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Review Article

Promoting Teamwork in Translational Medical Teams: Insights and Recommendations from Science and Practice

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Abstract

Translational medical teams are transdisciplinary, highly collaborative, and operate within dynamic environments to solve time-sensitive and complex problems. These teams are tasked with turning observations in the laboratory and clinic into effective interventions that improve the health of individuals and the public. The nature of the problems they seek to solve requires coordination among clinicians, scientists, and experts from various scientific disciplines. Characteristically, translational medical teams have complex compositions, structure, and pluralistic goals, which pose significant challenges and barriers to enacting effective teamwork, compromising team performance. Given these challenges, it is imperative to glean insights from teams research and the science of team science on how to execute efficacious teamwork. Consequently, the purpose of this paper is to discuss specific teamwork processes (i.e., trust, communication, self-correction, backup behavior, shared mental models, and conflict management) that are critical to translational medical team performance and offer mechanisms to better equip such teams. Utilizing a theoretical framework of transdisciplinary teamwork adapted from the science of team science and tailored to translational medical teams, we describe each of these processes, their relation to translational medical team outcomes, and how they can be leveraged to improve teamwork. Such a discussion aims to provide practical guidance for conceptualizing and enhancing teamwork in translational medical teams.

ABBREVIATIONS

SMM: Shared Mental Model; TMS: Transactive Memory System

INTRODUCTION

Translational medicine is a discipline within the biomedical and public health research domains that seeks to improve individual and community health by "translating" scientific medical findings into evidence-based, practical tools. Its main objective is to deliver new treatments and cures more quickly to patients. Humans are affected by thousands of diseases, but only about 500 have FDA approved treatments [1]. Translational

medical teams try to close this gap by taking basic discoveries about disease causes and progression and converting this knowledge into a new treatment – be it a drug, device, diagnostic intervention, or behavioral intervention – and demonstrating that the treatment tangibly improves health [1]. This process has colloquially been described as 'from bench to bedside', where *bench* refers to research conducted in a controlled laboratory and *bedside* describes hands-on patient care [2]. Successful bench to bedside translation is a complex process riddled with pitfalls and challenges [3], such as navigating the lexical differences across disciplines, among others. The purpose of this paper is to provide translational medical teams with recommendations for optimizing teamwork that have been culled from organizational teams research and the science of team science (i.e., the study of "collaboration across disciplines" [4]).

Translational medical teams are transdisciplinary [5] (i.e., composed of interdisciplinary researchers seeking to synthesize and extend discipline-specific theories, methods, and concepts; [6]), highly collaborative [1], and operate within dynamic environments to solve time-sensitive and complex problems [1]. The nature of the problems they seek to solve requires coordination among clinicians, scientists, and experts from various scientific disciplines, including efficacy, toxicity, data sharing, biomarkers, and clinical application [1], whose knowledge, experience, and location vary [7]. Furthermore, these teams often represent collaborations between some mix of government, academia, industry, and nonprofit patient organizations [1]. Members of translational medical teams work jointly to develop and use shared conceptual frameworks that synthesize and extend discipline-specific theories, concepts, and/or methods to create new models and language to facilitate faster and better healthcare delivery. Because their objective is so broad, they often pursue competing goals simultaneously [8], thereby exacerbating the complexity of their work.

The complexity that characterizes translational medical teams' structure, composition, and pluralistic goals poses significant challenges and barriers to enacting effective teamwork, and thus compromises team performance. Fortunately, we may draw from organizational team science to provide translational medical teams with guidance for overcoming teamwork barriers common to their work. Teamwork refers to the "dynamic, simultaneous and recursive enactment of process mechanisms which inhibit or contribute to team performance outcomes" [9]. More simply stated, teamwork is characterized by the affective, behavioral, and cognitive processes that underpin coordinated team performance [10,11] and is critical to translational medicine [12]. One review found that 60% of the transdisciplinary science literature identifies teamwork factors such as communication, leadership, and trust as important determinants of transdisciplinary team goal attainment and success [13]. Furthermore, research on translational medical teams explores teamwork as a critical process by which they accomplish goals and is cited in widely accepted frameworks pinpointing factors for translational medical team success [8,14,15]. For example, management and coordination have been identified as critical to scientists' fluency in bringing together different languages characteristic to their epistemic backgrounds [16,17].

