcome stress. | Communication | Work load | Team performance (rated by observers on behavioral and performance items) (T) | Teams receiving adaptation training demonstrated improved team performance and improvements in various team processes (communication). |

Note: Setting of Study (Field; Lab); Level of Antecedent (O= Organizational; T=Team; I=Individual composition variables aggregated to team-level); Type of Adaptation (task- or team-based); Level of Outcome (O= Organizational; T=Team; I=Individual); Measurement Approach ([1]=survey; [2]= raters; [3]=objective measurement).

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|---|---|---|---|---|---|---|---|---|
| Gibson & Birkinshaw, 2004 | 4,195 respondents from 41 business units (Field) | Organizational context (O)) | Task-based (dynamic environment) | Ambidexterity – includes alignment and adaptability[1]<br><br>(measured with 3 survey items) – sample item "The management systems in this organization encourage people to challenge out-moded traditions, practices, sacred cows." Respondents were senior and middle management. | N/A | N/A | Performance (T) | The organizational context enhances ambidexterity. The contextual ambidexterity mediates the relationship between organizational context features and business unit performance. |
| Gorman et al., 2010 | 32 three-person teams engaged in an activity where they had to take reconnaissance photographs (Lab) | Training (cross-training, procedural, and perturbation) (T) | Task-based (i.e. cutting communication, disguised target, etc.) | Response to novel events[3] Time to overcome roadblocks in the simulation. | N/A | N/A | Team performance (composite measure - number of missed targets, time to process targets) (T). | Procedurally trained teams were least adaptive. Cross-training led to adaptation in one test; however, perturbation-trained teams outperformed teams in the other conditions in two of the three test missions. |
| Grote et al., 2010 | 42 cockpit crews from a commercial | Task load (T) and standardization | Task-based (non-routine events) | N/A - adaptation assumed to be the means by which | N/A | N/A | Implicit coordination and heedful | Implicit coordination and heedful interrelating were more prevalent in teams with high task load. Additionally, |

| | | | | | |
|---|---|---|---|---|---|
| airline engaged in simulator training sessions (Lab) | (T) | | teams overcome non-routine events. | | interrelating (T) | | teams showed more implicit coordination and less heedful interrelating in highly standardized work phase. |

**Note:** Setting of Study (Field; Lab); Level of Antecedent (O= Organizational; T=Team; I=Individual composition variables aggregated to team-level); Type of Adaptation (task- or team-based); Level of Outcome (O= Organizational; T=Team; I=Individual); Measurement Approach ([1]=survey; [2]= raters; [3]=objective measurement).

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|---|---|---|---|---|---|---|---|---|
| Han & Williams, 2008 | 39 service teams from an electric power utility company in Korea (Field) | Individual Adaptive Performance (I); Learning Climate (T) | N/A | Team adaptive performance[1] (measured with 14 survey items) – sample item: "When nonroutine occurs, this team rapidly selects appropriate members to handle it." | N/A | N/A | N/A | A substantial amount of variance in team adaptive performance was due to individual adaptive performance; teams with strong, positive learning climates demonstrated greater levels of team adaptive performance. |
| Hollenbeck et al., 2011 | 93 four-person teams in a command and control simulation (Lab) | Team structure at Time 1 (T) | Task-based (team structure change – centralized or decentralized) | Adaptability[3] The simulation counted the number of times teams appropriately addressed novel situations. | N/A | Type of structure at Time 2 | Team performance at Time 2 (T) | Moderation tests indicate it was more difficult to shift from decentralized to a centralized structure. Team efficiency and adaptability mediated the negative effects from this type of shift - teams showed a lack of adaptability and no gains in efficiency. |

**Note:** Setting of Study (Field; Lab); Level of Antecedent (O= Organizational; T=Team; I=Individual composition variables aggregated to team-level); Type of Adaptation (task- or team-based); Level of Outcome (O= Organizational; T=Team; I=Individual); Measurement Approach ([1]=survey; [2]= raters; [3]=objective measurement).

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|---|---|---|---|---|---|---|---|---|
| Johnson et al., 2006 | 320 students on 80 four person teams (Lab) | Reward structure (T) | Task-based (reward structure change – competitive or cooperative between Time 1 and Time 2) | N/A - adaptation assumed to be the means by which teams overcome changes. | Information sharing at time 1 and time 2 | Type of reward structure at time 2 | Performance: Speed and Accuracy (T) | Information sharing partially mediated the time 1 and time 2 relationships between reward structure and accuracy. Interaction tests show that cutthroat cooperation changed performance patterns; teams that change from competitive to cooperative reward structures have lower team decision accuracy and take longer than teams shifting in the opposite direction. |
| Kahol et al., 2011 | Observation of 10 trauma team cases (Field) | Complexity of trauma case (T); experience of team leader (T) | Task-based (task complexity) | Team Deviations - extent to which teams deviated from the Advanced Trauma Life Support protocol[2] | N/A | N/A | N/A | Deviations occurred more often in more severe trauma cases; more deviations were reactive vs. proactive; teams with more experienced leaders had more deviations. |

**Note:** Setting of Study (Field; Lab); Level of Antecedent (O= Organizational; T=Team; I=Individual composition variables aggregated to team-level); Type of Adaptation (task- or team-based); Level of Outcome (O= Organizational; T=Team; I=Individual); Measurement Approach ([1]=survey; [2]= raters; [3]=objective measurement).

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|---|---|---|---|---|---|---|---|---|
| Klein et al., 2006 | Interviews of 33 members of Trauma Resuscitation Unit (TRU); 150 hours of observations of 100 patients in the TRU (Field) | Dynamic delegation by leader (T) | Task-based (TRU teams dealt with extreme and complex cases) | N/A – adaptation assumed to be the means by which teams deal with extreme and complex cases | N/A | N/A | Team Performance (T) | Dynamic delegation prevents/manages errors. |
| Langfred, 2007 | 35 self-managing MBA student teams over three time periods (Field) | Task and relationship conflict (T) | Team-based (task conflict is the disagreement about the job; relationship conflict is the perceived interpersonal incompatibility) | N/A - adaptation assumed to be the means by which teams overcome conflict (i.e. changes in autonomy and interdependence). | N/A | N/A | Autonomy, task interdependence (T) | Results indicate that teams restructure themselves in light of conflict such that conflict lowers individual autonomy and reduces task interdependencies. |

**Note:** Setting of Study (Field; Lab); Level of Antecedent (O= Organizational; T=Team; I=Individual composition variables aggregated to team-level); Type of Adaptation (task- or team-based); Level of Outcome (O= Organizational; T=Team; I=Individual); Measurement Approach ([1]=survey; [2]= raters; [3]=objective measurement).

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|---|---|---|---|---|---|---|---|---|
| LePine, 2003 | 219 students assigned to 73 three-person teams (Lab) | Member cognitive ability (I), member achievement (I), member dependability (I), member openness to experience (I) | Task-based (communication breakdown - abrupt) | Role structure adaptation *Count measure*[3]: The number of postchange trials in which teams used a newly developed role structure to address the communication breakdown.<br><br>*Rated measure*[2]: two raters assessed team transcripts for eight items – sample item: "members of this team developed a routine that accomplished the team's work." Rater's scores were averaged. | N/A | N/A | Post change decision making performance (T) | Postchange performance was better for teams with higher cognitive ability, achievement, openness to experience and lower dependability. Role structure adaptation mediated the relationships between inputs and outputs. |
| LePine, 2005 | 192 undergraduate students who were part of 64 | Member cognitive ability (I), learning orientation (I), | Task-based (communication breakdown - gradual) | Role structure adaptation *Count measure*[3]: Number of postchange | N/A | N/A | Post change decision making performance | Cognitive ability was positively associated with adaptation. Teams with difficult goals and with high learning orientation were more likely to adapt. |