A number of authors have noted the need for research that

describes the skills necessary for participation in transdisciplinary teams [8], focuses on competencies that drive interdisciplinary team development [13], and determines what components of team functioning are most applicable to translational science [18-21]. To answer these calls and address a gap in the literature, we integrate findings from organizational teams research with a theoretical framework of transdisciplinary teamwork that has been adapted from previous models [14,15] and tailored to translational medical teams (see Figure 1). In so doing, we provide more granularity to extant models of transdisciplinary teamwork, which conceptualize team process at a macro level of understanding. Although generality may be necessary in initial stages of model development, a generalist approach does not afford a clear understanding of how transdisciplinary work is completed. Model specificity lends itself to the operationalization, measurement, and testability of relationships that serve to explain the mechanisms through which system inputs are converted to outcomes. However, thorough testing of the model we present goes beyond the scope of the current paper. Instead, our main objective is to begin elucidating the teamwork components that are applicable to translational science, allowing us to present practical recommendations for translational medical teams.

CONCEPTUAL MODEL OF TRANSLATIONAL MEDICAL SCIENCE COLLABORATION

Translational medical science collaborations can be modeled as sets of antecedent, process, and outcome variables that influence and are influenced by one another. *Antecedents* refer to factors that affect the "collaborative readiness" of research teams [15] and how teams go about meeting their goals [22,23]. As shown in Figure 1, antecedents of translational medical teams include characteristics of the individual team members (intrapersonal), the context in which the team operates (environmental), and the organizations or institutions affiliated with the team (organizational/institutional [15]). *Processes* refer to members' cognitive, verbal, and behavioral interdependent activities and dynamic team properties directed at organizing taskwork and converting inputs into outcomes to achieve collective goals [24]. Collectively, processes are the mechanisms by which teams take inputs (e.g. resources, expertise) and generate products and innovations. Research on transdisciplinary teams has identified
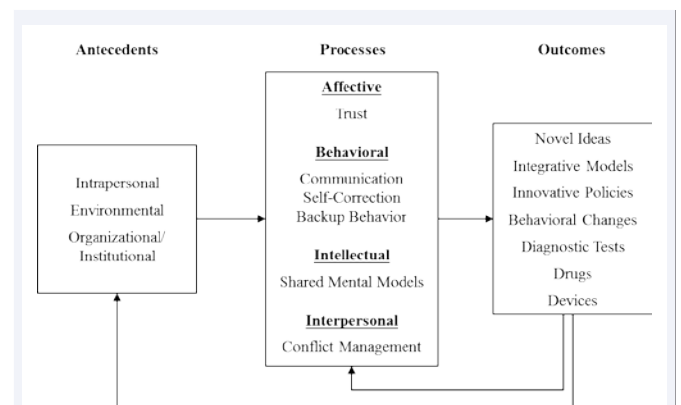

Figure 1 Conceptual model of translational medical science collaboration. Adapted from Fuqua et al. and Stokols et al.[14-15].

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four categories of processes that directly affect team outcomes. These process categories are: a) affective, b) behavioral, c) intellectual, and d) interpersonal. *Affective* processes refer to those beliefs and feelings team members possess that impact other team processes and outcomes. *Behavioral* processes are those physical activities in which team members engage in an effort to meet team objectives. *Intellectual* processes describe the team's cognitions and efforts to generate novel ideas and integrate conceptual frameworks. *Interpersonal* processes refer to the dynamics that take place between team members (i.e., team member relations) [15]. These processes all contribute to the creation of team *outcomes*, which are the products or results that the team expects to achieve. Outcomes of translational medical teams can include novel ideas, integrative models of multiple epistemic perspectives, innovative policies, behavioral changes, diagnostic tests, drugs, and devices.

The antecedents, processes, and outcomes in Figure 1 are presented in the model based on their inclusion and prevalence in previous models of transdisciplinary collaboration [14,15,25,26], standing in organizational teams research [27], importance to medical teamwork [28,29], and relevance to translational medical research [1,8]. The arrows pointing to the right in Figure 1 indicate the influence of antecedent factors on collaborative processes and the impact of those processes on team outcomes (e.g., creation of a new device for treating a disease). The arrows pointing to the left indicate that translational medical team outcomes can, in turn, influence succeeding collaborative processes (e.g., conflict management) as well as change the antecedents (e.g., team composition through attrition or addition of team members) that affect collaborative processes. These arrows underscore the cyclical relationships between the model variables that manifest as a feedback loop that denotes the continually evolving nature of teams [30].

Since teamwork, by definition, is the process through which team goals are achieved [9], we focus the remainder of this paper on presenting a more nuanced view of the four process categories (i.e., affective, behavioral, intellectual, and interpersonal) identified in conceptual models of transdisciplinary science. We chose to focus solely on elaborating processes rather than antecedent or outcomes for two reasons: processes are modifiable and they are more strongly related to translational team performance outcomes, such as innovation and creativity, than are antecedents [31]. Team members can control processes; they have much less control over antecedents, which are often static or difficult to change. As an example, translational medical teams will have very little control over the organizational culture(s) in which they operate. Indeed, even if it is conceptually possible to change an antecedent (e.g., organizational culture), it may not be practical. Instead, teams must learn to make do with what they have.

Using the framework presented in Figure 1 as an organizing structure, we have identified six specific teamwork constructs that are relevant to translational medical team performance. Though not an exhaustive list of all the processes in which translational medical teams may engage as part of their work, the constructs we present were selected because a) each are often cited in extant models of organizational teamwork (trust [11,32-34], communication [11,27,32,33,35-42], self-correction

[7,32,34,35,42,43], backup behavior [7,24,33,35,36,38,41], shared mental models [7,9,27,32,33, 42] and conflict management [7,24,27,36,38,40,41]), b) all team members contribute to their quality (i.e., it is not traditionally the sole responsibility of one team member, such as leadership), c) they do not necessarily require external resources to enact, and d) they have conceptual relevance to translational medical teams. In the sections that follow, we describe each of these processes, their relation to translational medical team outcomes, and how they can be leveraged to facilitate optimal teamwork within translational medical teams and improve the outcomes resulting from these collaborations. For a summary of the processes, refer to Table 1.

Affective processes

Trust: Trust is the willingness of an individual to be vulnerable to the actions of another party based on the expectation that the other will perform a particular deed important to the trustor, irrespective of the ability to monitor or control the trusted party [44,45]. As such, trust has been described as a psychological state comprised of intentions to accept vulnerability based on positive expectations of the trustee [45]. Risk is an inherent component in models of trust, such that one must chance psychological or physical harm in order to engage in a trusting action or behavior [46-48]. Trusting behaviors within the context of a translational medical team are characterized by team members' willingness to speak up with ideas, questions, and concerns as they arise, and for the rest of the team members to positively receive new ideas, questions, and concerns [49].

Vulnerability among collaborators contributes to the attainment of translational team initiatives like innovation, discovery of treatments and cures, and the integration of inter-disciplinary concepts [50,51]. In fact, it has been argued that being vulnerable with teammates complements the adoption and implementation of process innovations and helps realize the full potential of creativity [52]. Additionally, being vulnerable with collaborators is linked to team learning behavior, task performance [48], and boundary spanning (i.e. role of linking internal and external networks) [50]. Boundary spanning is important for translational medical teams since they rely on cross-functional collaborations and, thus, must often engage in external communication to attain information that facilitates the execution of a team's goals [53]. Ultimately, in order for translational medical teams to successfully apply research findings to clinical settings, it is essential that team members trust each other; they must feel comfortable sharing information, dissenting from popular opinion, questioning other experts, and admitting mistakes without fear that their actions will be received negatively. Moreover, teammates must also be willing to accept such risk-taking behaviors and believe that they serve to propel the team's goals.

To ensure that trust is fostered and maintained within translational medical teams, we offer several recommendations. First, since trust is often built through the reciprocation of information [54,55], one recommendation is to discuss each of the team members' functional background, expertise, and level of experience at the start of a team initiative so that team members feel confident in the competence of their teammates. By doing so, ability-based trust can emerge whereby the competence

Table 1: Team-based Recommendations for Translational Medical Teams.