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| 3-person teams working on decision-making task (Lab) | member performance orientation (I), difficulty of team goals (T), transition (T), interpersonal (T), and action processes (T) | trials in which teams used a newly developed role structure to address the communication breakdown. *Rated measure*[2]: two raters assessed transcripts for eight items – sample: "members developed a routine that accomplished the team's work." Rater's scores were averaged. | (T) | Finally, difficulty of goals and goal orientation predicted team processes which in turn predicted team adaptation. |

**Note:** Setting of Study (Field; Lab); Level of Antecedent (O= Organizational; T=Team; I=Individual composition variables aggregated to team-level); Type of Adaptation (task- or team-based); Level of Outcome (O= Organizational; T=Team; I=Individual); Measurement Approach ([1]=survey; [2]= raters; [3]=objective measurement).

## TABLE 3 (continued): SUMMARY OF TEAM ADAPTATION STUDIES

| Study Citation | Sample and Participants (Setting of Study) | Antecedent(s) (Level of Analysis) | Type of Adaptation Trigger (details regarding trigger) | Adaptation Variable(s), (Measurement Approach) | Mediator(s) | Moderator(s) | Outcomes | Key Findings (include any moderating relationships noted) |
|---|---|---|---|---|---|---|---|---|
| Marks et al., 2000 | 79 three-person teams (276 undergraduates) engaged in a low-fidelity tank simulation (Lab) | Leader briefings (T), Team Training (T) | Task-based (scenarios included non-routine events such as shifting from grasslands to an archipelago) | N/A - adaptation assumed to be the means by which teams overcome non-routine events. | Mental models, communication processes | Routine/non-routine nature of task | Team Performance (T) | Mental models and communication processes predicted performance more strongly in non-routine tasks. Additionally, leader briefings and team training affected mental model development, which in turn positively affected communication processes and performance. |
| Moon et al., 2004 | 252 students in 63 four-person teams (Lab) | Team structure (T) | Task-based (structural change from functional to divisional or divisional to functional) | N/A - adaptation assumed to be the means by which teams overcome changes. | Team coordination (supportive behavior, communication behavior) | Team cognitive ability | Team performance (T) | Results indicate that performance was better for teams that changed structure from functional to divisional over the opposite shift. The relationship between structure and performance was mediated by coordination and moderated by cognitive ability. |

**Note:** Setting of Study (Field; Lab); Level of Antecedent (O= Organizational; T=Team; I=Individual composition variables aggregated to team-level); Type of Adaptation (task- or team-based); Level of Outcome (O= Organizational; T=Team; I=Individual); Measurement Approach ([1]=survey; [2]= raters; [3]=objective measurement).

## TABLE 3 (continued): SUMMARY OF TEAM ADAPTATION STUDIES

| Study Citation | Sample and Participants (Setting of Study) | Antecedent(s) (Level of Analysis) | Type of Adaptation Trigger (details regarding trigger) | Adaptation Variable(s), (Measurement Approach) | Mediator(s) | Moderator(s) | Outcomes | Key Findings (include any moderating relationships noted) |
|---|---|---|---|---|---|---|---|---|
| Porter et al., 2010 | 548 students assigned to 137 four-person teams over three time periods (Lab) | Learning orientation (T), performance orientation (T) | Task-based (changes to workload) | N/A – adaptation inferred from the performance improvements over time | N/A | Slack resources; time together | Change in Performance from Time 1 to Time 2 and Time 2 to Time 3 (T) | Learning and performance orientation enable teams to adjust to workload changes in the presence of slack resources. Performance was related to the interaction of learning and performance orientation when no slack resources exist. |
| Randall et al., 2011 | 222 undergraduate students in 74 3-person teams working on a decision-making task (Lab) | Sensegiving (T), cognitive ability (I), psychological collectivism (I), mental models (T), behavioral information sharing (T) | Task-based (change from simulated city requiring growth strategies and then changed to simulated city with revitalization strategies required) | Reactive strategy adaptation[2] Time taken to implement desired strategies. | N/A | N/A | Decision effectiveness (population of simulated city after 24 simulated months) (T) | Sensegiving prompted mental models; psychological collectivism enhanced information sharing; cognitive ability positively associated with both mental models and information sharing; mental models and information sharing enabled reactive strategy adaptation. |
| Resick et al., 2010 | 56 four-person teams (undergraduate students) engaged in a decision-making activity (Lab) | Mental model (similarity and quality) (T) | Task-based (i.e. earthquake hit simulated city and team had to figure how to restore their city) | Team adaptation[2] Time taken to implement desired strategies. | N/A | N/A | Team decision effectiveness (simulated city population at end of activity) (T). | Adaptation was critical for decision effectiveness; mental models predicted team adaptation and mental model quality and similarity interacted leading to adaptation. |