Process	Construct	Recommendations

Affective Processes	**Trust:** Be vulnerable with your teammates	• Engage in reciprocity of information
		  1. Share functional background and expertise information with team
		• Develop a safe climate with:
		  1. Sensitive feedback
		  2. Communication protocols

Behavioral Processes	**Communication:** Be open, adaptable, concise, clear, and accurate	• Engage in closed-loop communication • Devise information exchange protocols • Take the perspectives of teammates

	Self-Correction: Adjust team attitudes, behaviors, and cognitions to achieve collaborative goals	• Provide feedback during:
		  1. Briefs
		  2. Huddles
		  3. Debriefs

	Backup Behavior: Ask for and offer help to team members	• Conduct cross training between translational team members • Engage in regular situation monitoring

Intellectual Processes	**Shared Knowledge Structures:** Attain an aligned understanding of the task, objectives, and associated strategies for collaborative goal attainment	• Ensure thorough project planning
		  1. Create team charters
		  2. Detail performance strategies
		  3. Communicate own expertise and familiarity with others' expertise

Interpersonal Processes	**Conflict Management:** Overcome team incompatibilities constructively	• Focus on content of interpersonal interactions rather than delivery style • Explicitly discuss reasons guiding final decisions regarding work assignments • Assign tasks to members who have relevant task expertise

and perceived credibility of each team member forms the foundation from which trust is fostered [44]. Establishing ability-based trust is important in translational medical teams that often must overcome implicit power differentials between professions, which potentially hinder transdisciplinary efforts. Academic cultures often deter collaboration between multi-disciplinary investigators, as it favors departmental efforts over interdisciplinary programs [56], and this hurts collaborative efforts. By sharing ones' background and expertise with the team and highlighting their unique contribution to the team it serves to reduce power concerns and reduce the culture of inhibition and restraint in communication associated with it. Rather, it will promote a sense of trust and subsequent open and safe communication [57].

A second recommendation for promoting trust is to provide feedback and conduct team debriefs in a structured yet positively framed manner [58]. Delivering feedback in a safe environment so that recommendations are not taken as personal criticisms [59] ensures that the reception of feedback is optimized, and that benevolence-based trust (i.e., the extent to which a trustee is believed to want to do good for the trustor apart from any profit motives [44] is maximized. In the same way, when giving negative feedback that involves one individual, it is important to provide this feedback individually, so as not to embarrass or undermine the credibility of the team member. Delivering feedback in this way will promote trust and improve team openness and collaboration.

To further support trust, translational medical teams should promote and develop a climate of psychological safety. A psychologically safe environment is a space in which team members feel they can take risks with each other without fear of negative consequences, and serves as a mechanism to encourage trust within a team. A psychologically safe environment allows team members to feel supported by peers and leaders [60,61], and enables team members to feel comfortable speaking up, seeking advice, delivering feedback, working through conflicts,

and admitting mistakes [62-64]. It serves to facilitate information sharing [65], especially among heterogeneous team members who are less likely to share new information [66]. Essentially, psychological safety contributes to a climate that is non-threatening, supportive, and encourages the use of each team member's creative potential.

To promote psychological safety within translational medical teams it is helpful to build in protocols (e.g., allowing contributions at all levels of seniority, setting ground rules for respectful resolution of debates, praising assertiveness) for team members to enact voice and speak up to advocate for the cause or collective goal being pursued. By doing so, the integrity component of trust, defined as the extent to which a trustee is believed to adhere to sound moral and ethical principles [44], can be established. In the context of translational medical teams, integrity includes ensuring team members feel a sense of fairness, justice, and promise fulfillment. By establishing ground rules and protocols for disagreements, team members will feel safe to speak up when their respective field has evidence or data that is discrepant from the rest of the teams' conclusions. Given that one of the drivers of translational team science is the enormously increased range of questions that lead to unique and insightful solutions, opportunities for taking risks and voicing concerns should not be inhibited, and thus the establishment of trust within the team is crucial.

Behavioral processes

Communication: Communication is one of the cornerstones of an effective translational medical team [8,13]. Formally defined, communication is "the exchange of information between a sender and a receiver" [67]. However, not all communication is equal. That is, effective communication is characterized by openness (not holding back), adaptability, conciseness, clarity, and accuracy [67]. Such communication allows teams to mitigate information overload as well as handle and adapt in dynamic situations, predict team members' needs, foster seamless coordination, and

execute plans efficiently [68], all behaviors which are crucial to teams aimed at uncovering and translating timely, clinically-related innovations. Additionally, communication fosters trust, cohesion, inclusiveness, and psychological safety, which are all attitudes essential for fruitful collaborations [69].

Although there have been suggestions within the translational teams literature on how to simply improve the flow of information (e.g., brainstorming sessions [15], workshops [70], regular meetings [71], interactive websites [26], and boundary spanners [16]), there are several specific mechanisms from teams research that have been touted for achieving not just more communication but optimal communication, such as closed-loop communication. Closed-loop communication is the process of acknowledging and clarifying information with the sender of the communicated message to assure that the recipient did receive and comprehend the information in the same manner as it was originally intended [72]. Simply stated, closed-loop communication is the process of quality assurance and affirming information for accuracy. Assurance and accuracy are particularly invaluable in a stressful, high-stakes environment with distributed team members (i.e., individuals not located in the same vicinity) of varying backgrounds and evolving technologies. Furthermore, assurance and accuracy are also central in situations when information is varied in terms of technical jargon, can originate from multiple sources, and is intended for several team members [67]. In fact, research has indicated that teams who engage in training that explicitly emphasizes closed-loop communication show improvement in communication as well as outcomes (e.g., patient care [73]). Given the varying sizes, multiple institutions and backgrounds of team members, and the necessity of electronic technologies to facilitate information exchange, it is paramount to 'close the communication loop' within translational medical teams to ensure that teams have a shared and accurate understanding.

Another mechanism noted for promoting exemplary communication is information exchange protocols. Information exchange protocols enable structured communication to facilitate information presentation and recall as well as a shared understanding [74]. Fostering presentation, recall, and shared understanding by leveraging information exchange protocols are absolutely essential for successful translational medical teams since they are typically transdisciplinary with extensive expertise and technical, discipline-specific jargon [8]. This heterogeneity often hinders communication and leads to confusion, ambiguities, and frustration due to specialized terminology [75], divergent opinions [26], and limited face-to-face conversations [26]. Attempting to alleviate these negative outcomes, structured communication provides a means to form common ground, a shared vocabulary, and an established convention for turn taking [68]. Indeed, empirical evidence has demonstrated that individuals who employ information exchange protocols have greater team attendance, greater satisfaction, and a decrease in missed information [76].

Considering evidence shows that individuals tend to interact with those of similar backgrounds [69,77,78] and translational medical teams are characteristically heterogeneous, it is integral to employ mechanisms that can increase and optimize communication [69], particularly as a team matures and

deep-level diversity (e.g., differences in values, beliefs, and experiences) begins to more strongly influence team outcomes [69,79,80]. Perspective-taking (i.e., attempts to understand the thoughts, motives, and feelings of another person [81] is one such mechanism for managing and capitalizing on the educational and experiential diversity inherent to translational medical teams. Perspective-taking enhances the creativity of teams by facilitating information elaboration [82]. Team members with expertise dissimilarity are more likely to behave creatively when the entire project team engages in tacit (i.e., subjective knowledge that is difficult to formalize and articulate to others, such as personal experiences, insights, and know-how) information sharing [83]. Such communication must be honed by adhering to the previously stated characteristics (i.e., open, adaptable, concise, and accurate) and leveraging the aforementioned mechanisms (closed-loop communication and information exchange protocols). Ensuring that team members communicate optimally while using tools appropriately is one key component to cultivating an effective translational medical team [84].

Self-correction: Team self-correction is the adjustment of team attitudes, behaviors, and cognitions without outside intervention [85]. Teams that employ self-correction methods demonstrate more similar shared mental models (SMMs; see discussion below) and greater effectiveness [86]. As such, self-correction helps translational medical teams achieve their pluralistic goals [87] and improve their collaborative processes and outcomes [69]. Self-correction is of particular importance to translational medical teams as there are bound to be mistakes in project work that is characterized by the integration of disparate knowledge bases. In transdisciplinary research, misunderstandings or misinterpretations of others' expertise can create missteps when integrating theories and concepts from multiple disciplines. Team self-correction is, therefore, necessary for enabling teams to rebound and move forward after errors in thinking or when solutions are less effective than anticipated.

Feedback, that is, information regarding performance [88] and process [88,89], is one mechanism that translational medical teams can use to facilitate self-correction. Constructive feedback identifies areas of strengths and weaknesses while simultaneously suggesting strategies for overcoming performance deficits. Feedback is most effective when it is timely [90-92], specific [90-93], and both positive and negative [90-93]. Timely feedback is more precise and salient as details are fresher in everyone's memory. Specific feedback enables an accurate understanding of the issues. Both positive and negative feedback are useful for learning [92]. Positive feedback reinforces desired processes whereas negative feedback may be the impetus to self-correction.