**Note:** Setting of Study (Field; Lab); Level of Antecedent (O= Organizational; T=Team; I=Individual composition variables aggregated to team-level); Type of Adaptation (task- or team-based); Level of Outcome (O= Organizational; T=Team; I=Individual); Measurement Approach ([1]=survey; [2]= raters; [3]=objective measurement).

## TABLE 3 (continued): SUMMARY OF TEAM ADAPTATION STUDIES

| Study Citation | Sample and Participants (Setting of Study) | Antecedent(s) (Level of Analysis) | Type of Adaptation Trigger (details regarding trigger) | Adaptation Variable(s), (Measurement Approach) | Mediator(s) | Moderator(s) | Outcomes | Key Findings (include any moderating relationships noted) |
|---|---|---|---|---|---|---|---|---|
| Riethmuller et al., 2012 | 24 final year medical students assigned to 6 teams engaged in an anesthesiology simulator (Lab) | Experience together (T) | Task based (Teams faced routine and then non-routine or unexpected medical complication) | N/A - adaptation assumed to be the means by which teams overcome non-routine events. | Implicit and explicit coordination | N/A | N/A | Participants demonstrated enhanced coordination adaptivity as the difference between explicit coordination in routine vs. complication phases decreased with experience together, while the difference between implicit coordination in routine vs. complication phases increased with experience together. |
| Stachowski et al., 2009 | 14 four- to six-person nuclear power plant control room crews working in a power plant simulator (Lab) | N/A | Task-based (teams faced various crisis events). | N/A - adaptation assumed to be the means by which teams overcome crisis events. | Team interaction patterns | N/A | Team performance (team communication anticipation ratio – ratio of anticipated vs. requested communication) (T) | Higher performing teams exhibited fewer, shorter, and less complex patterns. |

**Note:** Setting of Study (Field; Lab); Level of Antecedent (O= Organizational; T=Team; I=Individual composition variables aggregated to team-level); Type of Adaptation (task- or team-based); Level of Outcome (O= Organizational; T=Team; I=Individual); Measurement Approach ([1]=survey; [2]= raters; [3]=objective measurement).

## TABLE 3 (continued): SUMMARY OF TEAM ADAPTATION STUDIES

| Study Citation | Sample and Participants (Setting of Study) | Antecedent(s) (Level of Analysis) | Type of Adaptation Trigger (details regarding trigger) | Adaptation Variable(s), (Measurement Approach) | Mediator(s) | Moderator(s) | Outcomes | Key Findings (include any moderating relationships noted) |
|---|---|---|---|---|---|---|---|---|
| van der Vegt et al., 2010 | 47 production teams in large truck manufacturing plant (Field) | Control variables: Team tenure (T); team tenure heterogeneity (T); changes in member experience (T) | Team-based (team turnover) | Team flexibility[1] (measured with 3 survey items) – sample item: "All team members fill in for one another if necessary." | N/A | N/A | Team effectiveness (% of work without unacceptable defects) (T) | Team turnover was negatively related to team flexibility; flexibility fully mediates the relationship between turnover and effectiveness. |
| Vera & Crossan, 2005 | 232 individuals across 38 teams in a municipal setting (Field) | Improvisation training (T) | Task-based (improvisation training focused on being responsive and creative under pressure) | Improvisation[1]; (measured with 7 survey items) – sample items: "The team deals with unanticipated events on the spot," and "The team identifies opportunities for new work processes." | N/A | Expertise, teamwork quality, experimental culture, real-time information and communication, and memory. | Innovation (T) | Improvisation is affected by training. In turn, improvisation is positively related to innovation moderated by team and contextual factors (expertise, teamwork quality, experimental culture, information and communication, memory). |
| Waller, 1999 | 10 flight crews engaged in a flight simulation (Lab) | N/A | Task-based (scenarios included non-routine events such as loss of hydraulic system) | N/A - adaptation assumed to be the means by which teams overcome non-routine events. | Information collection, task prioritization, task distribution | Non-routine events | Crew performance (frequency of errors) (T) | Crew performance increased as the time taken to engage in task prioritization or task distribution activities after a non-routine event decreased. |

**Note:** Setting of Study (Field; Lab); Level of Antecedent (O= Organizational; T=Team; I=Individual composition variables aggregated to team-level); Type of Adaptation (task- or team-based); Level of Outcome (O= Organizational; T=Team; I=Individual); Measurement Approach ([1]=survey; [2]= raters; [3]=objective measurement).

## TABLE 3 (continued): SUMMARY OF TEAM ADAPTATION STUDIES

| Study Citation | Sample and Participants (Setting of Study) | Antecedent(s) (Level of Analysis) | Type of Adaptation Trigger (details regarding trigger) | Adaptation Variable(s), (Measurement Approach) | Mediator(s) | Moderator(s) | Outcomes | Key Findings (include any moderating relationships noted) |
|---|---|---|---|---|---|---|---|---|
| Waller et al., 2004 | 14 four- to six-person nuclear power plant control room crews working in a power plant simulator (Lab) | N/A | Task-based (scenarios included non-routine events such as loss of hydraulic system) | N/A - adaptation assumed to be the means by which teams overcome non-routine events. | Information collection, task prioritization, task distribution, shared mental model development | Non-routine events | Crew performance (frequency of errors) (T) | During non-routine situations, higher performing crews engaged in more information collection and more shared mental model development activities. |
| Wiedow & Konradt, 2011 | Study 2: 211 members from 50 work teams from 10 German organizations in various industries (Field) | N/A | N/A | Team adaptation[1] (measured with 3 survey items) – sample item: "After agreements have been made in this team, everyone does things in the same manner." | Coordination (member- and leader- ratings) | N/A | Team performance (T); (Member- and leader-ratings) | Results indicate that team adaptation was positively related to coordination (member-rated). Similarly, team adaptation was positively related to team performance (member- and leader-rated). |
| Woolley, 2009 | Experiment with 90 three person undergraduate student teams (Lab) | Outcome focus (T), process focus (T), and action identification (T) | Task-based (membership change or a loss of critical building materials) | Process adaptation[2] (measured by two raters – whether teams combined structures and used materials in unique ways). Problem adaptation[2] (two raters coded the discussions following the trigger for alteration of strategy) | N/A | N/A | Task performance (T) | Outcome-focused teams were better able to identify problems and in turn, adapt their work processes. Adaptation was positively related with task performance. |

**Note:** Setting of Study (Field; Lab); Level of Antecedent (O= Organizational; T=Team; I=Individual composition variables aggregated to team-level); Type of Adaptation (task- or team-based); Level of Outcome (O= Organizational; T=Team; I=Individual); Measurement Approach ([1]=survey; [2]= raters; [3]=objective measurement).