Briefs, huddles, and debriefs are meetings that provide teams with opportunities to self-correct through feedback [33], learning from experience, reinforcing shared understanding [86], and re-strategizing [94]. *Briefs* occur before teams embark on a new task. In addition to creating an opportunity for teams to establish a shared understanding of goals, responsibilities, and expectations prior to beginning project work [95], briefs may be used to isolate possible project pitfalls and make changes to the team strategy before errors can occur. A project kickoff meeting is an example of a brief that a translational team would experience. When unanticipated issues inevitably arise during

the course of a translational project, any team member may convene a *huddle* (an ad hoc planning meeting [96]) with the other team members to discuss how to manage the problem. For instance, if preliminary research findings were misleading, a huddle may be convened to brainstorm an explanation for the contrary results. When conducting a huddle, the team should suspend related activities (e.g., manuscript preparation), discuss strategies for addressing the problem, and take corrective action as needed. As a project or project phase ends, *debriefs*, which may be led by any team member [86], afford time for a review of prior work, discussion of successes and failures, and strategies on how to prevent similar failures in the future [97]. Teams that use debriefs experience higher levels of team performance, efficacy, openness of communication, and cohesion [98]. Indeed, translational medical teams may be able to improve performance by as much as 25% when they successfully debrief [97]. Debriefs are effective when they promote active self-learning [99], are initiated with the intent to develop knowledge, skills and attitudes rather than criticize [93], and allow for input from all team members [89]. Debrief discussions should focus on teamwork as well as taskwork [58,85]. Utilizing briefs, huddles, and debriefs to deliver feedback can enable teams to quickly learn from errors and can cultivate a shared understanding of how to improve, refine, and adapt practices for enhanced teamwork and taskwork [100]. Through leveraging self-correction techniques, translational medical teams can elicit team process changes, such as effective adaptation [101,102], that lead to functional outcomes for the entire team [101].

Backup Behavior: Closely related to team self-correction is backup behavior. Backup behavior involves the shifting of workload among team members to achieve balance so that the team and each individual member are able to perform capably to reach their goals [33,72,103,104]. Also known as mutual support, backup behavior may include filling in for a fellow team member or helping him or her to correct mistakes [105]. Effective engagement in backup behavior requires an understanding of fellow members' responsibilities and the willingness and ability to provide and seek assistance when needed [33,104,105]. Team members should provide backup when they notice that a team member is not able to effectively perform a task without assistance. For instance, a team member may be overloaded with other responsibilities, may not have the requisite expertise or experience to perform the task, or may simply have made a mistake (s)he needs to rectify.

Though the transdisciplinary nature of translational teams may limit the extent to which members are able to step in and perform one another's tasks given the distributed nature of expertise, backup is still a critical process for the success of these collaborations. One strategy for facilitating backup is cross-training (i.e., training team members in the duties of his or her teammates [106]). Though it would not be expected that translational team members would learn the details of each other's disciplines, cross-training can ensure that members are knowledgeable about each other's roles and responsibilities on a high level so that they are able to recognize and provide assistance when it is needed [107].

A second strategy that translational teams can immediately and continually implement is situation monitoring, which is the

process of actively scanning activities and behaviors to assess situational elements that could impact the team. Included in situation monitoring is the regular assessment of fellow team members. Continuous assessment keeps team members current about what could impact team performance. The resulting situation awareness can be utilized to determine when one should reach out to a team member who may require task assistance. Seeking and offering task assistance (i.e., backup) will keep translational projects running smoothly even when individual members are experiencing difficulties with contributing to the project [33]. Backup may become particularly important for translational teams during periods of intense activity.

Intellectual processes

Shared knowledge structures: Perhaps the defining characteristic of transdisciplinary research teams is distributed expertise. The unique, domain-specific expertise that each member holds "creates the potential for teams to complete work outside the scope of any one individual's capabilities" [34]. However, in order to reap the benefits of distributed expertise, translational medical teams need to effectively combine these disparate knowledge-bases [66].