## TABLE 4: SUMMARY OF TEAM RESILIENCE STUDIES

| Study citation | Sample and Participants | Analog to NASA? | Resilience (Measurement Approach) | Antecedent(s) (Level of Analysis) | Mediator(s)/ Moderator(s) | Outcomes | Key Findings (include any moderating relationships noted) |
|---|---|---|---|---|---|---|---|
| Gomes, Borges, Huber, Carvalho (2014) | 26 participants from Brazilian agencies conducted a simulation of a nuclear power plant emergency<br><br>(Field) | Near | Resilience[2]. Case study approach (qualitative research). | Team diversity (T), Team communication (T), Team organization (T) , Team reorganization (T), Physical distribution (T), Team Coordinator activities (T), Team size (T), Debriefing (T), Small/Modular Plans (T), Visual Support (T) | N/A | Team resilience (T), brittleness (lack of resilience) (T) | Resilience may have benefitted from communication, diversity of knowledge base, smaller and modular plans, and reorganization (small groupings) for discussions. Brittleness arose from lack of briefing/debriefing, lack of cognitive support, and structured/coordinated planning. |
| Lundberg & Rankin (2014) | 3 focus groups (14 members) of Swedish small crisis response team members that experienced the Asian Tsunami of 2004 and/or the Israel-Lebanon Crisis of 2006 (Field) | Near | Resilience[2]. Resilience categories within role improvisation were derived (qualitative research). | Improvisation (T) | N/A | Resilience (T)<br><br>Vulnerability(T) | Resilience was a positive side effect of improvised work; however, there could be a negative side effect by getting stuck in an improvised role. |

**Note:** Setting of Study (Field; Lab); Level of Antecedent (O= Organizational; T=Team; I=Individual composition variables aggregated to team-level); Level of Outcome (O= Organizational; T=Team; I=Individual); Measurement Approach ([1]=survey; [2]= raters; [3]=objective measurement).

## TABLE 4 (continued): SUMMARY OF TEAM RESILIENCE STUDIES

| Study citation | Sample and Participants | Analog to NASA? | Resilience (Measurement Approach) | Antecedent(s) (Level of Analysis) | Mediator(s) / Moderator(s) | Outcomes | Key findings |
|---|---|---|---|---|---|---|---|
| Stephens, Heaphy, Carmeli, Spreitzer, & Dutton (2013) | Study 1-Indiv. Level, 649 University Staff;<br><br>Study 2- Team Level, 82 top management teams (TMTs) from Israeli firms (Field) | Distant | Individual Resilience[1] (Study 1, measured with 5 survey items) – sample item – "I bounce back when I confront setbacks at work."<br><br>Team Resilience[1] (Study 2, measured with 5 survey items) – sample item – "This TMT knows how to cope with challenges." | Relationship closeness (Study 1) (I), Trust (Study 2) (T) | Emotional carrying capacity (Study 1, Study 2) | Individual Resilience (Study 1) (I),<br><br>Team Resilience (Study 2) (T) | At the individual level, emotional carrying capacity positively influenced individual resilience and mediated the relationship between closeness and resilience. At the team level, emotional carrying capacity positively influenced team resilience and mediated the relationship between trust and resilience. |
| Stevens, Galloway, & Lamb (2014) | 2 junior officer submarine navigation teams (Field) | Near | Resilience[2]. Behavioral rating of team resilience (4 levels: Unstressed Battle Rhythm, Leader-Dependent Battle Rhythm, Team-Based Resilience, and Advanced Team Resilience) on 5 practices: Dialogue, Decision Making, Critical Thinking, Bench Strength, Problem-Solving | Team resilience (T) | | Neurodynamic Synchrony/Coherence (T) | Teams that had higher levels of team resilience showed fewer periods of neurodynamic synchrony of smaller magnitude than in teams with lower levels. |