Combining knowledge requires that teams establish shared mental models (SMMs), which are organized knowledge structures common across team members [108]. More simply stated, SMMs are similar mental pictures or representations of the organizational context (e.g., the culture, policies, etc.), project goals and timeline, the tasks that need to be completed, the strategies that will be used to complete these tasks, and the equipment available and necessary for project completion [109]. SMMs have been found to improve team performance [109,110] through its positive association with implicit coordination [111]. For example, accidents and errors in the aviation, [112] and military [113] industries have been attributed to lack of SMMs. Furthermore, SMMs are expected to contribute to higher quality solutions by teams working to solve ill-defined problems [114].

Another type of knowledge structure that, when developed and maintained, benefits translational teams is an effective Transactive Memory System (TMS). A TMS is "a cooperative division of labor for learning, remembering, and communicating relevant team knowledge" [115]. As such, an effective TMS is one in which team members know who knows what information, and believe that other team members' information is accurate [115,116]. Accurate SMMs of the TMS allow team members with unique expertise to combine their disparate knowledge into a novel product or outcome that extends beyond any one discipline. In so doing, distributed expertise frees team members to specialize deeply in their preferred discipline [115,116]. As a result, rather than being burdened with knowing a little about a lot (breadth of knowledge), team members are able to learn a lot about a little (depth of knowledge). TMSs have been associated with improved team effectiveness [116-118], team learning [115,119], and member satisfaction [116,117], all desirable outcomes for translational medical teams.

Shared knowledge structures do not develop automatically; it requires purposeful interpersonal interactions [120]. One way for teams to create shared knowledge structures is through project planning [121], which lays the groundwork for effective

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team functioning [122]. Translational teams should capitalize on the opportunity to clearly articulate project plans in thoughtful statements of work and use project kickoff meetings to reaffirm or refine study goals, tasks, and each member's roles and responsibilities throughout project duration. Such planning facilitates team performance by cultivating an understanding of both taskwork and teamwork whereby team behavior (i.e., coordination) and interpersonal processes are optimized [122,123]. In order to maximize performance, teams should take the time to create team charters and performance strategies that describe teamwork and taskwork expectations [123]. After the start of the project, huddles and debriefs may be used as opportunities for translational teams to revise dissimilar mental models [86]. As discussed above, open communication within a psychologically safe environment will facilitate the success of project planning meetings and team goal attainment.

Another way to cultivate shared knowledge is through the exchange of information between team members regarding their respective area(s) of expertise and role(s) on the team [120]. Labeled *role identification behaviors* [124], discussion of specialized knowledge and skills creates awareness among teammates of who knows what [125]. Such communication seems to be particularly important at the beginning and planning phases of a project [126,127]. This may serve two goals: (1) creating a TMS so that team members know with whom specific expertise and task responsibilities resides, and (2) facilitating the planning process by allowing tasks to be assigned to members with the most relevant expertise. Thus, we recommend that translational medical teams discuss each member's expertise early on in the planning process, especially when teammates are unfamiliar with one another or ill acquainted with the content domain of each other's disciplines. Additionally, initial ideas for how to integrate these differing knowledge bases should be discussed. It is recommended that a designated facilitator should guide the discussion [128,129] in order to mitigate potential production blocking (i.e., forgetting one's train of thought) and apprehensiveness of team members to contribute. In this way, all members will be more likely to contribute fully and the group will have fewer process losses, leading to a more successful TMS.

Interpersonal processes

Conflict management: Conflict refers to perceived incompatibilities in the interests, beliefs, or views held by one or more team members [130,131]. Conflict may stem from differences in viewpoints or opinions regarding how best to complete team tasks (i.e., task-based), individual differences that create annoyance or tension between team members (i.e., relationship-based [131,132]), or differing opinions on how to divide and delegate responsibilities among team members (i.e., process-based [132,133]). In addition to stemming from multiple sources, teams can experience variations in the level of conflict intensity and how they interact regarding their differences, all of which can impact team performance [130], often in different ways.

If ignored, suppressed, or ineffectively managed, conflict and power struggles can diminish individual and team performance by reducing team members' ability to cooperate interpersonally [134]. As an example, in translational medical teams, interpersonal

tensions can weaken affective commitment to the team [135], thereby undermining intellectual collaboration and presenting a barrier to the generation of innovative ideas [135,131] and integration of conceptual models across disciplines. However, when managed effectively, conflict can provide a healthy outlet for handling negative attitudes, moods, and emotions [137,138]. A successful team will deal with issues by purposefully exploring and embracing team member emotions before the underlying issues can disrupt healthy team processes and weaken outcomes [139]. Furthermore, under the right conditions, teams may actually be able to capitalize on the benefits of conflict. For instance, task conflict that occurs within a psychologically safe environment can actually improve team performance [140], in part because at moderate levels it can stimulate team creativity [141]. Thus, creating a sense of team psychological safety via the recommendations above will not only facilitate trust but may also cultivate an environment in which conflict is less damaging – and possibly even helpful– to team performance.