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|---|---|---|---|---|---|---|---|
| | | | Capacity | | | | |
| West, Patera, Carsten (2009) | 101 three or four person student teams in a classroom activity across two time periods (Field) | Distant | Resilience[1]. Based on Luthans et al. (2007) adapted to team level (measured with 6 survey items) – sample item – "Our team usually manages difficulties one way or another when working." | Team efficacy (T), Team optimism(T), Team resilience(T) | | Team cohesion (T), Team cooperation (T), Team coordination (T), Team conflict (T), Team satisfaction (T) | Initially, team optimism positively influenced cohesion, cooperation, coordination, and satisfaction. Later, team resilience positively related to cohesion and team resilience and efficacy related to cooperation; team optimism was positively related to coordination and satisfaction at later stages. |

**Note:** Setting of Study (Field; Lab); Level of Antecedent (O= Organizational; T=Team; I=Individual composition variables aggregated to team-level); Level of Outcome (O= Organizational; T=Team; I=Individual); Measurement Approach ([1]=survey; [2]= raters; [3]=objective measurement).

## TABLE 5: SUBMARINE TEAM BEHAVIORAL TOOL

The Submarine Team Behavioral Tool
http://www.public.navy.mil/subfor/underseawarfaremagazine/Issues/Archives/issue_55/STBT.html#

Four levels of resilience: Unstressed Battle Rhythm, Leader-Dependent Battle Rhythm, Team-Based Resilience, and Advanced Team Resilience.

**Unstressed Battle Rhythm.** A team at this level can perform basic functions and will adhere to standard checklists and procedures for simple problems. As long as nothing goes wrong, they will appear to be formal and proficient. Tested with an unanticipated event, though, elevated stress will cause them to struggle with basic functions and communications. Confronted with complex problems or casualties, they will quickly become overwhelmed. This is a brittle team.

**Leader-Dependent Battle Rhythm.** Sometimes a weak team can remain convincingly functional under the guidance of a strong coordinating presence, such as an experienced Contact Manager, Sonar Supervisor, Assistant Navigator, or Officer of the Deck (OOD). The team is able to maintain structure under stress so long as a leader acts quickly to prioritize objectives and refocus the operators when necessary. The operators will rely on the leader's direction not just for decision-making, but basic problem-solving as well. A team in this state is also brittle, as they will fracture if the leader becomes confused or distracted in a complex problem.

**Team-Based Resilience.** True resilience emerges when individual operators begin to naturally think beyond the context of their individual watch stations. Operators at this level process the information as well as the data and provide meaningful backup to tactical decision makers. Routine functions and formal reports are automatic, so they don't consume important mental resources and they continue to occur under elevated levels of stress and complexity. Importantly, a team operating at this level is aware of its own limitations and will take action to bring additional resources (such as extra watchstanders) to bear when appropriate.

**Advanced Team Resilience.** An exceptionally proficient team may reach this level with sufficient effort and experience. Operators at the advanced level will have the flexibility and processing power to manage a variety of dynamic problems and unexpected events simultaneously. They will anticipate one another's needs for information and actively challenge their own and others' assumptions. Tactical decisions will emerge from deep within the team as sound recommendations, and senior leaders will become comfortably detached from the detailed problem-solving, instead providing big-picture oversight and mission focus.

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Given that future space crews of long-duration exploration missions will have to be more autonomous and handle any disruptions that they may face with less assistance from ground personnel than has been the case with prior space missions, the topics of team adaptation and resilience are becoming more salient for mission effectiveness. Accordingly, with this project, we sought out to gain a deeper understanding of the team adaptation and resilience nomological networks. To accomplish this goal, we performed an extensive literature review focused, in particular, on factors that give rise to team adaptation and resilience; as well as the resulting by-products of these two related (but distinct) constructs. Additionally, we conducted nine 1-hour interviews of various NASA personnel to understand their experiences regarding team adaptation and resilience and to gain their insights in regards to how these constructs will likely be different within future long-duration missions. Upon integrating the lessons learned from each of these parts of the project, we outline our recommendations for future missions as well as some research projects that should be explored in order to better understand team adaptation and resilience.

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