A critical aspect of successful transdisciplinary teams is the ability to manage conflict, so team objectives are not derailed by interpersonal struggles [142]. Conflict resolution is a process for mitigating the negative impact of conflict on a team and restoring fairness, effectiveness, and working relationships [143]. It encompasses a range of activities including communication, problem solving, emotion control, and understanding different perceptions or standpoints [144,145]. The most successful teams are those that anticipate the need for conflict resolution and adopt multiple conflict management strategies [133]. Managing conflict requires trust that team members will perform their roles and protect the team [146-148]. Trust encourages positive team attitudes (e.g., mutual respect) and cognitions (i.e., shared understanding of goals [149]) that motivate team members to work together.

To manage conflict, translational teams should a) focus on the content of interpersonal interactions rather than delivery style; b) explicitly discuss reasons guiding final decisions regarding work assignments; and c) assign tasks to members who have relevant task expertise [133]. As an intrapersonal characteristic, delivery style can influence teamwork, particularly through its potential to cause relationship conflict. Translational teams may be at particular risk of conflict incited by delivery style differences given the diverse backgrounds of its members. When team members differ on deep-level (i.e., psychological) characteristics, the teams they serve experience reduced performance via process loss [80]. While delivery style might be malleable with training and feedback, a more viable option for avoiding relational conflict is for team members to ignore the delivery of information and instead attend to the message. Task (and relational) conflict can be avoided by the equitable assignment of taskwork to team members who have relevant experience, rather on the basis of favoritism or political agendas. Teams that are committed to finding an appropriate (though not necessarily equal) way for members to contribute are more likely to achieve high performance goals and satisfaction [133]. When the reasons for tasking decisions are transparent team members experience less negative attitudes that contribute to conflict.

The effective management of conflict allows creativity and collaboration to flourish in translational teams, thereby

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improving their ability to generate new outcomes. While some degree of conflict may be beneficial for actually stimulating intellectual processes [131], failure to manage emerging disputes can inhibit cooperation [134].

CONCLUSION

Model limitations

We should note that this model is not without limitations. We attempted to answer the call by other authors [8,13,18-21] who have noted the need for explication of trandisciplinary and translational team processes. As such, this paper and the model wherein, provide a preliminary platform upon which further investigations can be based. Future research will need to take a more comprehensive look at translational team processes. While impactful, those processes presented here only begin to scratch the surface in our understanding of translational teamwork. Furthermore, future work will need to articulate and test relationships between specific antecedents, processes, and outcomes related to translational medical team performance. Fortunately, our model may be used to guide this future work. For instance, future research may explore how translational teams innovate and the antecedents that influence the processes related to innovation. We have cited work from organizational teams science that indicates trust [52], communication [31,83], and conflict management [135] may contribute to team innovation and creativity and that the team composition profile of expertise similarity or dissimilarity (an intra-team antecedent) can influence how teams should communicate in order to be more creative [82]. Relationships such as these merit further testing within translational medical teams. Such investigations will naturally build on previous work aimed at operationalizing and measuring team process [150] to expand the current knowledge of translational medical teamwork but are beyond the scope of the current paper. The model we have presented can guide these initial efforts.

While their structure, composition, varying location, and pluralistic goals pose unique challenges, this paper serves to provide recommendations from team science that can be applied to translational medical teams. Specifically, effective translational medical teams will take interpersonal risks, communicate critical information, self-correct to manage error, provide backup between team members, establish shared knowledge structures, and resolve conflict effectively. Utilizing a theoretical framework of transdisciplinary teamwork adapted from the science of team science and tailored to translational medical teams, we describe each of these processes, their relation to translational medical team outcomes, and how they can be enhanced within translational medical teams. In so doing, we have presented practical, theoretically driven, and empirically-based guidance and recommendations for understanding and improving teamwork in translational medical teams.

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